CS-5630 / CS-6630
Visualization for Data Science
Data

Alexander Lex
alex@sci.utah.edu

THE UNIVERSITY OF UTAH

[xkcd]

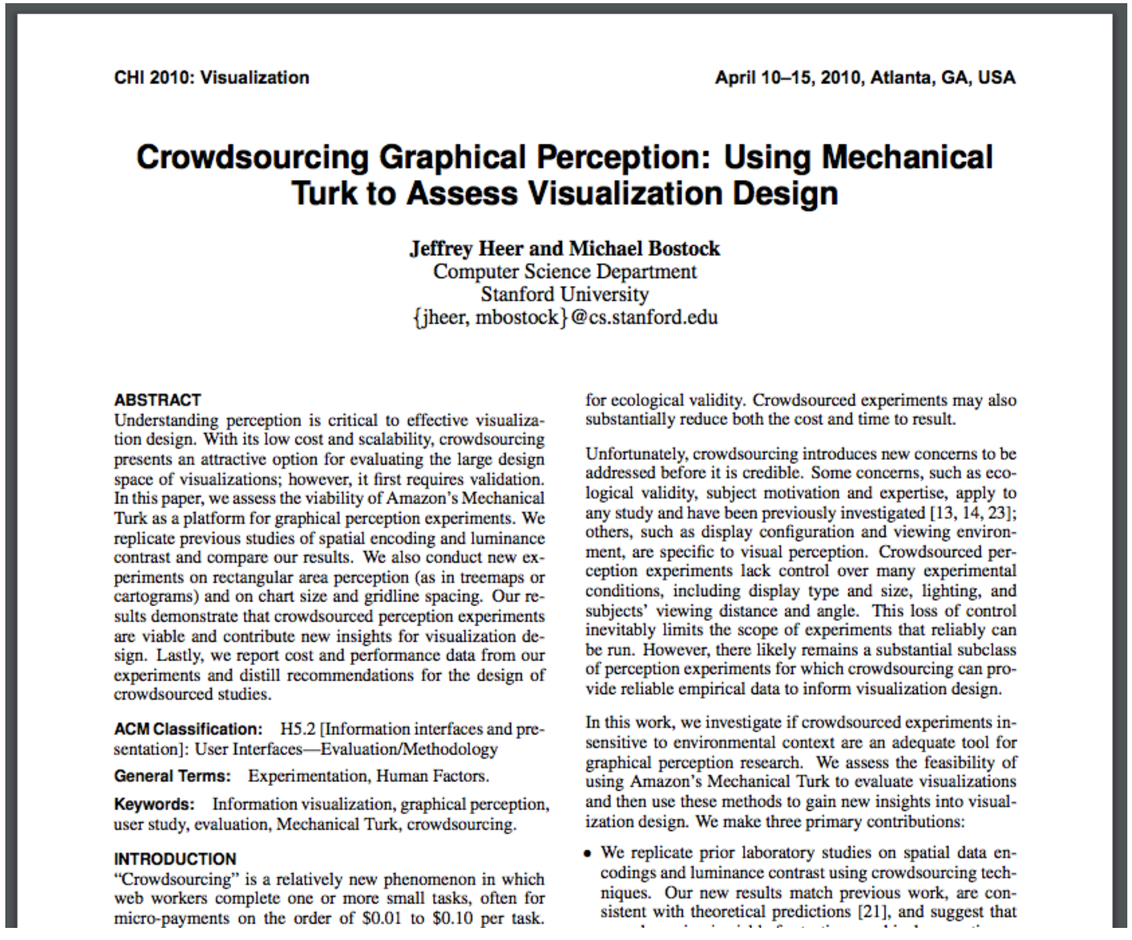
Next Week

Tuesday: JavaScript and D3 Intro

Wednesday: HW2 Lab

Thursday: Visualization Alphabet

Mandatory Reading: Crowdsourcing graphical perception: using mechanical turk to assess visualization design. Jeff Heer, Mike Bostock



CHI 2010: Visualization April 10–15, 2010, Atlanta, GA, USA

Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design

Jeffrey Heer and Michael Bostock
Computer Science Department
Stanford University
{jheer, mbostock}@cs.stanford.edu

ABSTRACT
Understanding perception is critical to effective visualization design. With its low cost and scalability, crowdsourcing presents an attractive option for evaluating the large design space of visualizations; however, it first requires validation. In this paper, we assess the viability of Amazon's Mechanical Turk as a platform for graphical perception experiments. We replicate previous studies of spatial encoding and luminance contrast and compare our results. We also conduct new experiments on rectangular area perception (as in treemaps or cartograms) and on chart size and gridline spacing. Our results demonstrate that crowdsourced perception experiments are viable and contribute new insights for visualization design. Lastly, we report cost and performance data from our experiments and distill recommendations for the design of crowdsourced studies.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces—Evaluation/Methodology

General Terms: Experimentation, Human Factors.

Keywords: Information visualization, graphical perception, user study, evaluation, Mechanical Turk, crowdsourcing.

INTRODUCTION
"Crowdsourcing" is a relatively new phenomenon in which web workers complete one or more small tasks, often for micro-payments on the order of $0.01 to $0.10 per task. for ecological validity. Crowdsourced experiments may also substantially reduce both the cost and time to result.

Unfortunately, crowdsourcing introduces new concerns to be addressed before it is credible. Some concerns, such as ecological validity, subject motivation and expertise, apply to any study and have been previously investigated [13, 14, 23]; others, such as display configuration and viewing environment, are specific to visual perception. Crowdsourced perception experiments lack control over many experimental conditions, including display type and size, lighting, and subjects' viewing distance and angle. This loss of control inevitably limits the scope of experiments that reliably can be run. However, there likely remains a substantial subclass of perception experiments for which crowdsourcing can provide reliable empirical data to inform visualization design.

In this work, we investigate if crowdsourced experiments insensitive to environmental context are an adequate tool for graphical perception research. We assess the feasibility of using Amazon's Mechanical Turk to evaluate visualizations and then use these methods to gain new insights into visualization design. We make three primary contributions:

- We replicate prior laboratory studies on spatial data encodings and luminance contrast using crowdsourcing techniques. Our new results match previous work, are consistent with theoretical predictions [21], and suggest that

Terms

Dataset Types

what can be visualized?

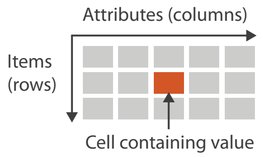
Data Types

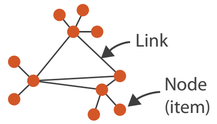
fundamental units

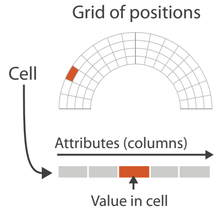
combinations make up Dataset Types

Dataset Types

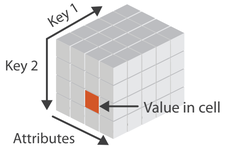
- Tables
- Networks
- Fields (Continuous)
- Geometry (Spatial)







- *Multidimensional Table*
- *Trees*



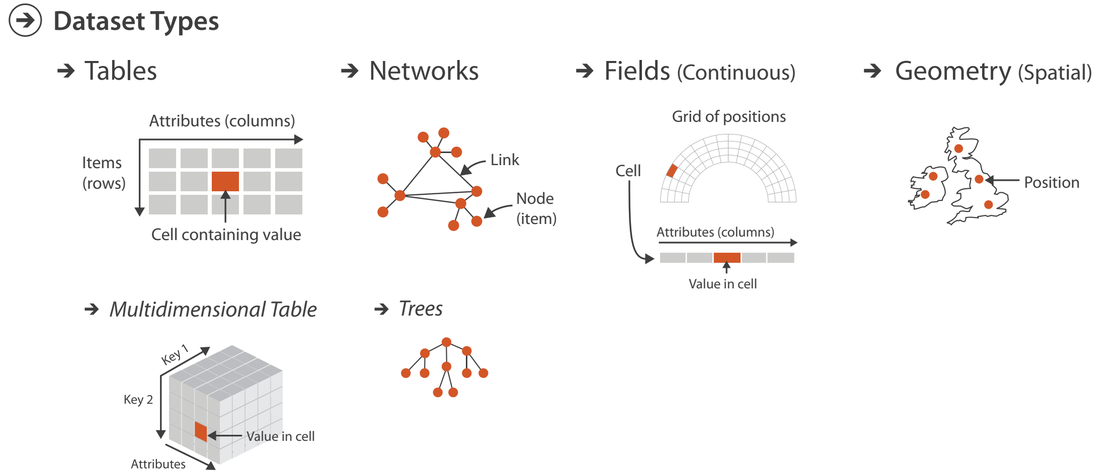
Data Types

- Items
- Attributes
- Links
- Positions
- Grids

Structure

Structured Data

known data types, semantics



Unstructured Data

no predefined data model

text-heavy, interspersed with facts (dates, times, locations)

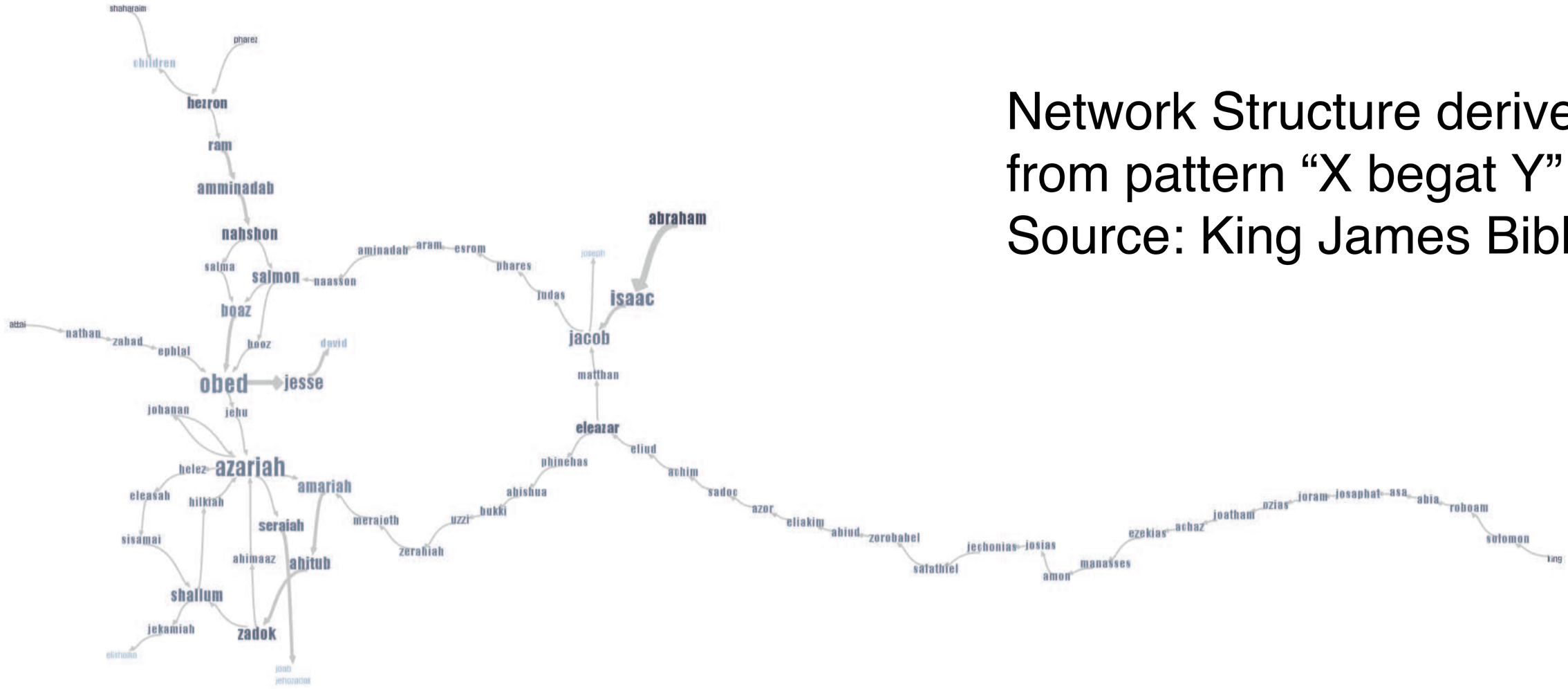
video, images

Translate into structured data

Natural Language Processing, Text mining (sentiment, keywords, concepts, categories)

