

CSC 544

Data Visualization

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Lecture 06

Data Abstraction

Feb. 6, 2023

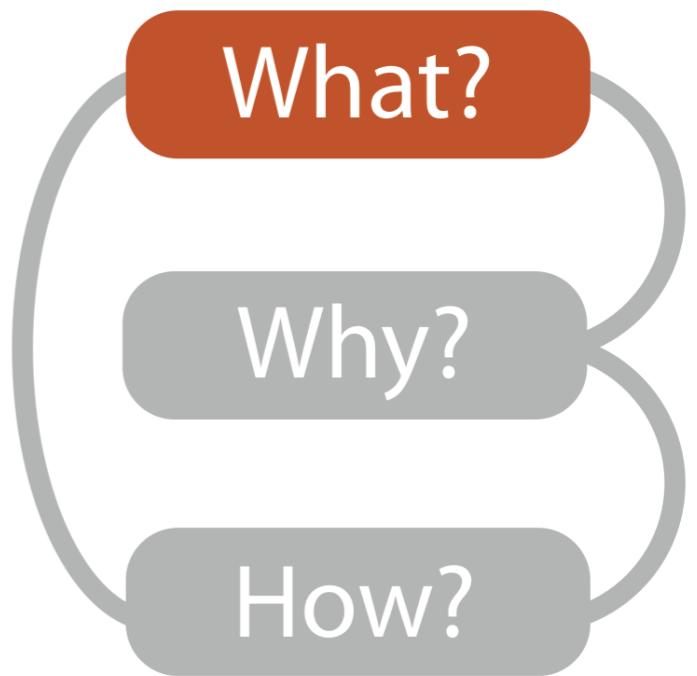
Today's Agenda

- Reminders:
 - A01 due!
 - P01, A02 posted, questions?
- Goals for today:
 - Discuss data abstraction

Data Taxonomy

Data Abstraction

- The “what” part of an analysis that pertains to the data
- Translation of domain-specific terms into words that are as generic as possible



Data Types

➔ Data Types

➔ Items ➔ Attributes ➔ Links ➔ Positions ➔ Grids

From Data Types to Dataset Types

→ Data Types

→ Items → Attributes → Links → Positions → Grids

→ Data and Dataset Types

Tables

Items

Attributes

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box		7/17/07
32	7/16/07	2-High	Medium Box		7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	item	5	Small Pack	0.44	6/6/05
69		5	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

attribute

cell

item

Working with Attributes

Semantics vs. Types

- For a given attribute we have both:
 - **Semantics:** Real-world meaning of the data.
 - **Type:** Interpretation in terms of scales of measurement.
- Can items have both semantics and type?

(Basic) Variable Types

- Physical type
 - Characterized by storage format & machine ops

Example: bool, short, int, float, double, string, ...

- Abstract type
 - Provide descriptions of the data
 - Characterized by methods / attributes
 - May be organized into a hierarchy

Examples: plants, animals, metazoans, ...

SCIENCE

Vol. 103, No. 2684

Friday, June 7, 1946

On the Theory of Scales of Measurement

S. S. Stevens

Director, Psycho-Acoustic Laboratory, Harvard University

FOR SEVEN YEARS A COMMITTEE of the British Association for the Advancement of Science debated the problem of measurement. Appointed in 1932 to represent Section A (Mathematical and Physical Sciences) and Section J (Psychology), the committee was instructed to consider and report upon the possibility of "quantitative estimates of sensory events"—meaning simply: Is it possible to measure human sensation? Deliberation led only to disagreement, mainly about what is meant by the term measurement. An interim report in 1938 found one member complaining that his colleagues

by the formal (mathematical) properties of the scales. Furthermore—and this is of great concern to several of the sciences—the statistical manipulations that can legitimately be applied to empirical data depend upon the type of scale against which the data are ordered.

A CLASSIFICATION OF SCALES OF MEASUREMENT

Paraphrasing N. R. Campbell (Final Report, p. 340), we may say that measurement, in the broadest sense, is defined as the assignment of numerals to objects or events according to rules. The fact that

Attribute Types

Attribute Types

→ Categorical

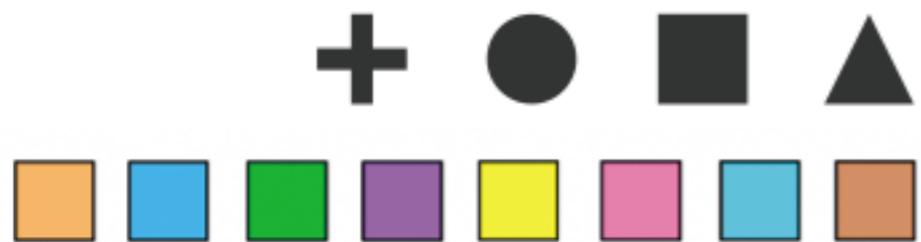
Attribute Types

- Categorical
 - no implicit ordering

Attribute Types

→ Categorical

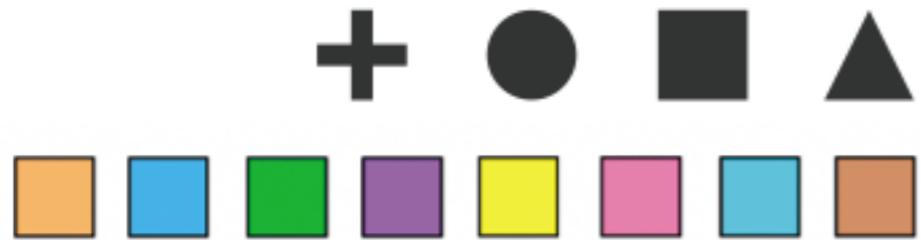
no implicit ordering



Attribute Types

→ Categorical

no implicit ordering



→ Ordered

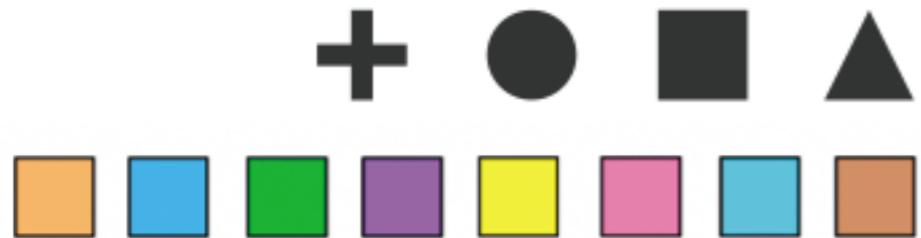
→ *Ordinal*

→ *Quantitative*

Attribute Types

→ Categorical

no implicit ordering



→ Ordered

→ *Ordinal*

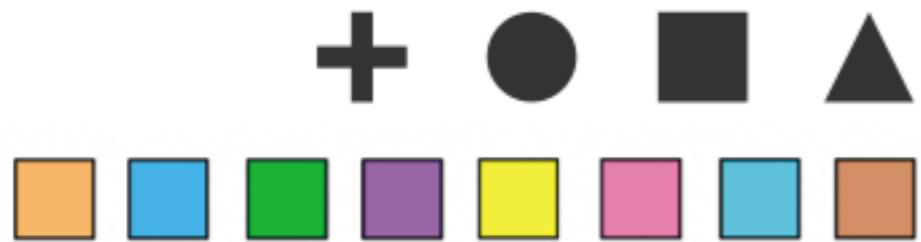
→ *Quantitative*

**well-defined
ordering**

Attribute Types

→ Categorical

no implicit ordering



→ Ordered

→ *Ordinal*

→ *Quantitative*

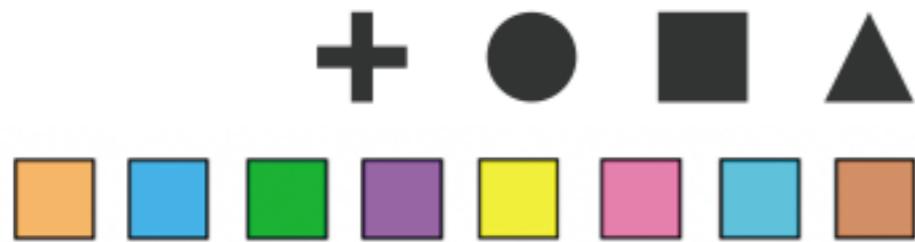
**well-defined
ordering**



Attribute Types

→ Categorical

no implicit ordering



→ Ordered

→ *Ordinal*

**well-defined
ordering**



→ *Quantitative*

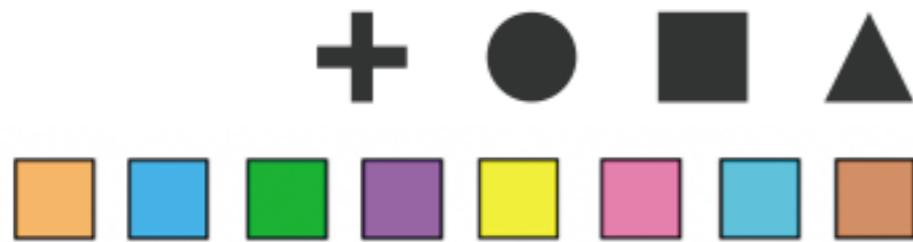
**meaningful magnitude,
can do arithmetic**



Attribute Types

→ Categorical

no implicit ordering



→ Ordered

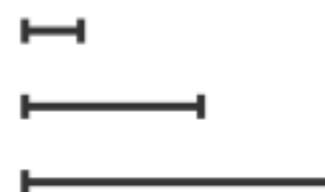
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**well-defined
ordering**



→ *Quantitative*

**meaningful magnitude,
can do arithmetic**



Attribute Types (N,O,Q)

S. S. Stevens. On the Theory of Scales of Measurement. *Science*, 103(2684), 1946.

Attribute Types (N,O,Q)

N - Nominal (same as Categorical)

- Fruits: Apples, oranges, ...