Object Recognition, Tracking

Text Example: Phrase Net



Network Structure derived from pattern “X begat Y”
Source: King James Bible

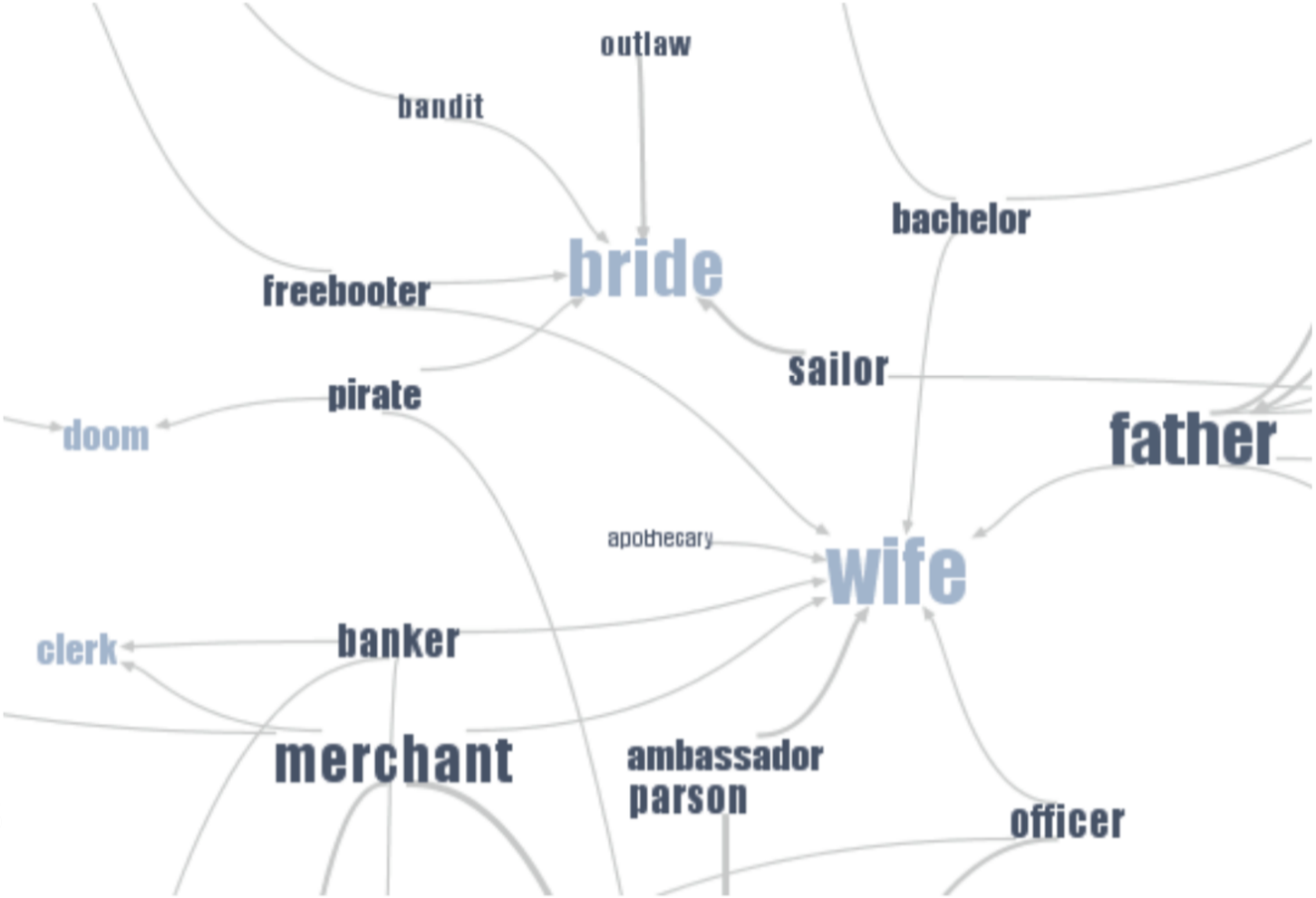
[van Ham, InfoVis 2009]

begat definition: bring (a child) into existence by the process of reproduction.

Example: Phrase Net

Pattern: “X’s Y”

18th & 19th century novels



More in Lecture
Text & Document Vis

[van Ham, InfoVis 2009]

Data Semantics

ID	Name	Age	Shirt Size	Favorite Fruit
1	Amy	8	S	Apple
2	Basil	7	S	Pear
3	Clara	9	M	Durian
4	Desmond	13	L	Elderberry
5	Ernest	12	L	Peach
6	Fanny	10	S	Lychee
7	George	9	M	Orange
8	Hector	8	L	Loquat
9	Ida	10	M	Pear
10	Amy	12	M	Orange

Basil, 7, S, Pear

What does it mean?

Semantics: real world meaning

Name? City? Fruit? Height? Age? Day of Month?

Metadata

Data Types

structural or mathematical interpretation of data

Item, Link, Attribute, Position, Grid

Different from data types in programming!

Items & Attributes

Item: individual entity, discrete

e.g., Patient, Car, Stock, City

"independent variable"

Attribute: measured, observed, logged property

e.g., Patient: height, blood pressure
Car: horsepower, make

"dependent variable"

Item: Person Attributes

ID	Name	Age	Shirt Size	Favorite Fruit
1	Amy	8	S	Apple
2	Basil	7	S	Pear
3	Clara	9	M	Durian
4	Desmond	13	L	Elderberry
5	Ernest	12	L	Peach
6	Fanny	10	S	Lychee
7	George	9	M	Orange
8	Hector	8	L	Loquat
9	Ida	10	M	Pear
10	Amy	12	M	Orange

Cell

Other Data Types

Links

- Express relationship between two items
- Friendship on Facebook, Interaction between proteins

Positions

- Spatial data -> location in 2D or 3D
- Pixels in photo, Voxels in MRI scan, latitude/longitude

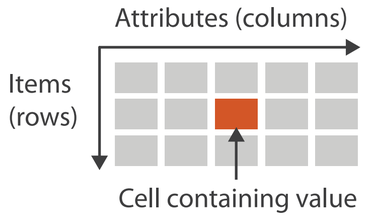
Grids

- Sampling strategy for continuous data
- How many Voxels in MRI scan, positions of weather stations in the US

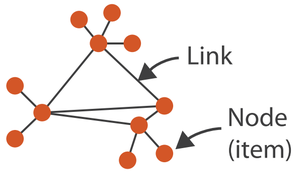
Dataset Types

Dataset Types

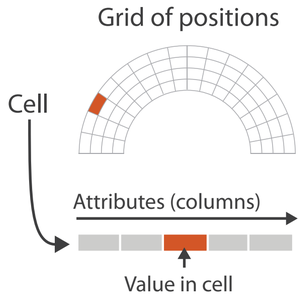
Tables



Networks

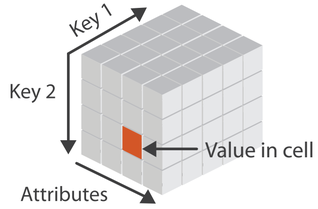


Fields (Continuous)



Geometry (Spatial)

Multidimensional Table



Trees

Tables

Flat Table

- one item per row
- each column is attribute
- unique (implicit) **key**
- no duplicates

Multidimensional Table

- indexing based on multiple keys

Attributes

Keys | Values

Item

ID	Name	Age	Shirt Size	Favorite Fruit
1	Amy	8	S	Apple
2	Basil	7	S	Pear
3	Clara	9	M	Durian
4	Desmond	13	L	Elderberry
5	Ernest	12	L	Peach
6	Fanny	10	S	Lychee
7	George	9	M	Orange
8	Hector	8	L	Loquat
9	Ida	10	M	Pear
10	Amy	12	M	Orange