Attribute Types (N,O,Q)

N - Nominal (same as Categorical)

- Fruits: Apples, oranges, ...

O - Ordered

- Quality of meat: Grade A, AA, AAA

Attribute Types (N,O,Q)

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- Quality of meat: Grade A, AA, AAA

Q - Interval (Location of zero arbitrary)

- Dates: Jan, 19, 2006; Location: (LAT 33.98, LONG -118.45)
- Only differences (i.e. intervals) may be compared

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- Only differences (i.e. intervals) may be compared

Q - Ratio (zero fixed)

- Physical measurement: Length, Mass, Temp, ...
- Counts and amounts

Attribute Types (N,O,Q)

N - Nominal (labels, categories)

- Operations: $=, \neq$

O - Ordinal (ordered)

- Operations: $=, \neq, >, <$

Q - Interval (location of zero arbitrary)

- Operations: $=, \neq, >, <, +, -$
- Can measure distances or spans

Q - Ratio (zero fixed)

- Operations: $=, \neq, >, <, +, -, \times, \div$
- Can measure ratios or proportions

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
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32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box		7/17/07
32	7/16/07	2-High	Medium Box		7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	item	5	Small Pack	0.44	6/6/05
69		5	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
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96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
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130	5/8/08	2-High	Medium Box	0.38	5/10/08
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193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08
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attribute

item

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32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	7/18/07
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quantitative
ordinal
categorical

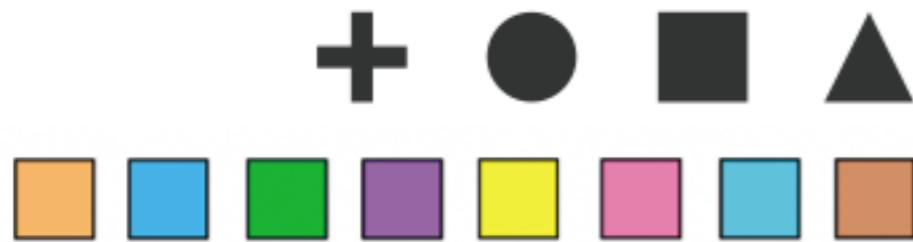
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194	4/5/08	3-Medium	Wrap Bag	0.24	4/7/08

quantitative
ordinal
categorical

Attribute Types

→ Categorical

no implicit ordering



→ Ordered

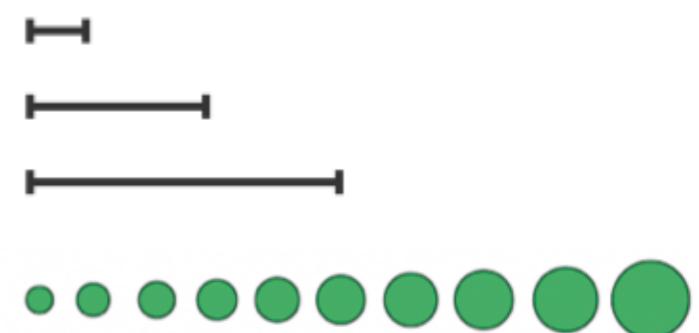
→ *Ordinal*

**well-defined
ordering**



→ *Quantitative*

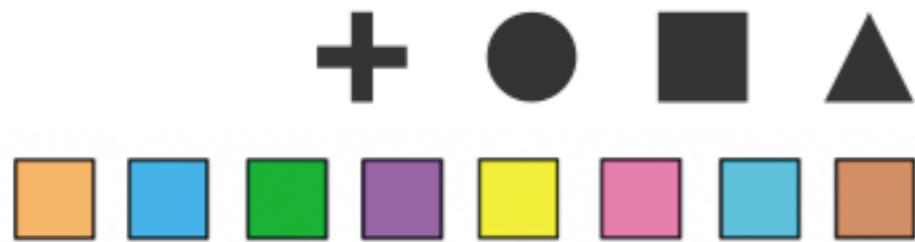
**meaningful magnitude,
can do arithmetic**



Attribute Types

→ Categorical

no implicit ordering



→ Ordered

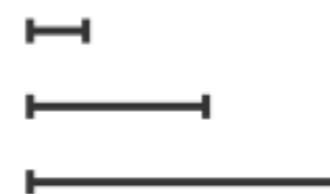
→ *Ordinal*

**well-defined
ordering**



→ *Quantitative*

**meaningful magnitude,
can do arithmetic**



→ Hierarchical

→ Sequential

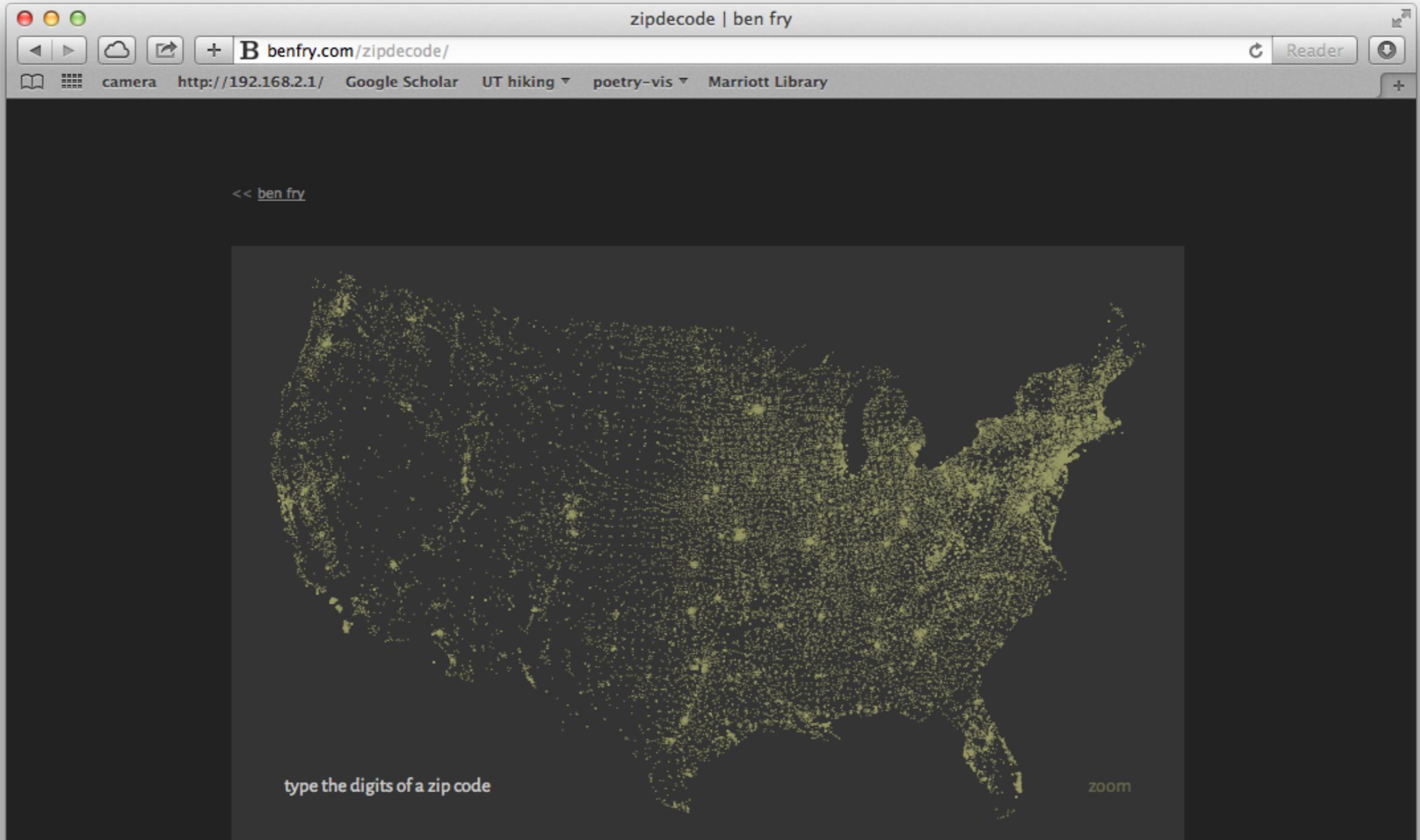


→ Diverging



→ Cyclic





Hit the letter **z**, or click the word **zoom** to enable or disable zooming.

zipdecode

This project began a very short sketch (a few hours) that I created in 1999 because I was curious about how the numbering works for postal codes in the states.