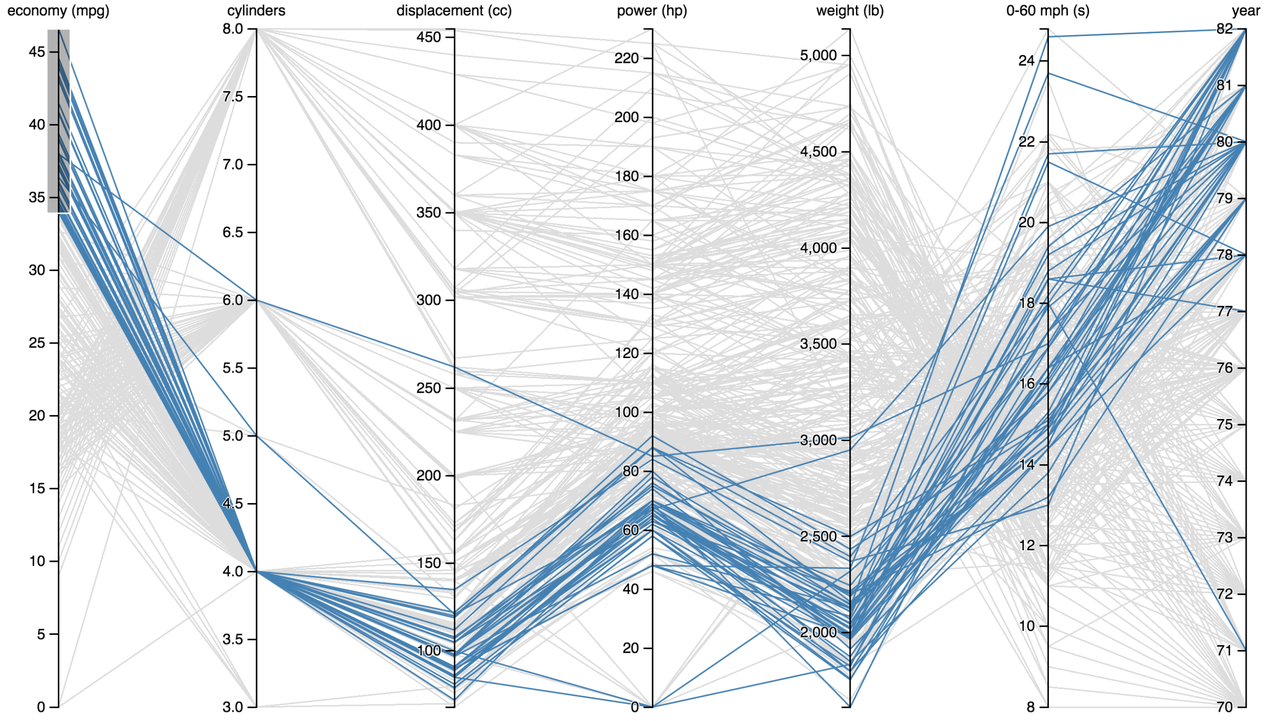
Multidimensional Tables

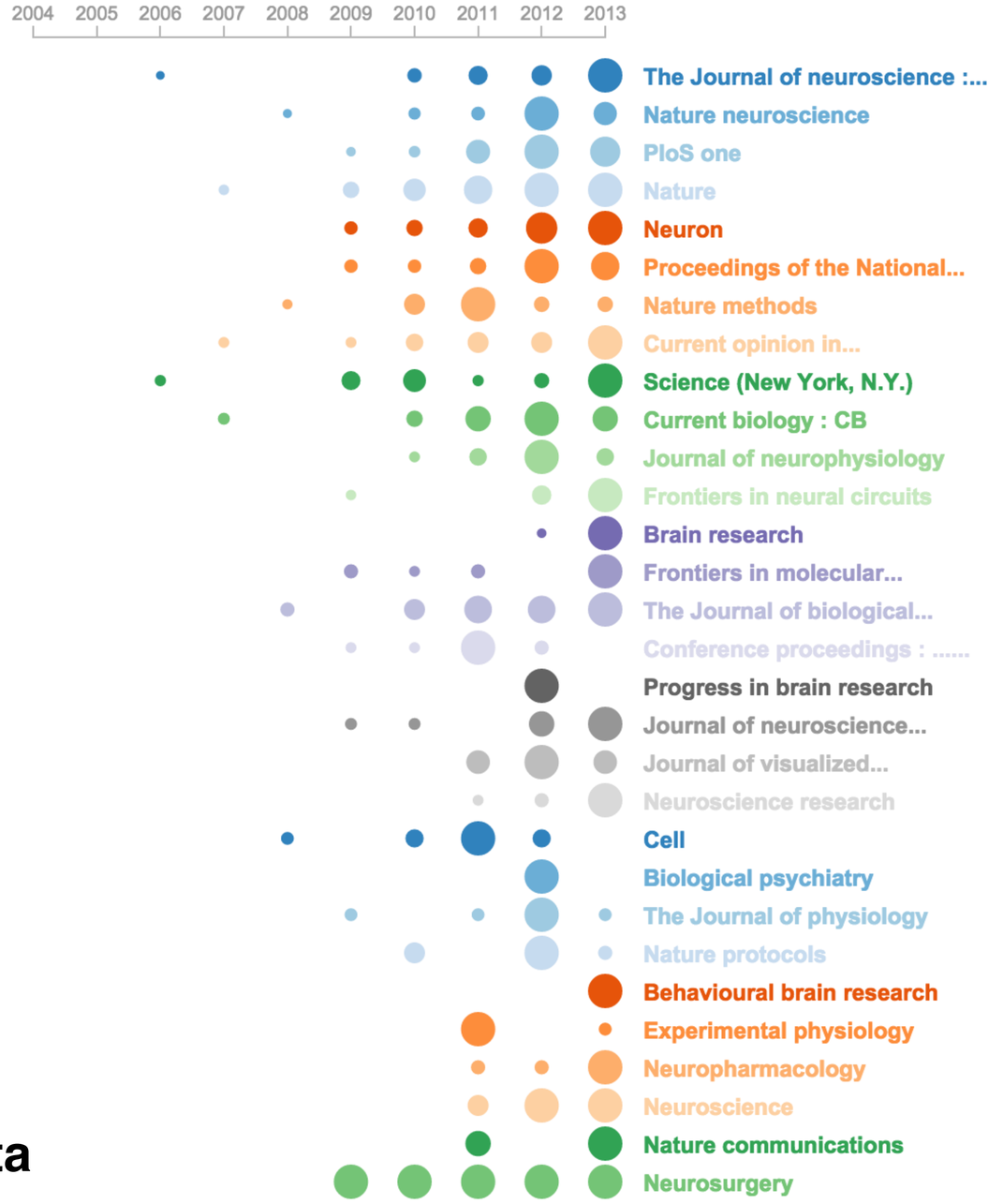
Keys: Genes

Patients

	A	B	C	D	E
1	#1.2				
2	1500	529			
3	GeneName	DESCRIPTION	TCGA-02-0001-01C-01R-0177-01	TCGA-02-0003-01A-01R-0177-01	TCGA-02-0004-01A-01R-0298-01
4	LTF	LTF	-1.265728057	2.377012066	4.123979585
5	POSTN	POSTN	2.662411805	3.932400324	5.031585377
6	TMSL8	TMSL8	-3.082217838	-2.243148513	-0.02313681
7	HLA-DQA1	HLA-DQA1	-1.739664398	4.577962344	3.127744964
8	RP11-35N6.1	RP11-35N6.1	-3.346352968	-2.895400157	-3.473035067
9	STMN2	STMN2	-2.578511106	-3.051605144	-1.729892888
10	DCX	DCX	-2.26078976	-2.529795801	-2.844966278
11	AGXT2L1	AGXT2L1	-2.639493611	-3.113204863	-0.403975027
12	IL13RA2	IL13RA2	-2.93596915	-1.873600916	2.976256911
13	SLN	SLN	-2.466718221	-2.208406749	1.025827904
14	MEOX2	MEOX2	-2.395054066	-1.062676046	1.783235317
15	COL11A1	COL11A1	1.211934832	-0.399392588	4.733608974
16	NNMT	NNMT	0.703745164	0.664082419	3.069030715
17	F13A1	F13A1	-0.224094042	2.222197544	1.171354775
18	CXCL14	CXCL14	-3.1309694	-1.395056071	2.569540659
19	MBP	MBP	-1.906390566	-2.037626447	-2.935744906
20	TF	TF	-4.334123292	-4.680680246	-2.975788866
21	KCND2	KCND2	-1.777692395	-2.100362021	-1.996306032

Visualizing Tables





More in Lecture on Tables & High-Dimensional Data

Collections

How we group items

Sets

Unique items, unordered

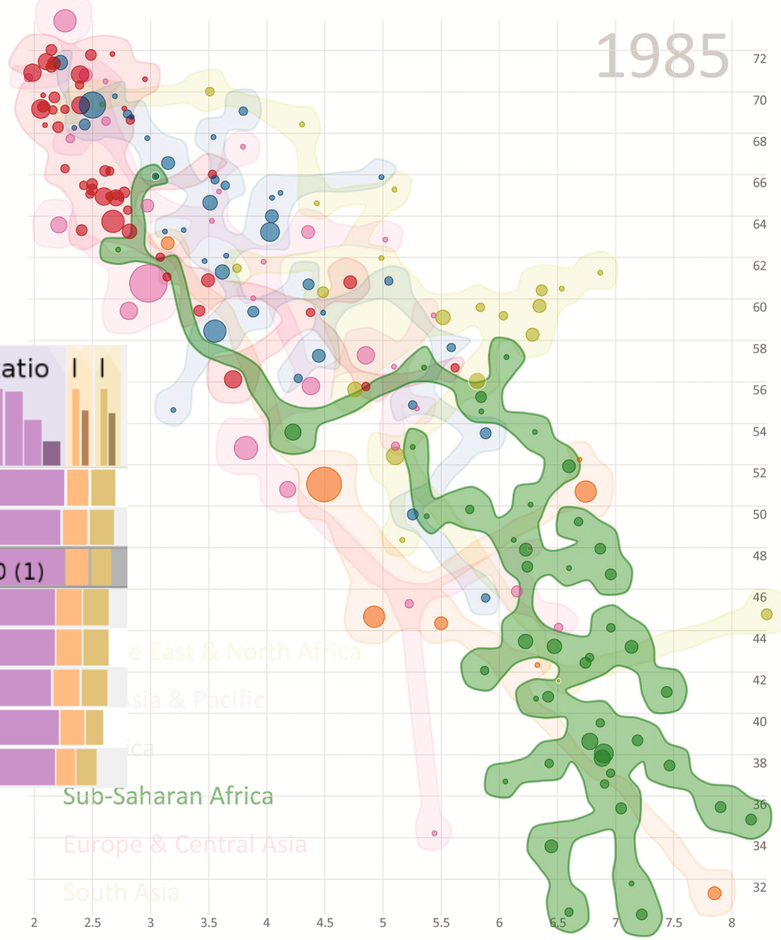
Lists

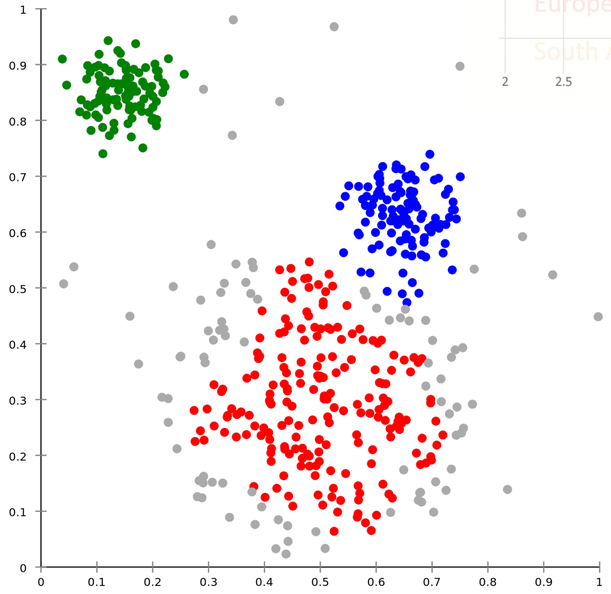
Ordered, duplicates allowed

Clusters

Groups of similar items

Rank	School Name	Academic repu	E	Facult	Citatio	I	I
	Filter: <None>						
1.	Massachusetts Inst						
2.	University of Camb						
3.	Harvard University	100 (1)			100 (1)		
4.	UCL (University Co						
5.	University of Oxfor						
6.	Imperial College L						
7.	Yale University						
8.	University of Chic						





Graphs/Networks

A graph onsists of a set of **vertices (nodes)** and a set of **edges (links)** connecting these vertices.

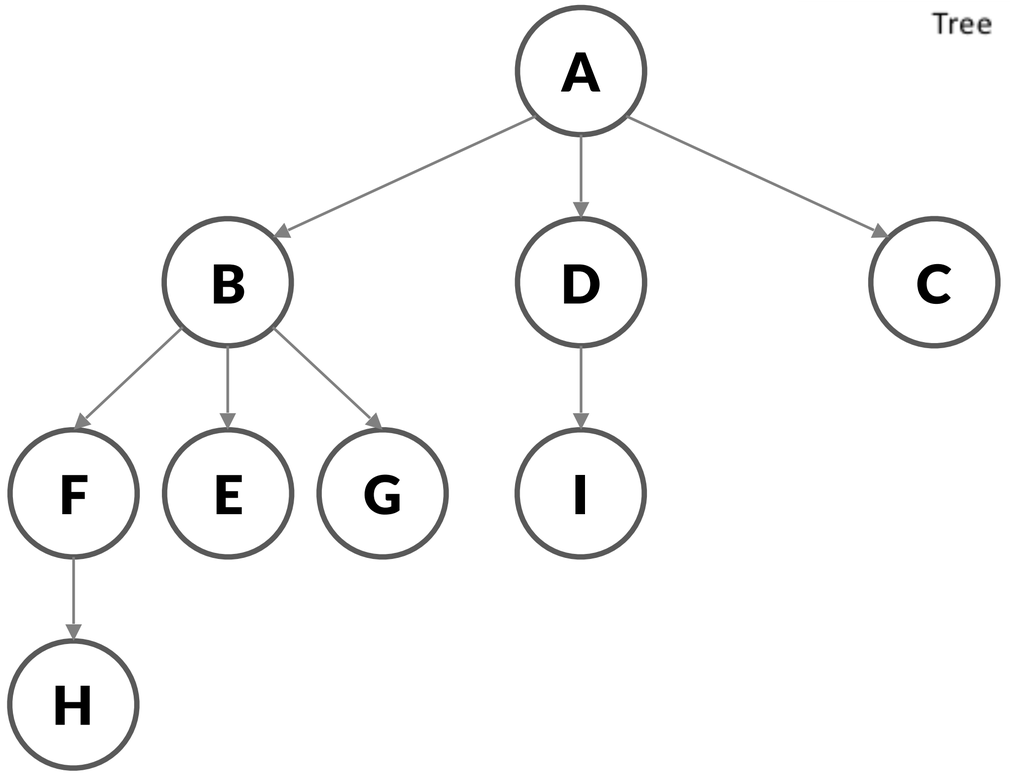
Diagrammatic Example

Trees Graphs

A ***tree*** is a graph with *no cycles*

Trees often also have roots and are directed

Tree

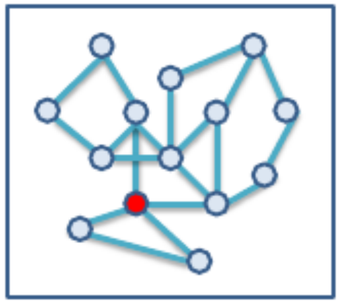


Special Graphs

A ***bipartite graph*** has vertices that can be partitioned into two independent sets