A detailed description of this project (and source code built with [Processing](#)) can be found in my book [Visualizing Data](#).

Updated September 2004 to add several features over the original, including zoom, some new colors (thanks to [Eugene Kuo](#)), and a better zip code database (because of all the people who emailed and were sad that they couldn't find themselves).

From Data to Datasets

Combinations of Data Types Result in Dataset Types

→ Data Types

→ Items → Attributes → Links → Positions → Grids

→ Data and Dataset Types

Tables

Items

Attributes

Networks &
Trees

Items (nodes)

Links

Attributes

Fields

Grids

Positions

Attributes

Geometry

Items

Positions

Clusters,
Sets, Lists

Items

Counterpoint: Interpretivist vs. Positivist Viewpoint on Data Abstractions

Guidelines For Pursuing and Revealing Data Abstractions

Alex Bigelow, Katy Williams, and Katherine E. Isaacs

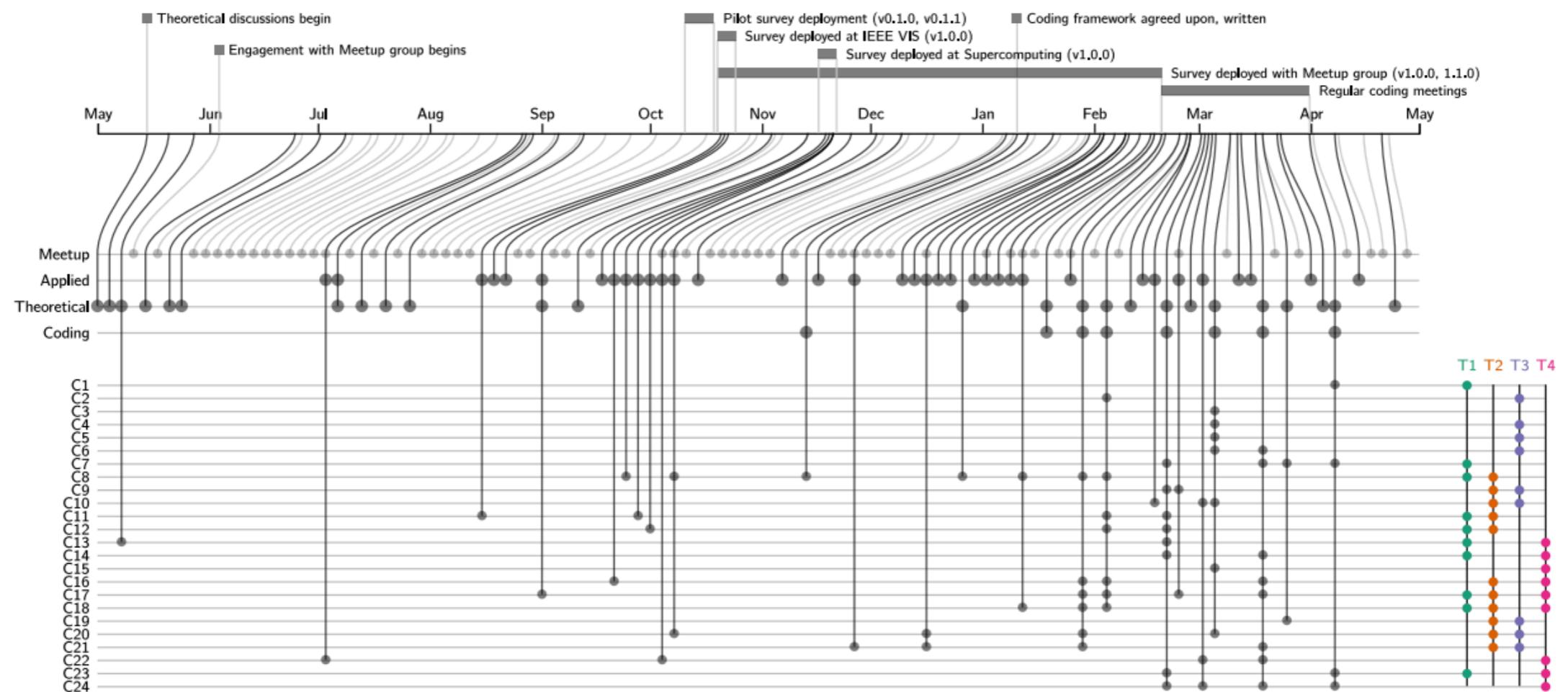


Fig. 1. A summary of study events over time, their temporal relationship with memos, memo relationships with codes, and code relationships with themes. The timeline at the top shows the timing of study events, with curved lines indicating when individual memos were created. The four rows below the timeline indicate the nature of the context in which memos were written, including Meetup attendance, when data workers discussed their applied datasets, when the authors engaged in theoretical discussions, and when the authors engaged in open coding. The bottom section shows the 24 codes and the four themes they inform. The columns T1–T4 show which codes directly inform which themes.

<http://hdc.cs.arizona.edu/people/kawilliams/abstractions/>

→ Data and Dataset Types

Tables

Items

Attributes

Networks & Trees

Items (nodes)

Links

Attributes

Fields

Grids

Positions

Attributes

Geometry

Items

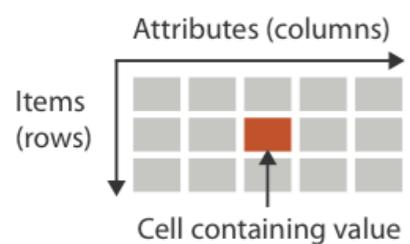
Positions

Clusters, Sets, Lists

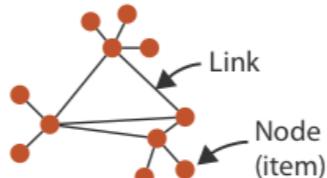
Items

→ Dataset Types

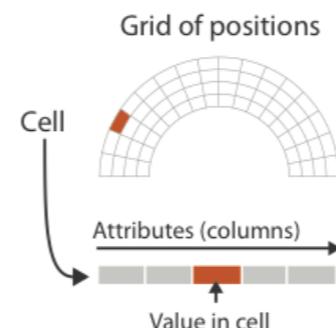
→ Tables



→ Networks



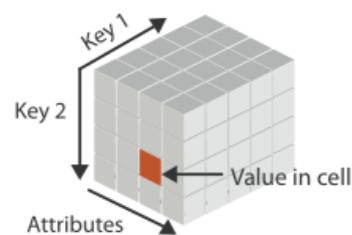
→ Fields (Continuous)



→ Geometry (Spatial)



→ Multidimensional Table



→ Trees



→ Data and Dataset Types

Tables

Items

Attributes

Networks & Trees

Items (nodes)

Links

Attributes

Fields

Grids

Positions

Attributes

Geometry

Items

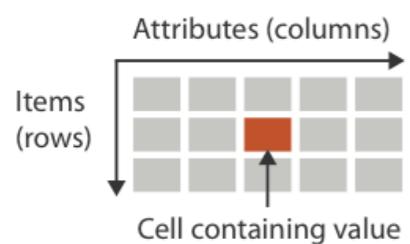
Positions

Clusters, Sets, Lists

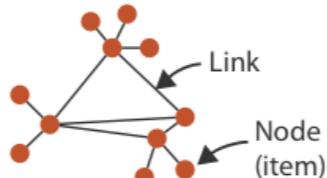
Items

→ Dataset Types

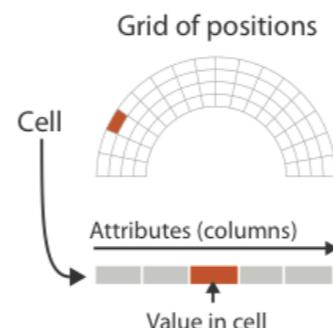
→ Tables



→ Networks



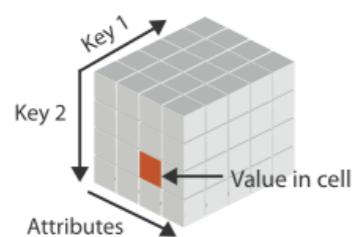
→ Fields (Continuous)