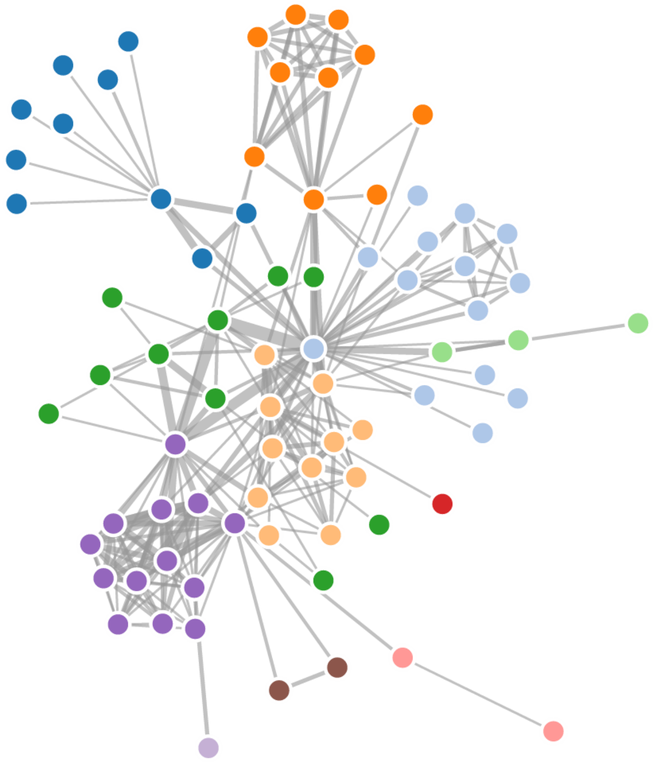
An ***articulation point*** is a Vertex, which if deleted from the graph would break up a ***connected graph*** into multiple graphs,or an ***unconnected graph***

Bipartite Graph

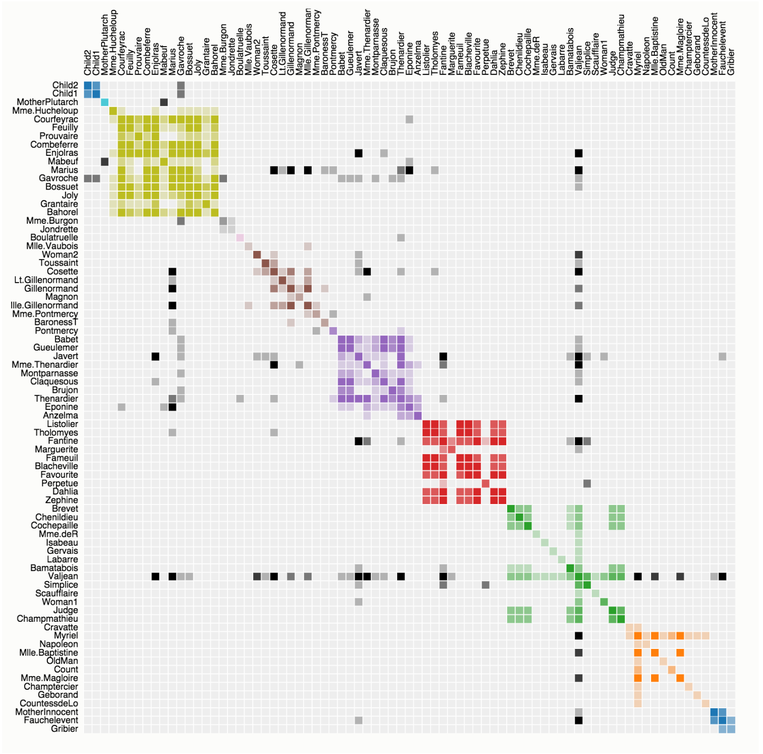


Articulation Point (red)

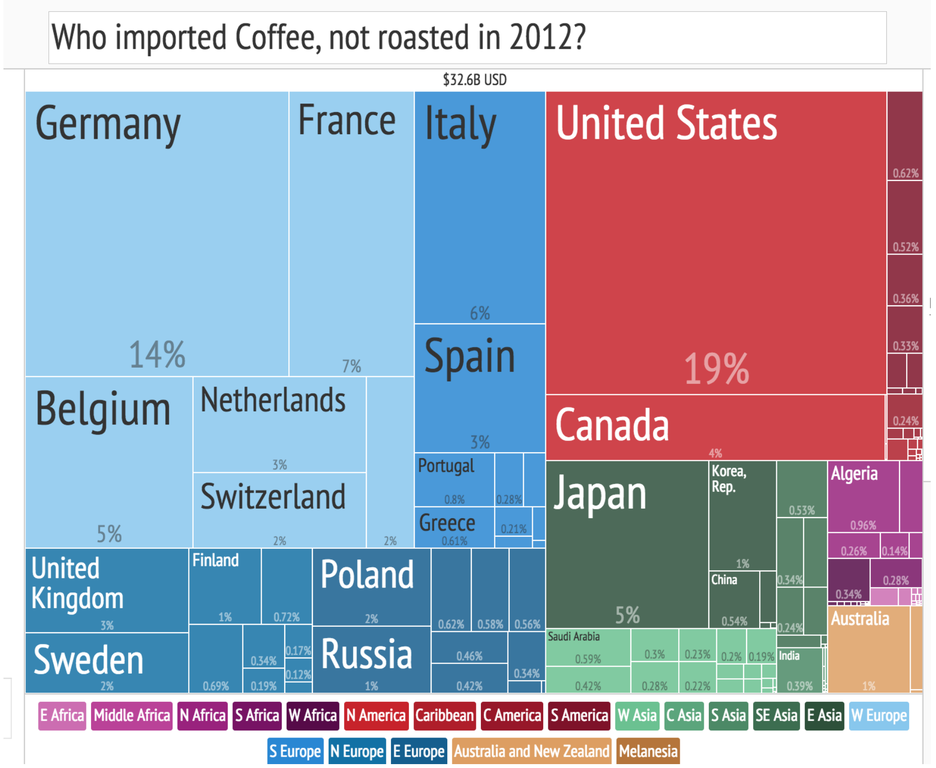
Visualizing Graphs



Node-Link Diagram



Matrix



Treemap (Implicit Tree Visualization)

More in Lecture on Graphs & Trees

Fields

Attribute values associated with cells

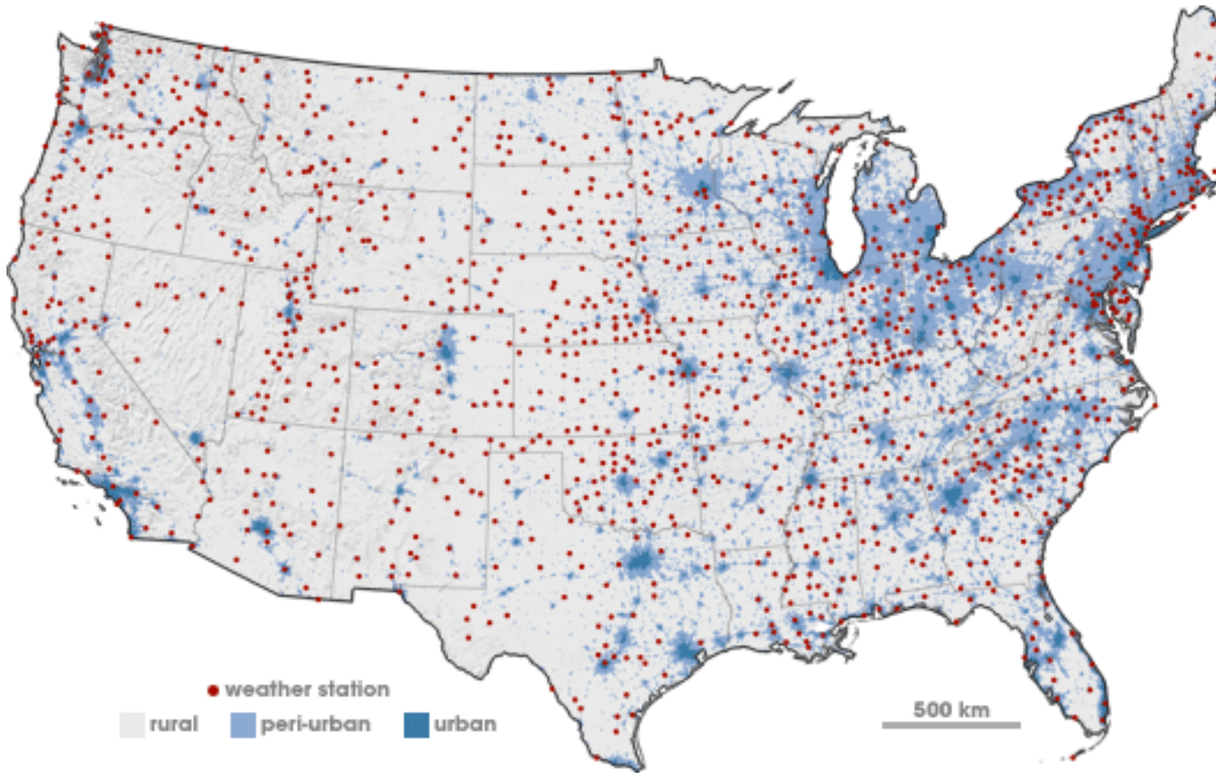
Cell contains data from continuous domain