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→ Multidimensional Table



→ Trees



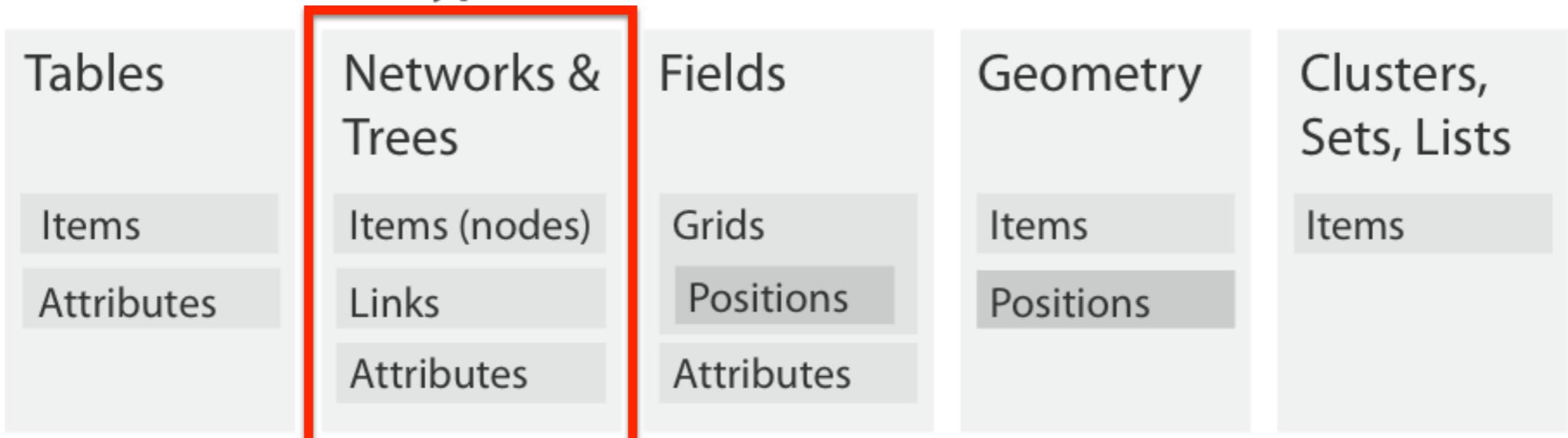
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130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
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193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

attribute

cell

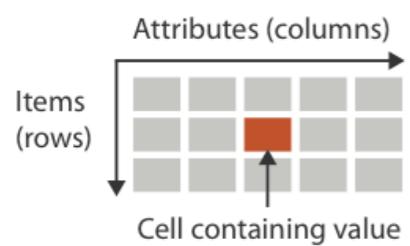
item

→ Data and Dataset Types

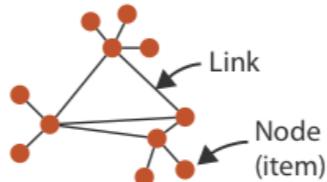


→ Dataset Types

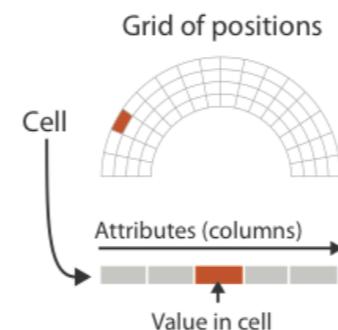
→ Tables



→ Networks



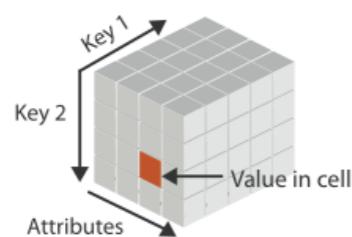
→ Fields (Continuous)



→ Geometry (Spatial)

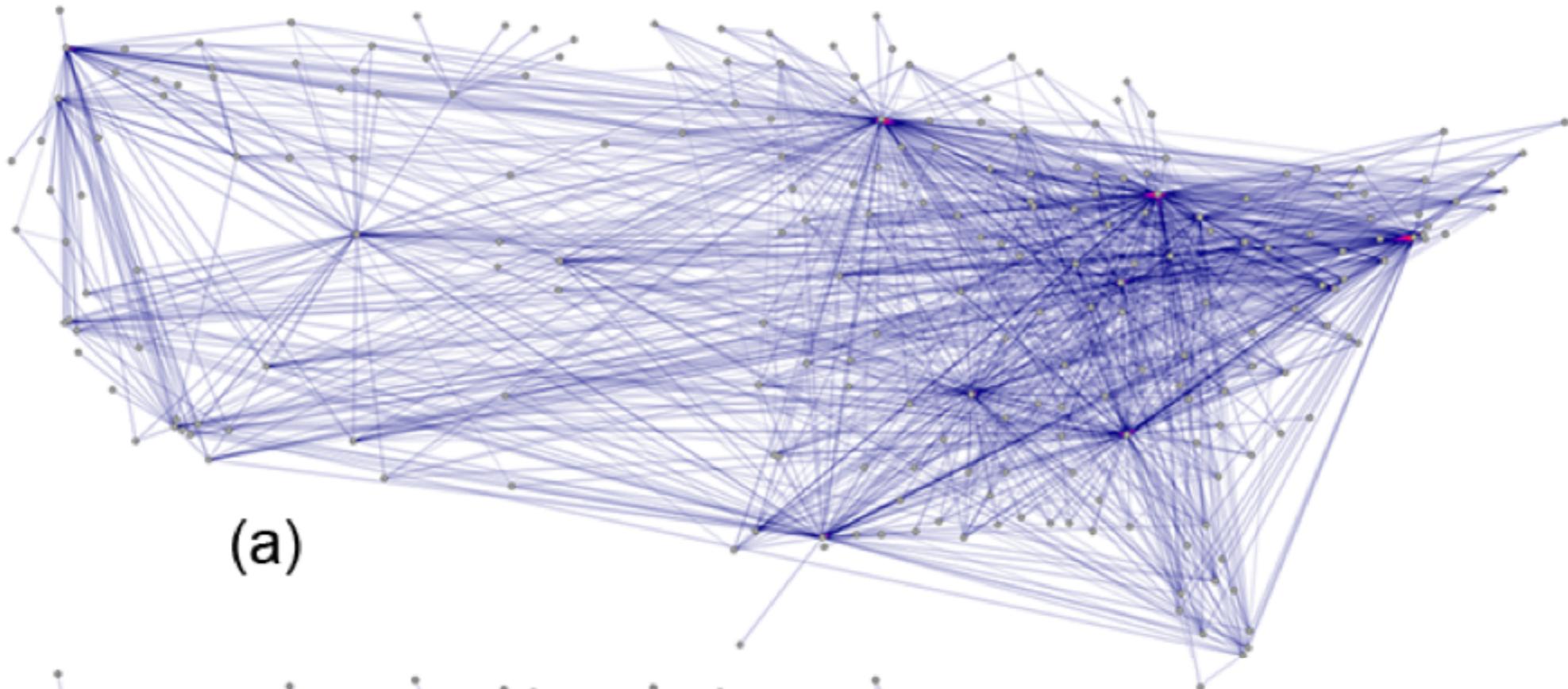


→ Multidimensional Table



→ Trees





(a)



(d)

US airlines graph (235 nodes, 2101 edges)

Holten, Wijk: Force-Directed Edge Bundling for Graph Visualization. CGF 2009

→ Data and Dataset Types

Tables

Items

Attributes

Networks &
Trees

Items (nodes)

Links

Attributes

Fields

Grids

Positions

Attributes

Geometry

Items

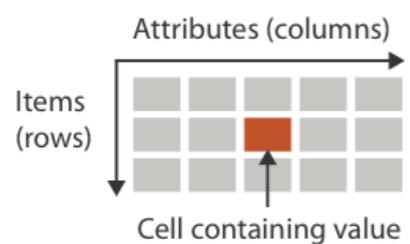
Positions

Clusters,
Sets, Lists

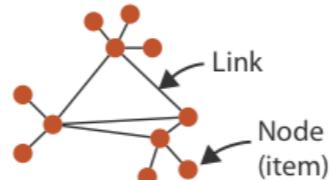
Items

→ Dataset Types

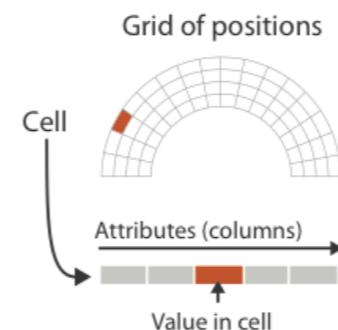
→ Tables



→ Networks



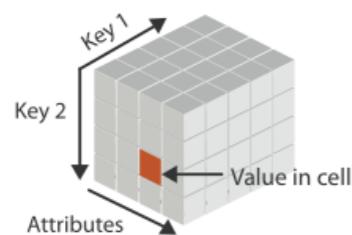
→ Fields (Continuous)



→ Geometry (Spatial)