- Temperature, pressure, wind velocity

Measured or simulated

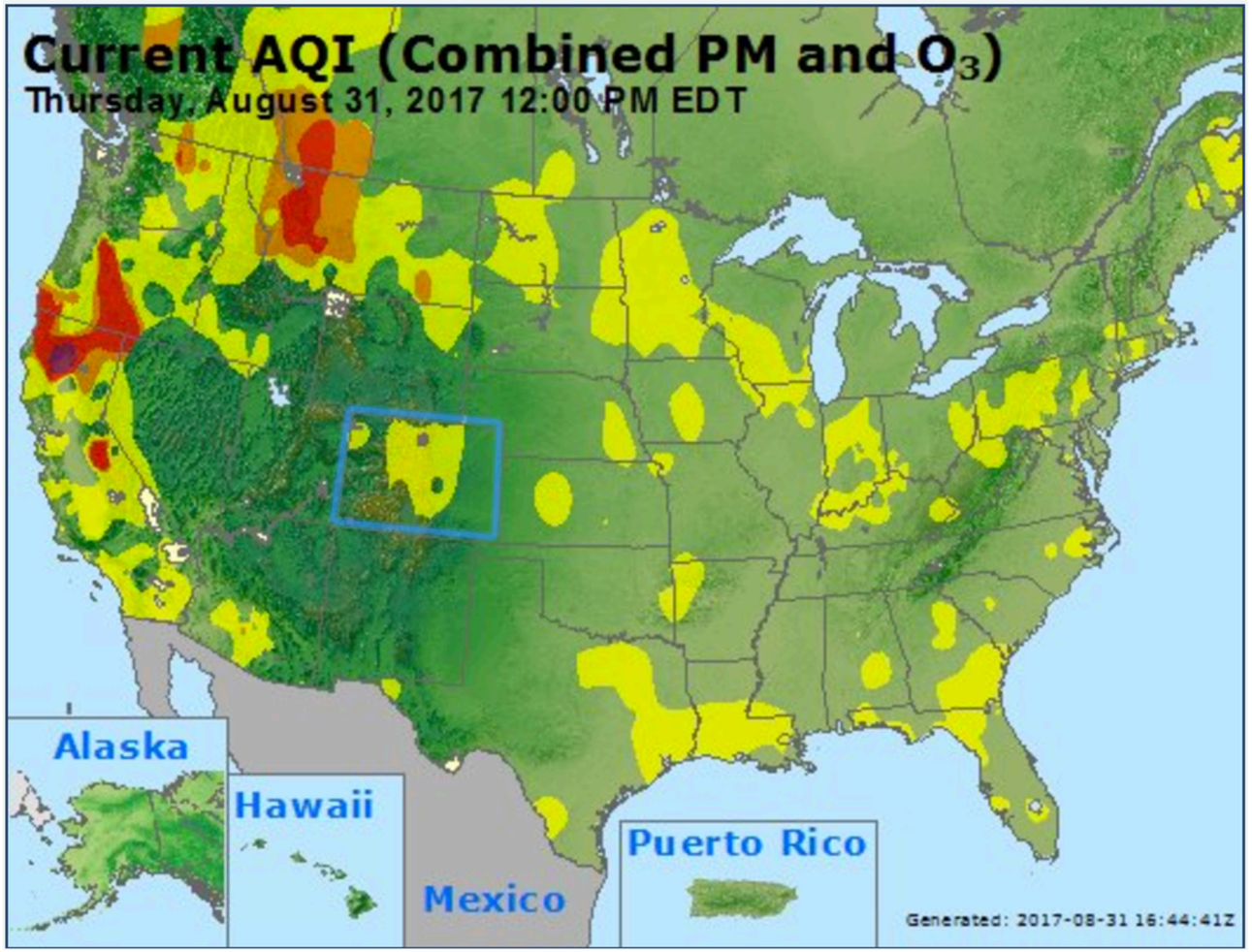
Sampling & Interpolation

- Signal processing & stats

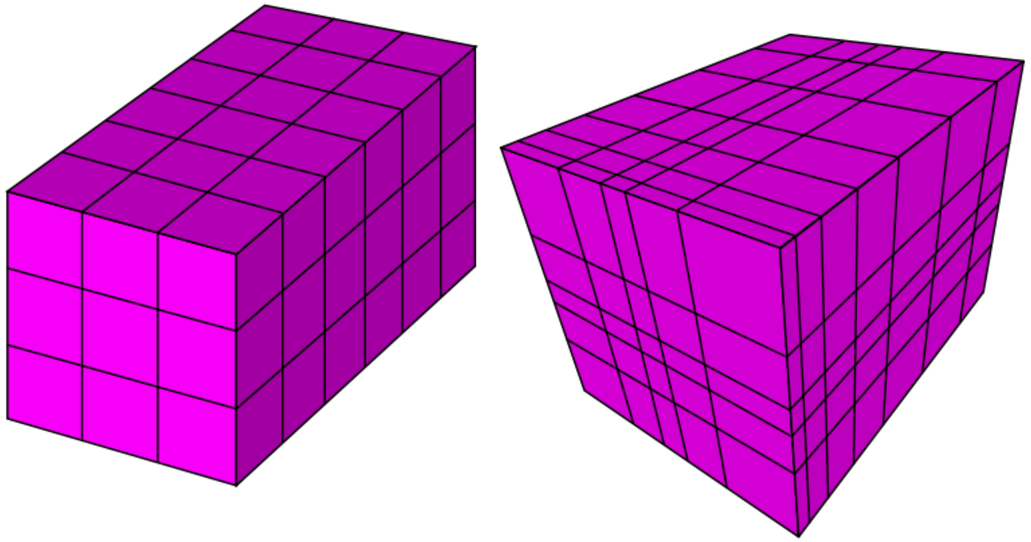


Weather Stations in the US. Source: NASA

Field Example: Air Quality



Fields: Grid Types



Uniform Grid

- Geometry & topology can be computed

Rectilinear Grid

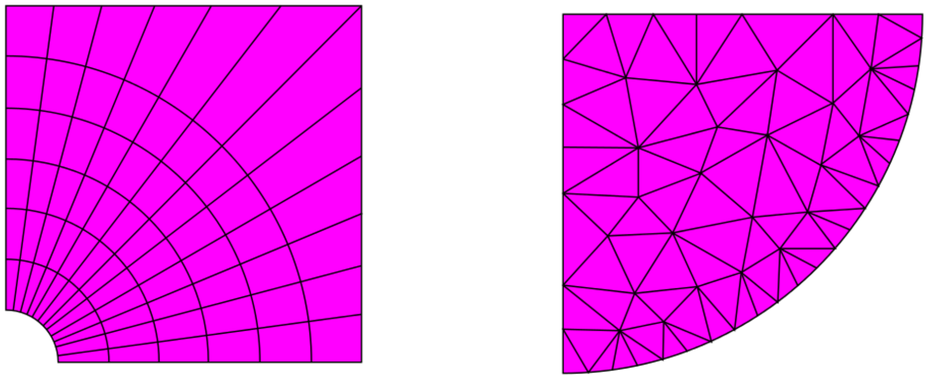
- Nonuniform sampling

Structured Grid

- allows curvilinear grids

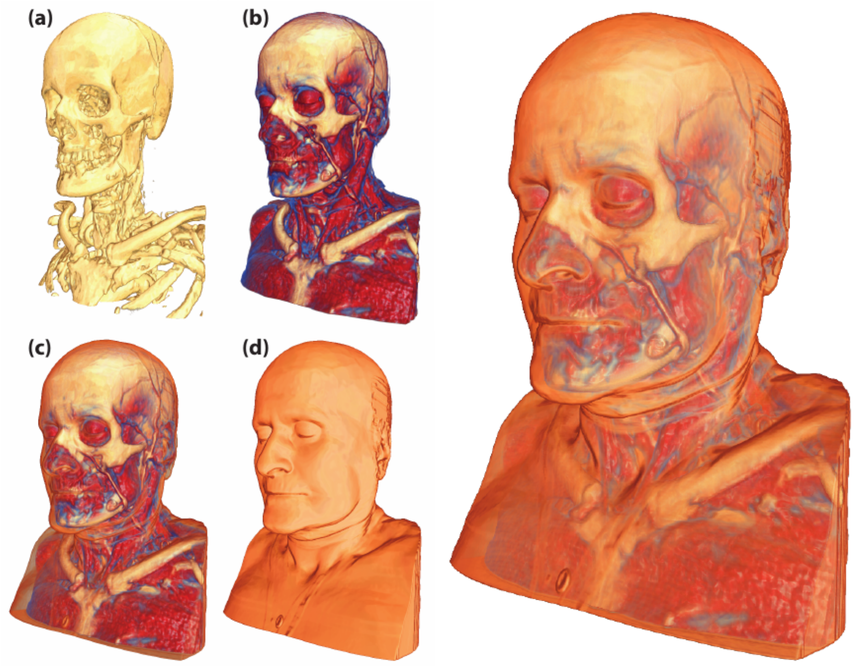
Unstructured Grid

- full flexibility, store position and connection

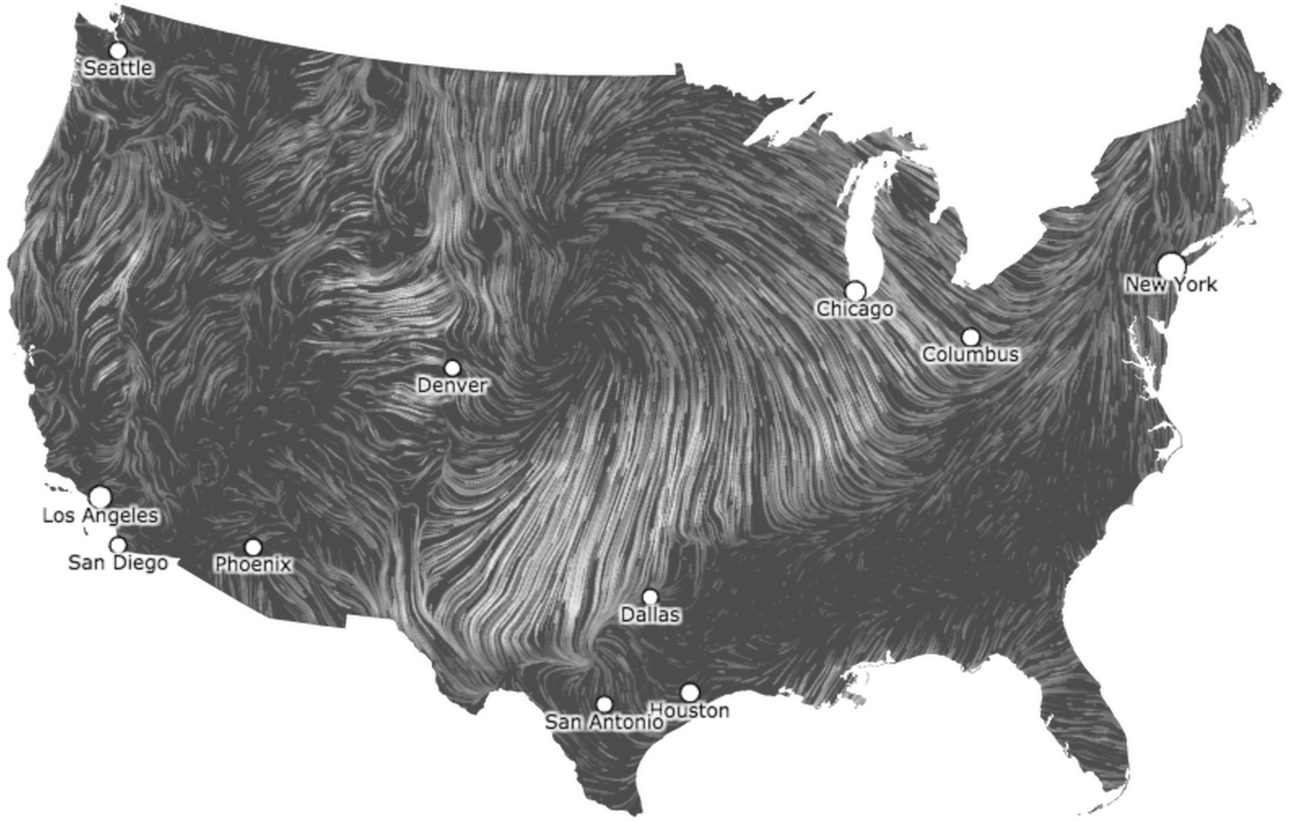


[Wikipedia]

Visualizing Fields



[Bruckner 2007]