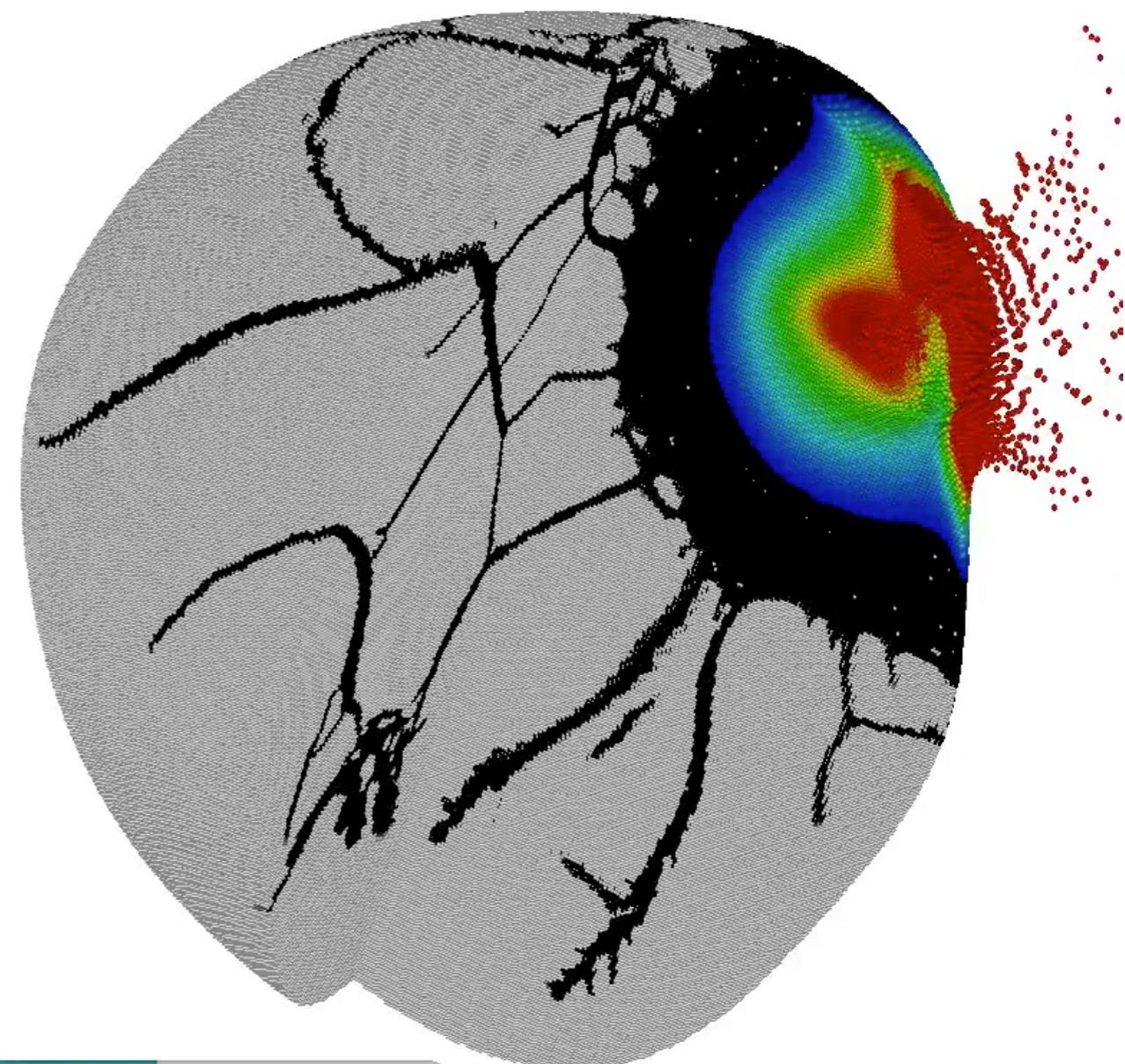
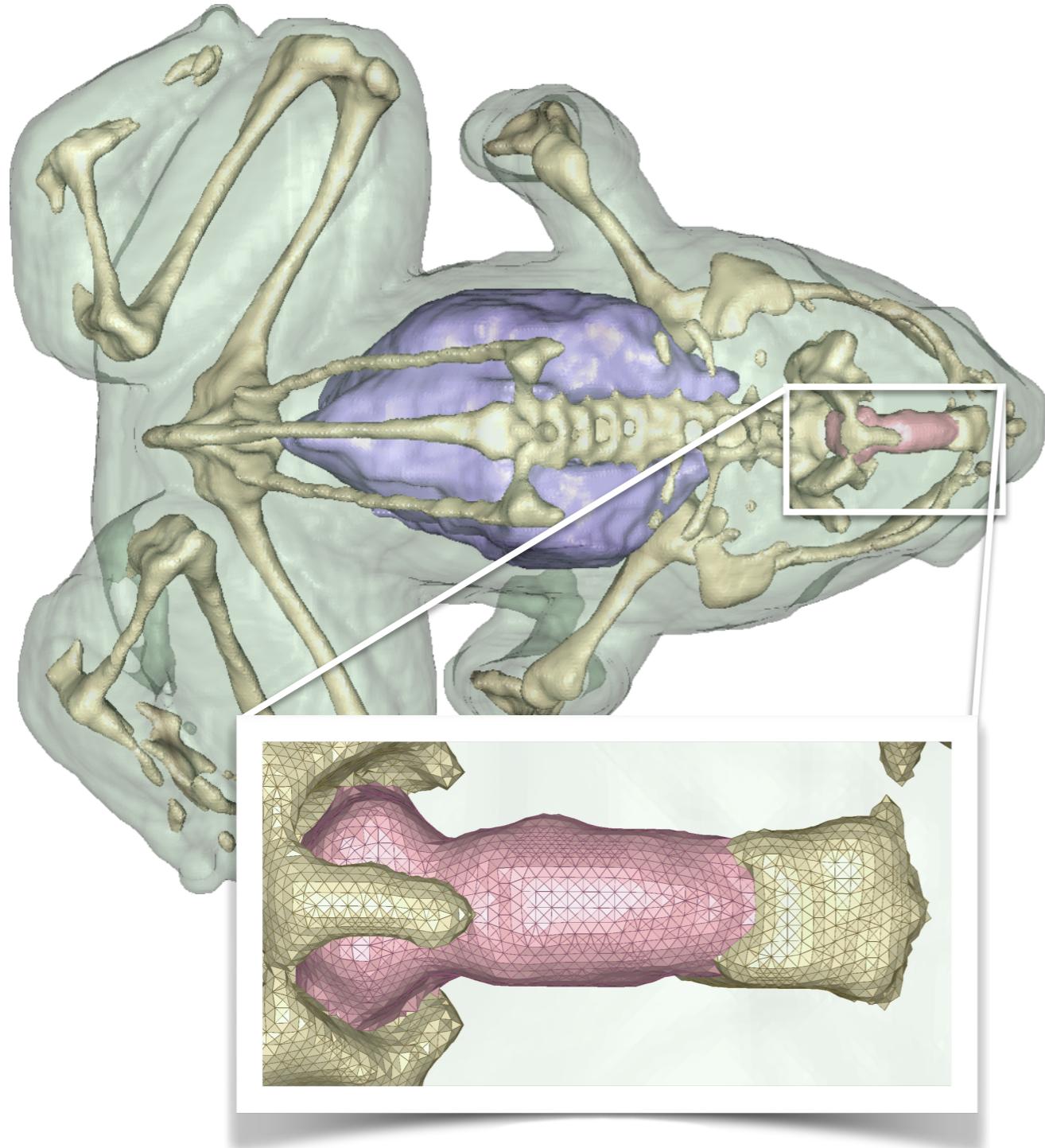
→ Multidimensional Table



→ Trees



Bronson et al. Lattice Cleaving: A Multimaterial Tetrahedral Meshing Algorithm with Guarantees. TVCG 2014



Time=22.0016

Rovny et al. Modeling impact cratering on Phobos. LPSC 2013.

→ Data and Dataset Types

Tables

Items

Attributes

Networks & Trees

Items (nodes)

Links

Attributes

Fields

Grids

Positions

Attributes

Geometry

Items

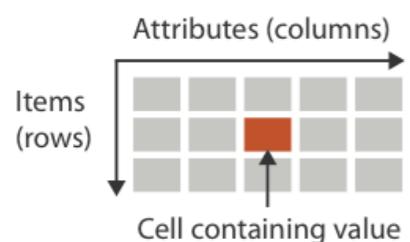
Positions

Clusters, Sets, Lists

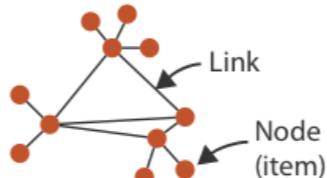
Items

→ Dataset Types

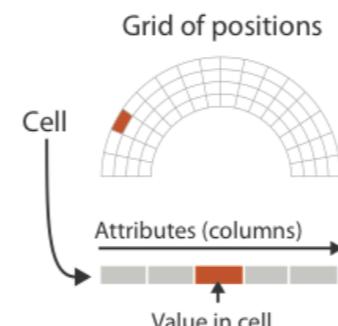
→ Tables



→ Networks



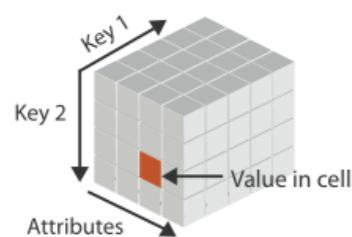
→ Fields (Continuous)



→ Geometry (Spatial)



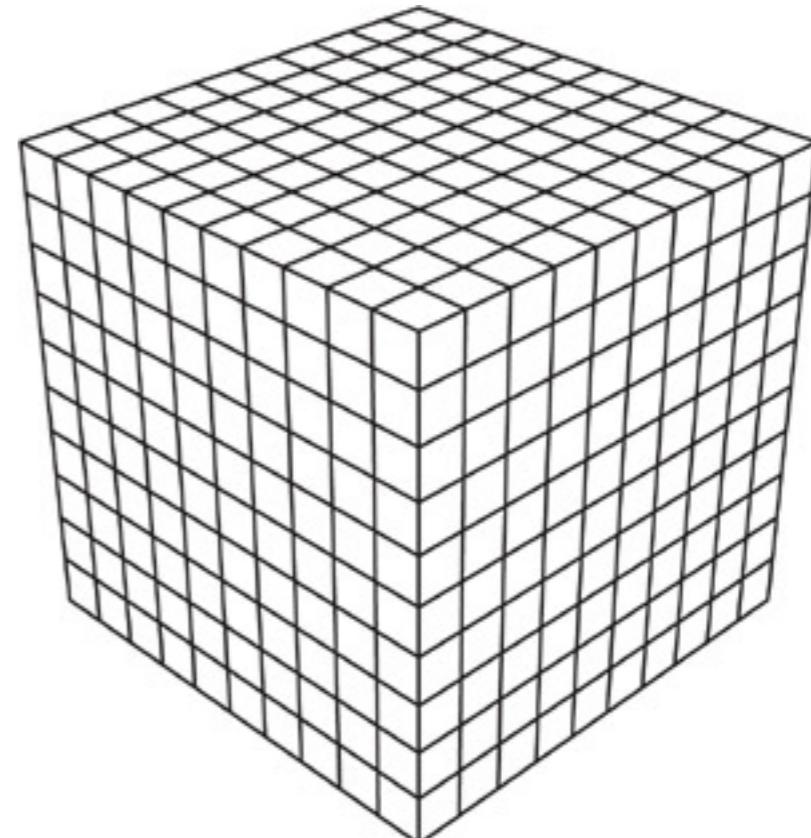
→ Multidimensional Table

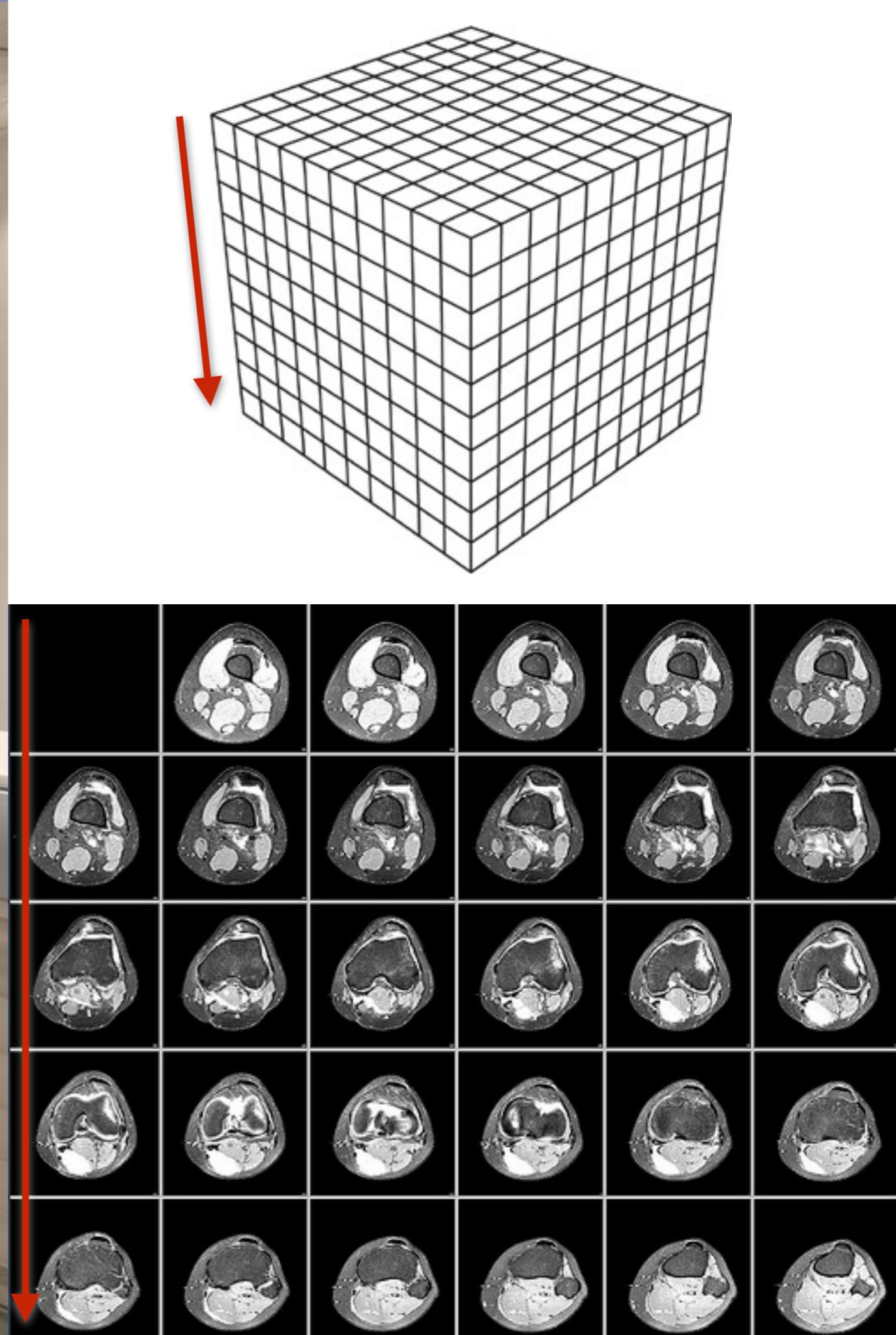


→ Trees





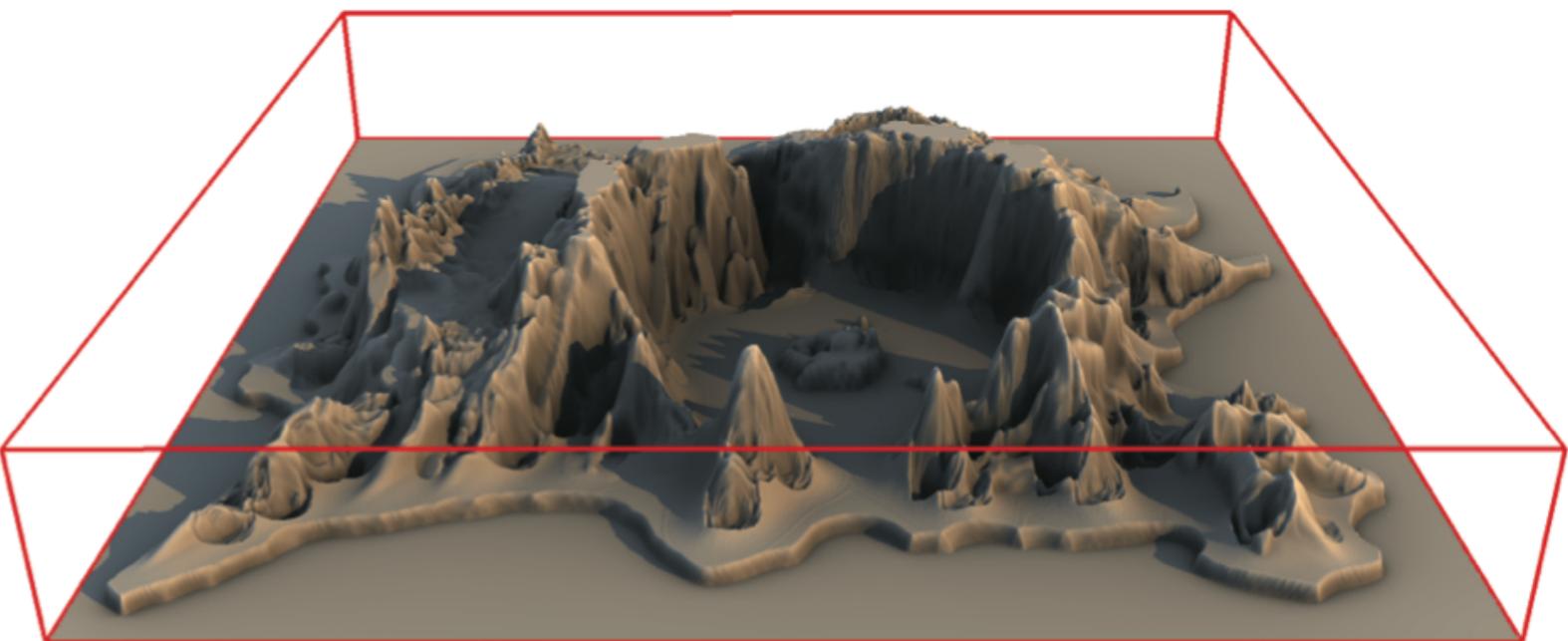




Bruckner et al. Illustrative Context-Preserving Volume Rendering. EuroVis 2005



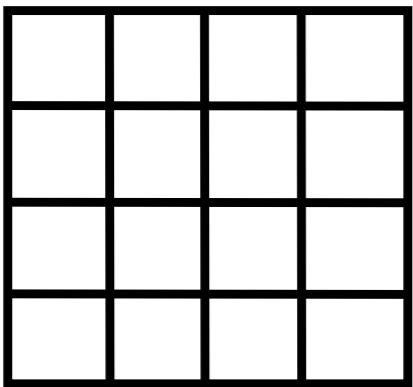
“Fields differ from tables in a fundamental way because they represent continuous rather than discrete data.”