More in Maps, CS 5635 / 6635 - Visualization for Scientific Data

Side Note: Academic Subfields

Information Vis

"Abstract Data"

- Tables, Graphs, Maps

Free to choose spatial layout

Perception Research

Visual Analytics

InfoVis + Stats + Machine learning

Applied Work

Systems

Funding buzzword

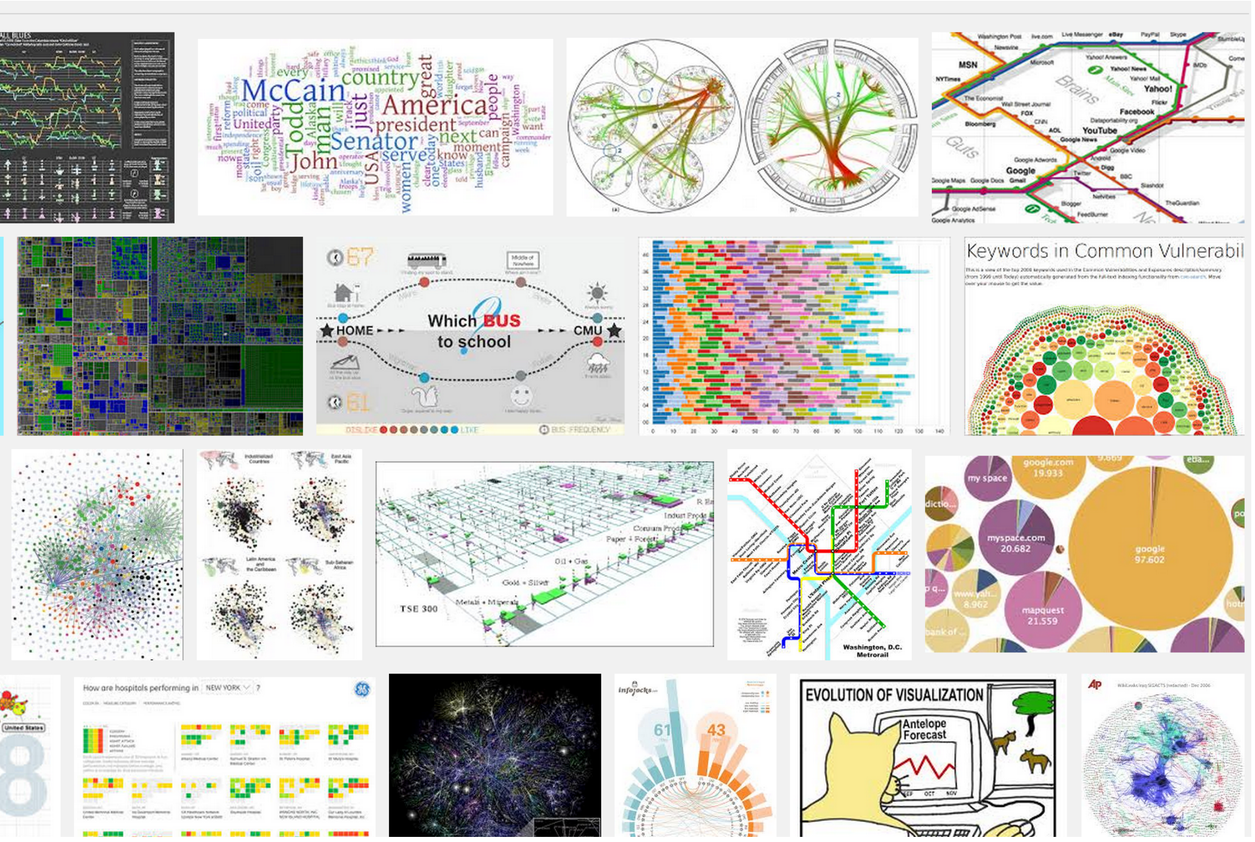
Scientific Vis

"Spatial Data" (Fields)

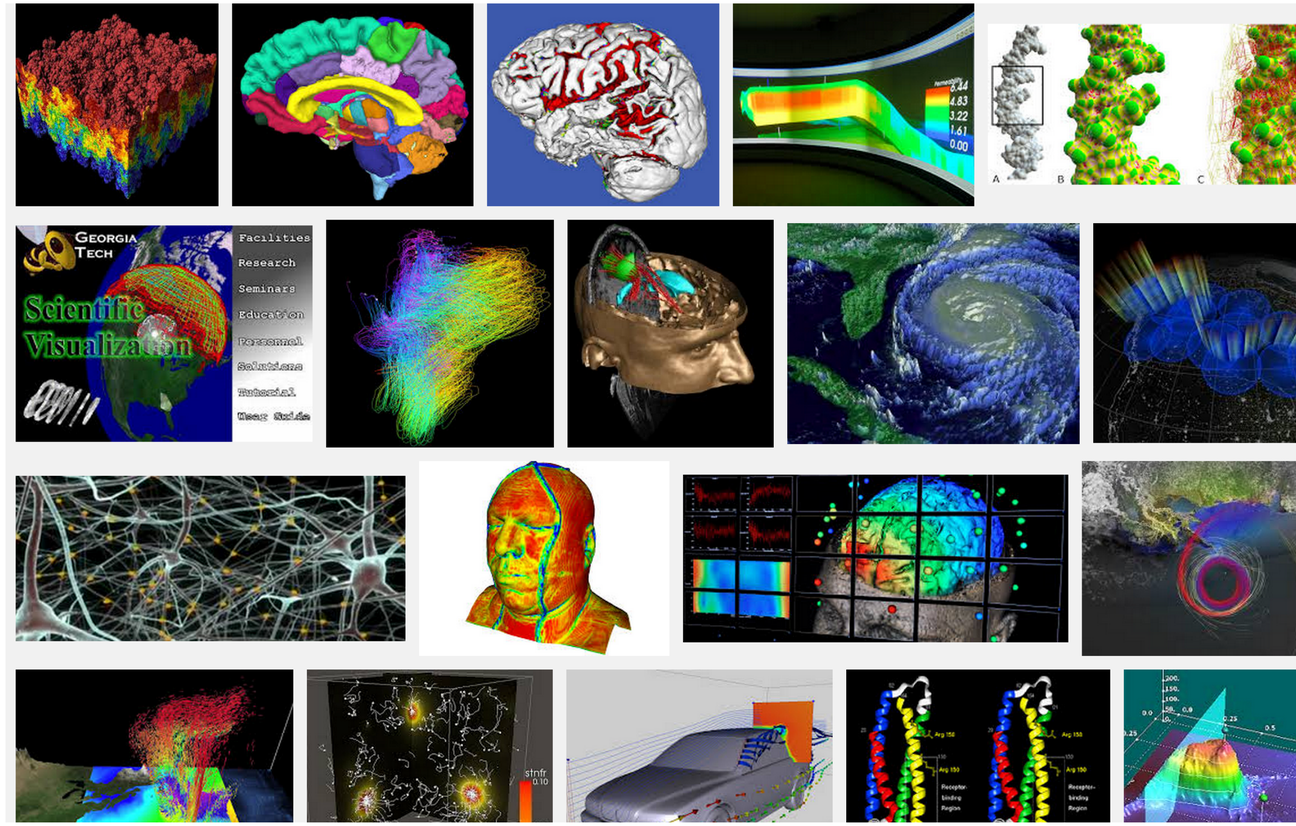
Not free to choose spatial layout

Find best way to depict reality

InfoVis or SciVis?