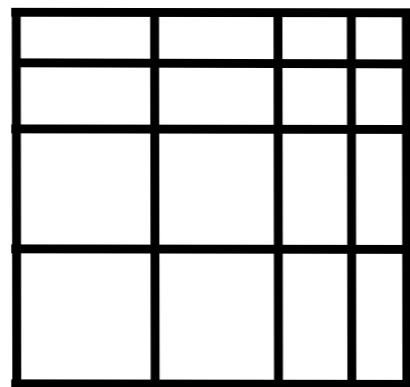
Baboud et al. Precomputed Safety Shapes for Efficient and Accurate Height-Field Rendering. IEEE TVCG 2012

Grids (Meshes)

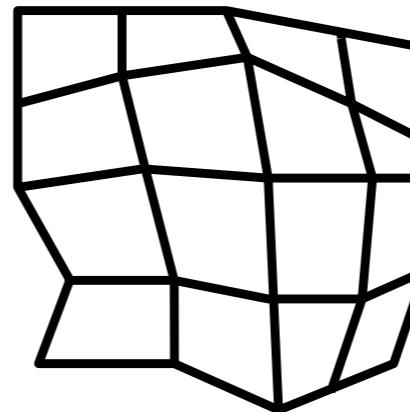
- Meshes combine positional information (geometry) with topological information (connectivity).
- Mesh type can differ substantially depending in the way mesh cells are formed.



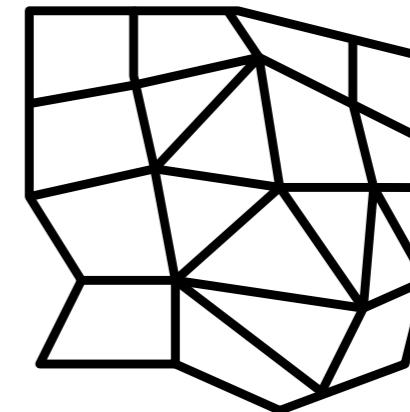
uniform



rectilinear



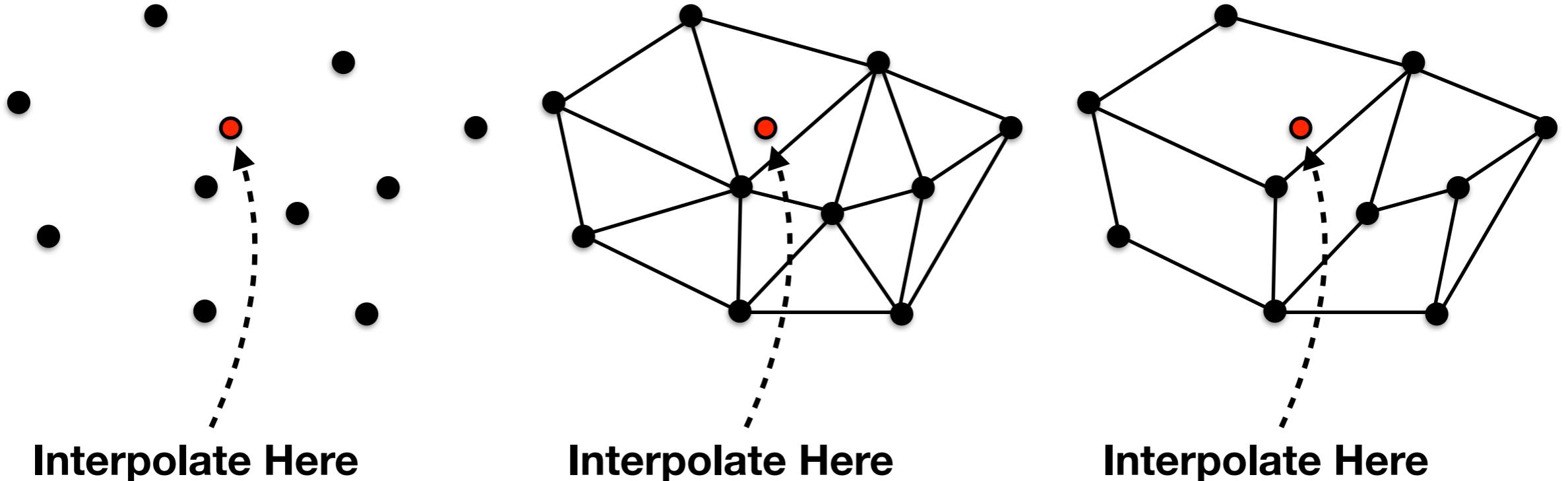
structured



unstructured

Mesh Choice Impacts How the Continuous Data is Interpreted

- Two key questions:
 1. **Sampling**, or the choice of where attributes are measured
 2. **Interpolation**, or how to model the attributes in the rest of space



→ Data and Dataset Types

Tables

Items

Attributes

Networks & Trees

Items (nodes)

Links

Attributes

Fields

Grids

Positions

Attributes

Geometry

Items

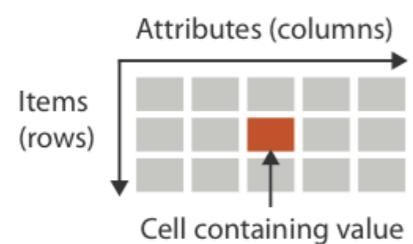
Positions

Clusters, Sets, Lists

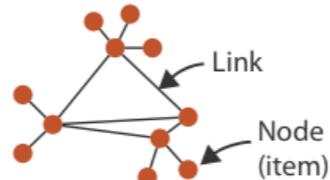
Items

→ Dataset Types

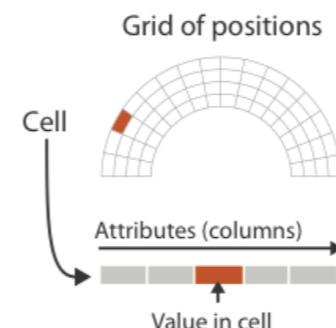
→ Tables



→ Networks



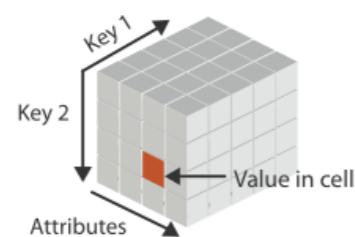
→ Fields (Continuous)



→ Geometry (Spatial)