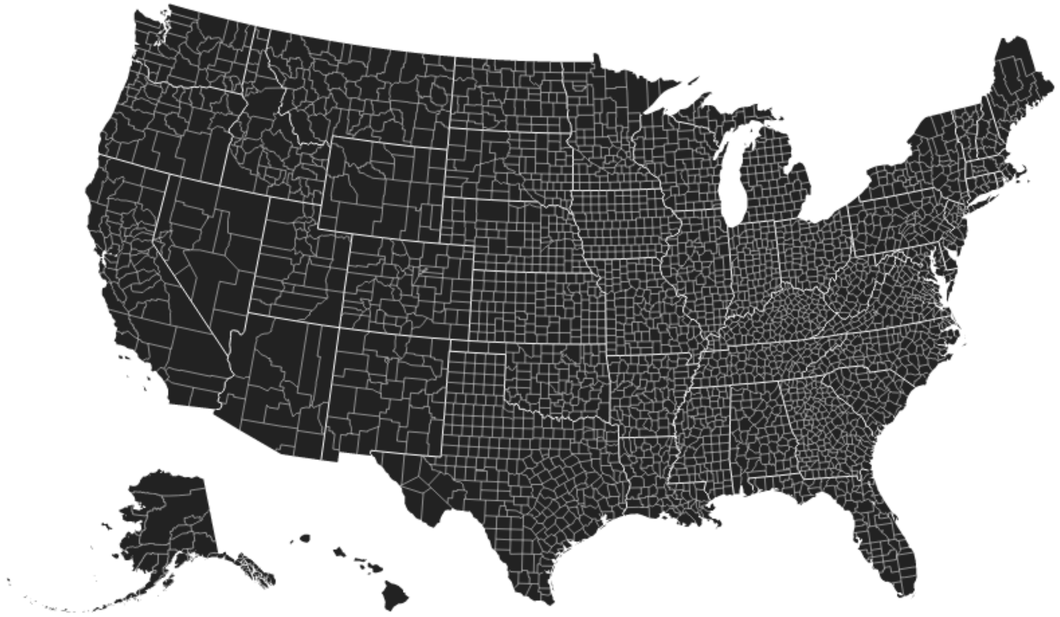


InfoVis: White Background



SciVis: Black Background

Geometry



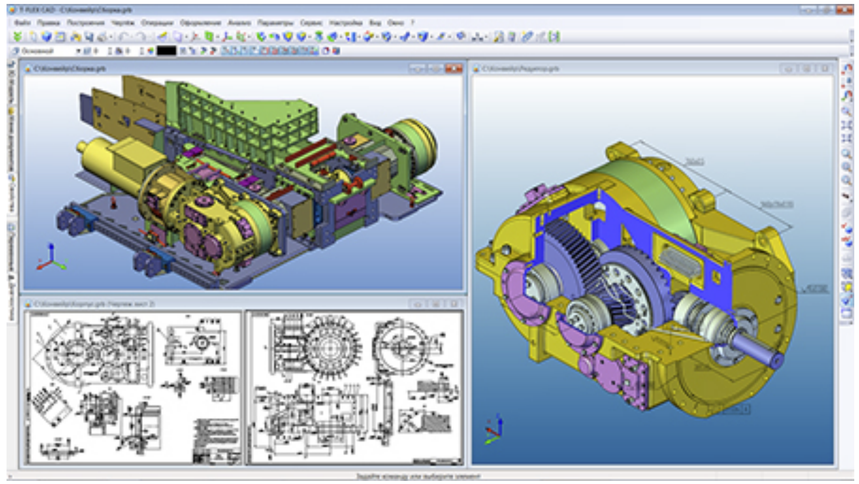
Shape of items

Explicit spatial positions

Points, lines, curves, surfaces, regions, volumes

Important in Computer Graphics, CAD, …

Not a core Vis topic

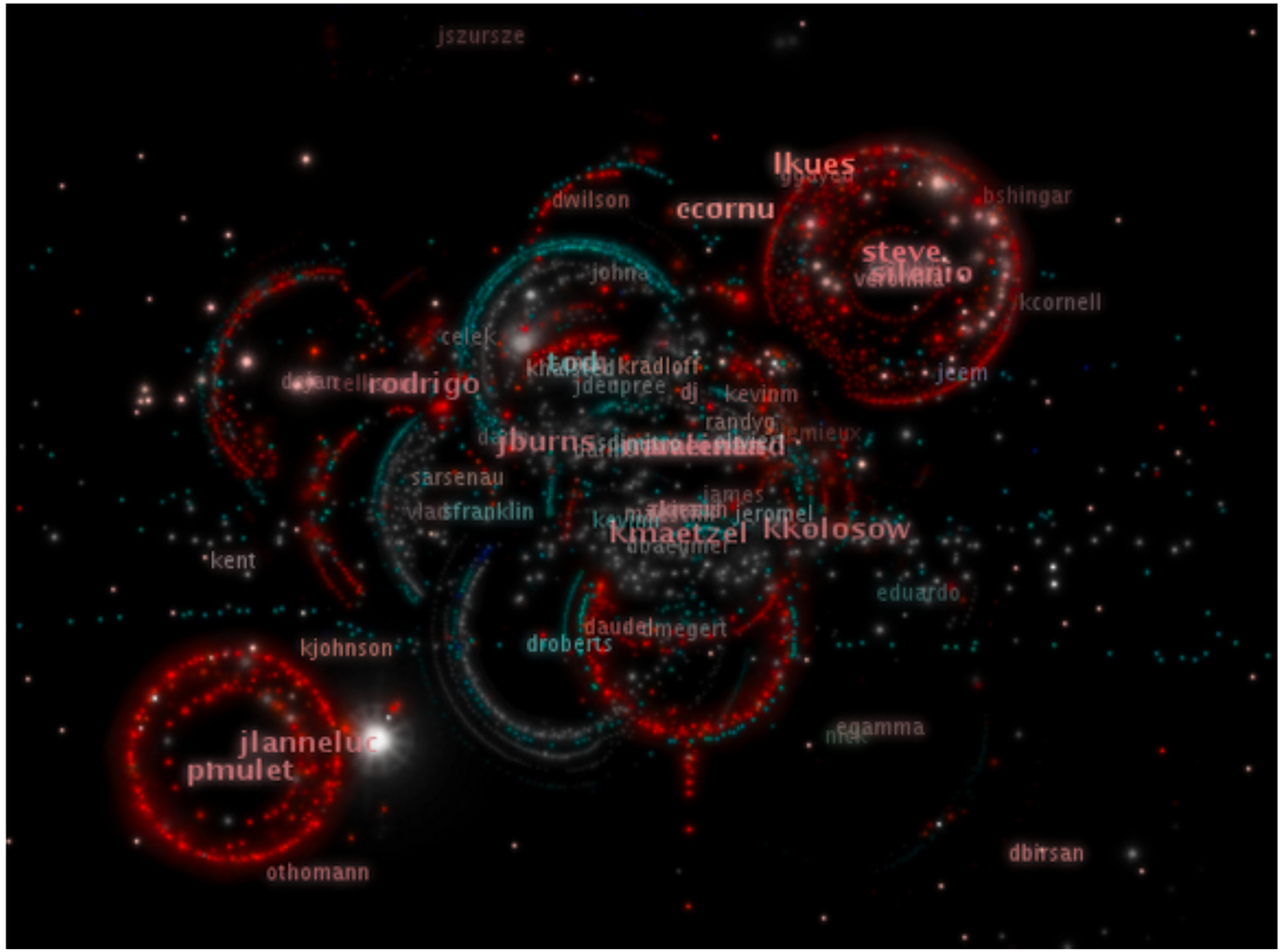


Design Critique

CodeSwarm

CodeSwarm

https://goo.gl/0DVhMT



code_swarm: A Design Study in Organic Software Visualization

by Michael Ogawa and Kwan-Liu Ma
University of California, Davis

Attribute Types

Attribute Types

Which classes of values & measurements are there?

Categorical (nominal)

- Compare equality
- *Fruit, Gender, Movie Genres, File Types*

Ordered

- Ordinal
  - Great/Less than defined
  - *Shirt size, Rankings, Car classes*

Quantitative

- Arithmetic possible
- *Length, Weight, Count, Temperature*

➔ Categorical

➔ Ordered

➔ *Ordinal*

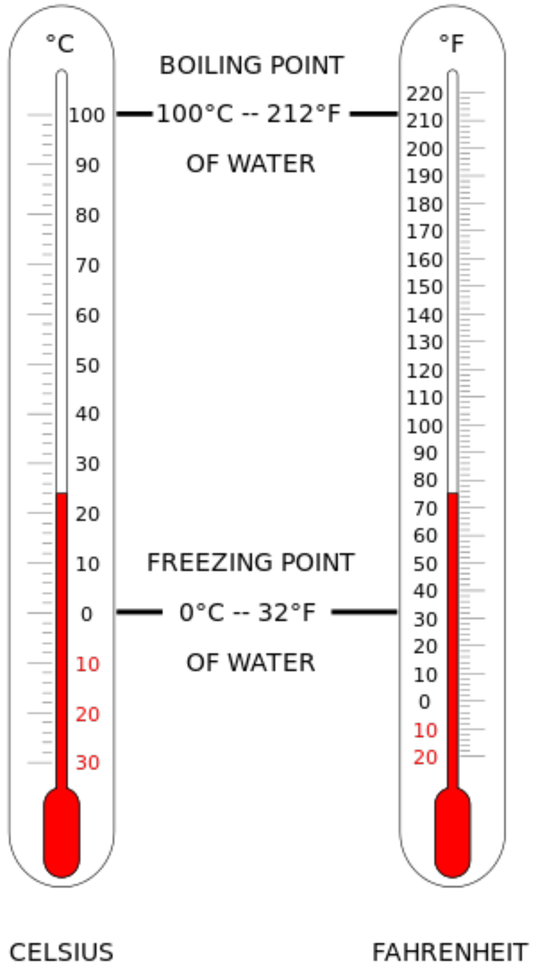
➔ *Quantitative*

Quantitative Data Type: Interval

There are equal differences between successive points on the scale but the position of zero is arbitrary.

Question to ask: does zero mean none?

- Dates: Jan 19; Location: (Lat, Long)
- Cannot compare directly. Temp in Celsius & Farenheit
- Only differences (i.e., intervals) can be compared



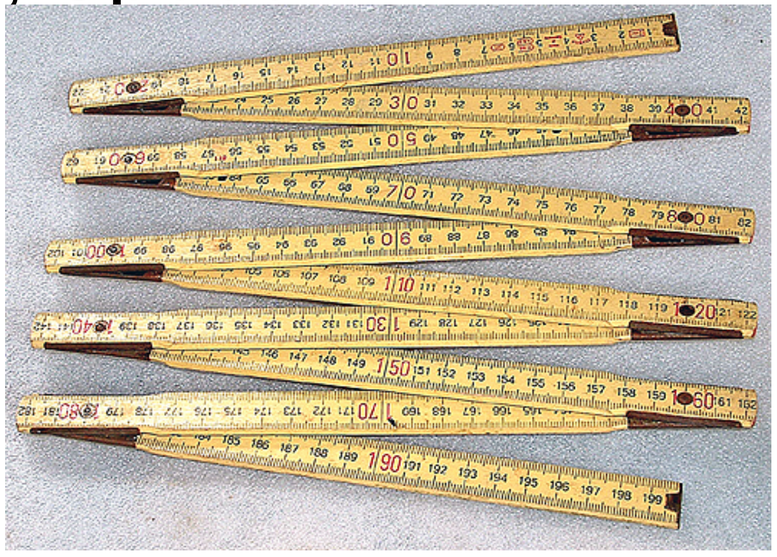
Quantitative Data Types: Ratio

The relative magnitudes of scores and the differences between them matter. The position of zero is fixed.

Zero: there is nothing of the measured entity observed

Measurements: Length, Mass, Age, Weight, Speed

Can measure ratios & proportions



Data Types

Nominal (categories, labels)

Operations: =, ≠

Ordinal (ordered)

Operations: =, ≠, >, <

Interval (location of zero arbitrary)

Operations: =, ≠, >, <, +, – (distance)

Ratio (zero fixed)

Operations: =, ≠, >, <, +, –,×, ÷ (proportions)

On the theory of scales and measurements [S. Stevens, 46]

Quiz!

What type of variable (Nominal, Ordinal, Interval, or Ratio) are the following:

1. 50 meter race times
2. College major
3. Amazon rating for a product
4. IQ Score
5. Product Name

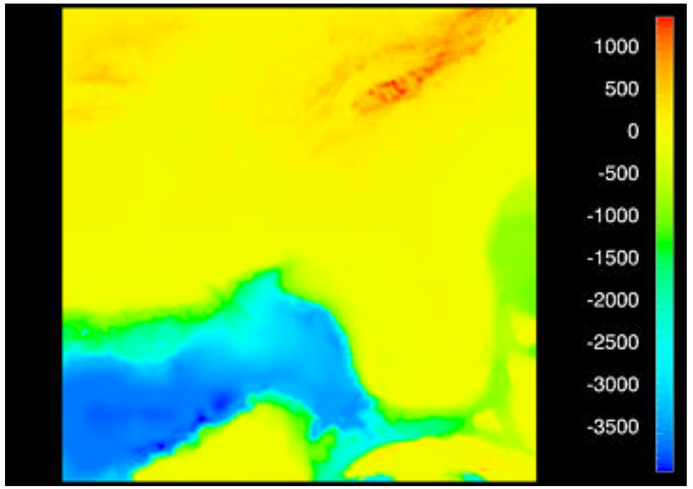
Sequential & Diverging Data

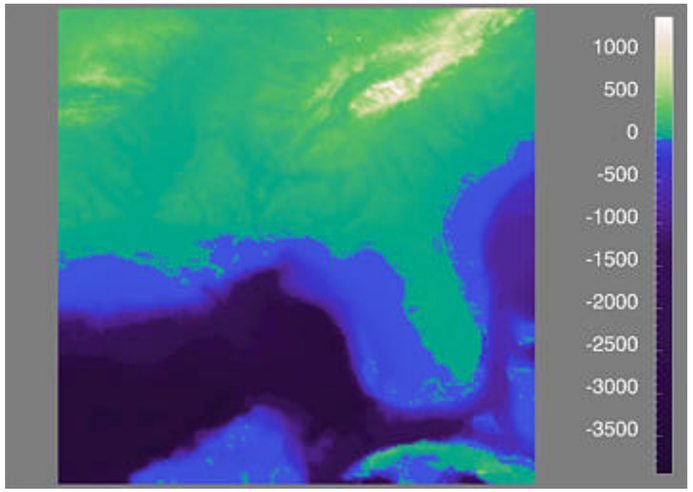
Sequential:

- homogeneous from min to max
- # people in countries

Diverging:

- two or multiple sequences that meet
- Elevation dataset: above sea level & below sea level
- Temperature of water: below or above freezing / boiling





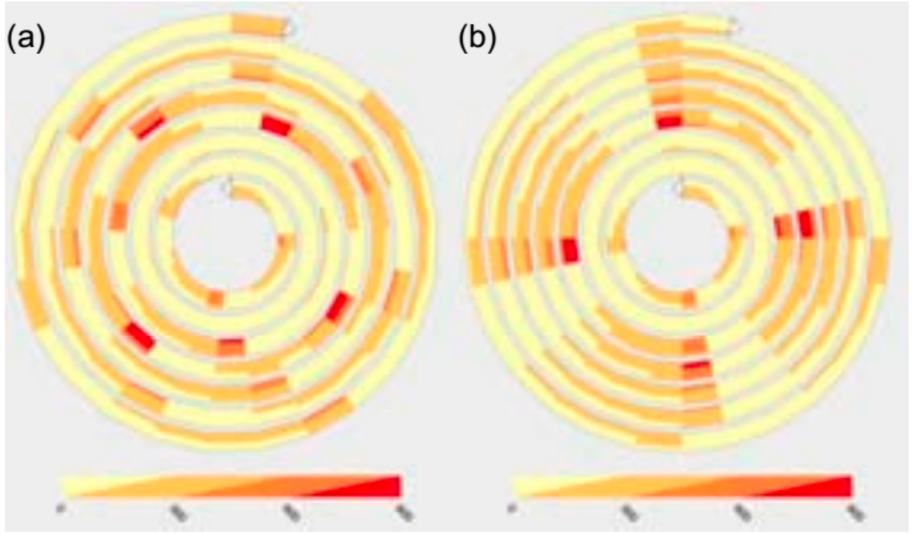
Other Structure

Cyclic data

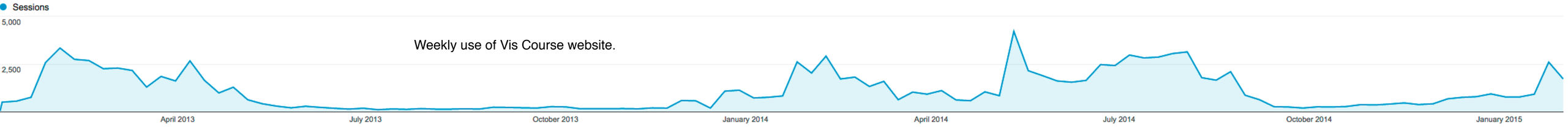
time (hours, week, month, year)

Aggregation

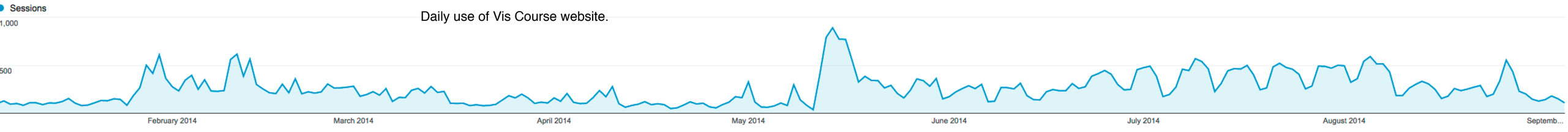
might be patterns on multiple levels



Respiratory disease cases.
Left: 25 day pattern
Right: 28 day pattern
[Tominski 2008]



Weekly use of Vis Course website.



Daily use of Vis Course website.

	A	B	C	S	T	U
1	Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
2	3	10/14/06	5-Low	Large Box	0.8	10/21/06
3	6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
4	32	7/16/07	2-High	Small Pack	0.79	7/17/07
5	32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
6	32	7/16/07	2-High	Medium Box	0.6	7/18/07
7	32	7/16/07	2-High	Medium Box	0.65	7/18/07
8	35	10/23/07	4-Not Specified	Wrap Bag		10/24/07
9	35	10/23/07	4-Not Specified	Small Box		10/25/07
10	36	11/3/07	1-Urgent	Small Box		11/3/07
11	65	3/18/07	1-Urgent	Small Pack		3/19/07
12	66	1/20/05	5-Low	Wrap Bag		1/20/05
13	69	6/4/05	4-Not Specified	Small Pack		6/6/05
14	69	6/4/05	4-Not Specified	Wrap Bag		6/6/05
15	70	12/18/06	5-Low	Small Box		12/23/06
16	70	12/18/06	5-Low	Wrap Bag		12/23/06
17	96	4/17/05	2-High	Small Box		4/19/05
18	97	1/29/06	3-Medium	Small Box	0.38	1/30/06
19	129	11/19/08	5-Low	Small Box	0.37	11/28/08
20	130	5/8/08	2-High	Small Box	0.37	5/9/08
21	130	5/8/08	2-High	Medium Box	0.38	5/10/08
22	130	5/8/08	2-High	Small Box	0.6	5/11/08
23	132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
24	132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
25	134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
26	135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
27	166	9/12/07	2-High	Small Box	0.55	9/14/07
28	193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
29	194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

Item/Element/
(Independent)
Variable

	A	B	C	S	T	U
1	Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
2	3	10/14/06	5-Low	Large Box	0.8	10/21/06
3	6	2/21/08	4-Not Specified	Small Pack		2/22/08
4	32	7/16/07	2-High	Small Pack		7/17/07
5	32	7/16/07	2-High	Jumbo Box		7/17/07
6	32	7/16/07	2-High	Medium Box		7/18/07
7	32	7/16/07	2-High	Medium Box		7/18/07
8	35	10/23/07	4-Not Specified	Wrap Bag		10/24/07
9	35	10/23/07	4-Not Specified	Small Box		10/25/07
10	36	11/3/07	1-Urgent	Small Box		11/3/07
11	65	3/18/07	1-Urgent	Small Pack		3/19/07
12	66	1/20/05	5-Low	Wrap Bag		1/20/05
13	69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
14	69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
15	70	12/18/06	5-Low	Small Box	0.59	12/23/06
16	70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
17	96	4/17/05	2-High	Small Box	0.55	4/19/05
18	97	1/29/06	3-Medium	Small Box	0.38	1/30/06
19	129	11/19/08	5-Low	Small Box	0.37	11/28/08
20	130	5/8/08	2-High	Small Box	0.37	5/9/08
21	130	5/8/08	2-High	Medium Box	0.38	5/10/08
22	130	5/8/08	2-High	Small Box	0.6	5/11/08
23	132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
24	132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
25	134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
26	135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
27	166	9/12/07	2-High	Small Box	0.55	9/14/07
28	193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
29	194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

Attribute/
Dimension/
(Dependent)
Variable/
Feature

	A	B	C	S	T	U
1	Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
2	3	10/14/06	5-Low	Large Box	0.8	10/21/06
3	6	2/21/08	4-Not Specified	Small Pack	.5	2/22/08
4	32	7/16/07	2-High	Small Pack	.9	7/17/07
5	32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
6	32	7/16/07	2-High	Medium Box	0.6	7/18/07
7	32	7/16/07	2-High	Medium Box	0.65	7/18/07
8	35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
9	35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
10	36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
11	65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
12	66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
13	69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
14	69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
15	70	12/18/06	5-Low	Small Box	0.59	12/23/06
16	70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
17	96	4/17/05	2-High	Small Box	0.55	4/19/05
18	97	1/29/06	3-Medium	Small Box	0.38	1/30/06
19	129	11/19/08	5-Low	Small Box	0.37	11/28/08
20	130	5/8/08	2-High	Small Box	0.37	5/9/08
21	130	5/8/08	2-High	Medium Box	0.38	5/10/08
22	130	5/8/08	2-High	Small Box	0.6	5/11/08
23	132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
24	132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
25	134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
26	135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
27	166	9/12/07	2-High	Small Box	0.55	9/14/07
28	193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
29	194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

Semantics

	A	B	C	S	T	U
1	Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
2	3	10/14/06	5-Low	Large Box	0.8	10/21/06
3	6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
4	32	7/16/07	2-High	Small Pack	0.79	7/17/07
5	32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
6	32	7/16/07	2-High	Medium Box	0.6	7/18/07
7	32	7/16/07	2-High	Medium Box		7/18/07
8	35	10/23/07	4-Not Specified	Wrap Bag		10/24/07
9	35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
10	36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
11	65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
12	66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
13	69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
14	69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
15	70	12/18/06	5-Low	Small Box	0.59	12/23/06
16	70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
17	96	4/17/05	2-High	Small Box	0.55	4/19/05
18	97	1/29/06	3-Medium	Small Box	0.38	1/30/06
19	129	11/19/08	5-Low	Small Box	0.37	11/28/08
20	130	5/8/08	2-High	Small Box	0.37	5/9/08
21	130	5/8/08	2-High	Medium Box	0.38	5/10/08
22	130	5/8/08	2-High	Small Box	0.6	5/11/08
23	132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
24	132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
25	134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
26	135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
27	166	9/12/07	2-High	Small Box	0.55	9/14/07
28	193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
29	194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

Keys?

Sheets Charts SmartArt Graphics WordAr

	A	B	C	S	T	U
1	Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
2	3	10/14/06	5-Low	Large Box	0.8	10/21/06
3	6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
4	32	7/16/07	2-High	Small Pack	0.79	7/17/07
5	32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
6	32	7/16/07	2-High	Medium Box	0.6	7/18/07
7	32	7/16/07	2-High	Medium Box	0.65	7/18/07
8	35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
9	35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
10	36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
11	65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
12	66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
13	69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
14	69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
15	70	12/18/06	5-Low	Small Box	0.59	12/23/06
16	70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
17	96	4/17/05	2-High	Small Box	0.55	4/19/05
18	97	1/29/06	3-Medium	Small Box	0.38	1/30/06
19	129	11/19/08	5-Low	Small Box	0.37	11/28/08
20	130	5/8/08	2-High	Small Box	0.37	5/9/08
21	130	5/8/08	2-High	Medium Box	0.38	5/10/08
22	130	5/8/08	2-High	Small Box		5/11/08
23	132	6/11/06	3-Medium	Medium Box		6/12/06
24	132	6/11/06	3-Medium	Jumbo Box		6/14/06
25	134	5/1/08	4-Not Specified	Large Box		5/3/08
26	135	10/21/07	4-Not Specified	Small Pack		10/23/07
27	166	9/12/07	2-High	Small Box	0.55	9/14/07
28	193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
29	194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

Attribute Types?

	A	B	C	S	T	U
1	Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
2	3	10/14/06	5-Low	Large Box	0.8	10/21/06
3	6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
4	32	7/16/07	2-High	Small Pack	0.79	7/17/07
5	32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
6	32	7/16/07	2-High	Medium Box	0.6	7/18/07
7	32	7/16/07	2-High	Medium Box	0.65	7/18/07
8	35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
9	35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
10	36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
11	65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
12	66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
13	69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
14	69	6/4/05	4-Not Specified	Wrap Bag	0.6	6/6/05
15	70	12/18/06	5-Low	Small Box	0.59	12/23/06
16	70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
17	96	4/17/05	2-High	Small Box	0.55	4/19/05
18	97	1/29/06	3-Medium	Small Box	0.38	1/30/06
19	129	11/19/08	5-Low	Small Box	0.37	11/28/08
20	130	5/8/08	2-High	Small Box	0.37	5/9/08
21	130	5/8/08	2-High	Medium Box	0.38	5/10/08
22	130	5/8/08	2-High	Small Box	0.6	5/11/08
23	132	6/11/06	3-Medium	Medium Box		
24	132	6/11/06	3-Medium	Jumbo Box		
25	134	5/1/08	4-Not Specified	Large Box		
26	135	10/21/07	4-Not Specified	Small Pack		
27	166	9/12/07	2-High	Small Box		
28	193	8/8/06	1-Urgent	Medium Box		
29	194	4/5/08	3-Medium	Wrap Bag		

Categorical

Ordinal

Quantitative

Data vs. Conceptual Model

Data Model: Low-level description of the data

Set with operations, e.g., floats with +, -, /, *

Conceptual Model: Mental construction

Includes semantics, supports reasoning

Data	Conceptual
1D floats	temperature
3D vector of floats	space

Data vs. Conceptual Model

From data model...

32.5, 54.0, -17.3, … (floats)

using conceptual model...

Temperature

to data type

Continuous to 4 significant digits (Q)

Hot, warm, cold (O)

Burned vs. Not burned (N)

Combinations, Derived Data

Networks can have attributes

Attributes have hierarchies

Data types can be transformed

Real life is complicated…