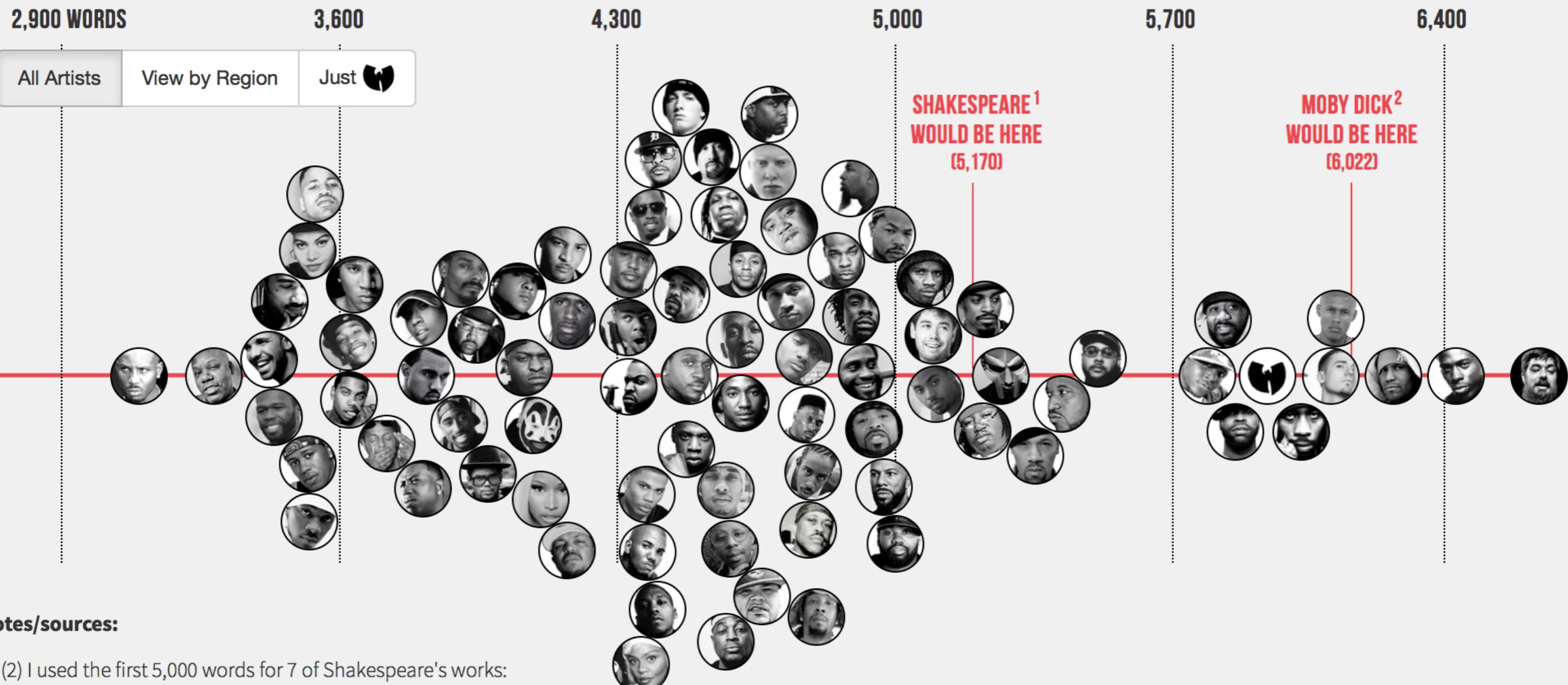
→ Multidimensional Table



→ Trees



OF UNIQUE WORDS USED WITHIN ARTIST'S FIRST 35,000 LYRICS



Notes/sources:

(1)(2) I used the first 5,000 words for 7 of Shakespeare's works:
Hamlet, Romeo and Juliet, Othello, Macbeth, As You Like It,
Winter's Tale, and Troilus and Cressida. For Melville, I used the first
35,000 words of Moby Dick.

All lyrics are provided by Rap Genius, but are only current to 2012.
My lack of recent data prevented me from using quite a few current
artists.

This data viz uses code by Amelia Bellamy-Royds's in [this jsfiddle](#).

Modeling and Semantics

Data Models vs. Conceptual Models

Data models are low-level descriptions of the data

- Math: Sets with operations on them
- Examples: floats with +, -, /, *

Conceptual models are mental constructions

- Include semantics and support reasoning

Examples (data vs. conceptual)

- (1D floats) vs. Temperatures
- (3D vectors of floats) vs. Space

Attribute Semantics

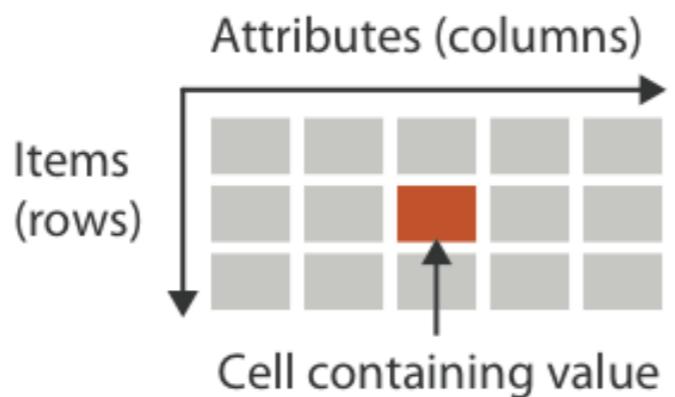
Keys vs. Values (Tables) or Independent vs. Dependent (Fields)

Attribute Semantics

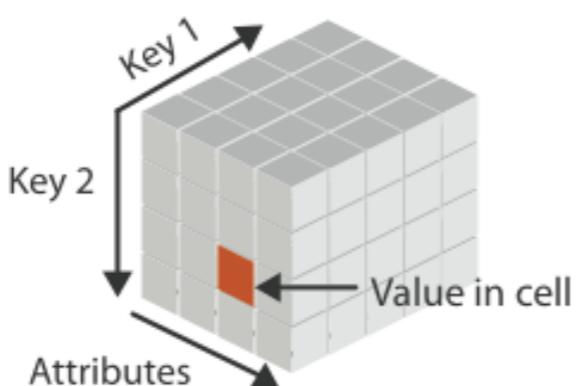
Keys vs. Values (Tables) or Independent vs. Dependent (Fields)

Tables

Flat



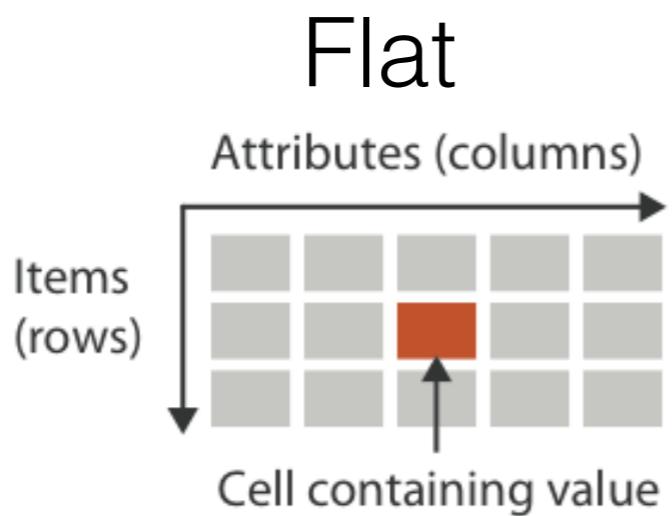
Multidimensional



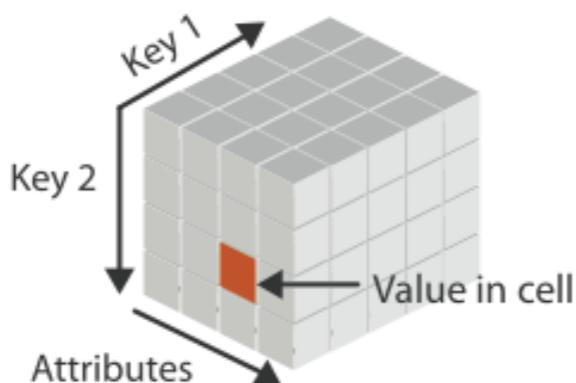
Attribute Semantics

Keys vs. Values (Tables) or Independent vs. Dependent (Fields)

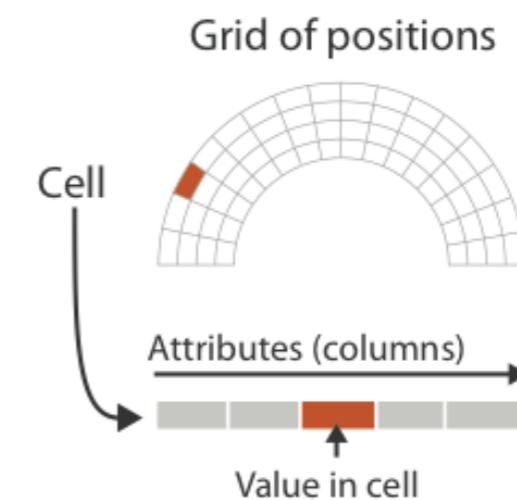
Tables



Multidimensional



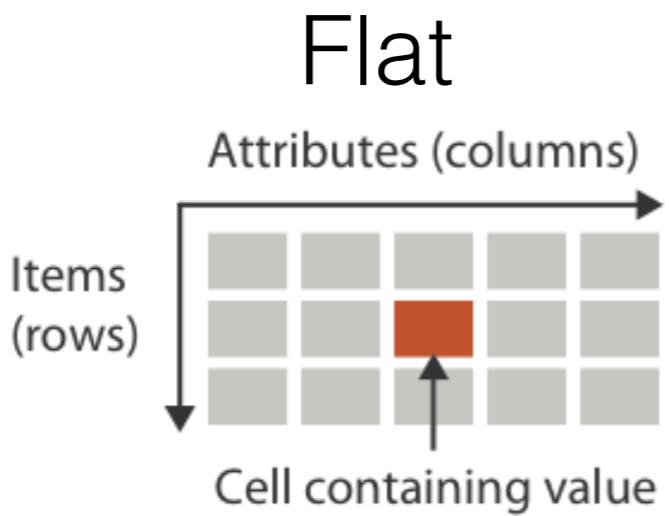
Fields



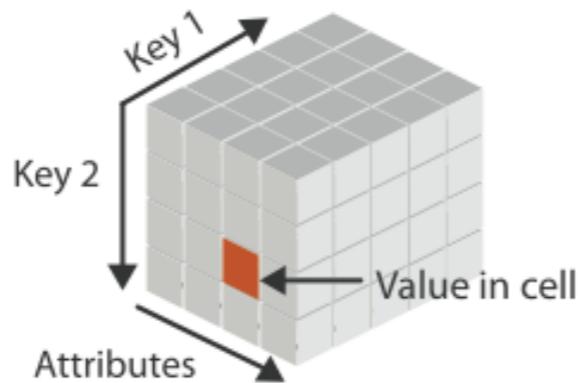
Attribute Semantics

Keys vs. Values (Tables) or Independent vs. Dependent (Fields)

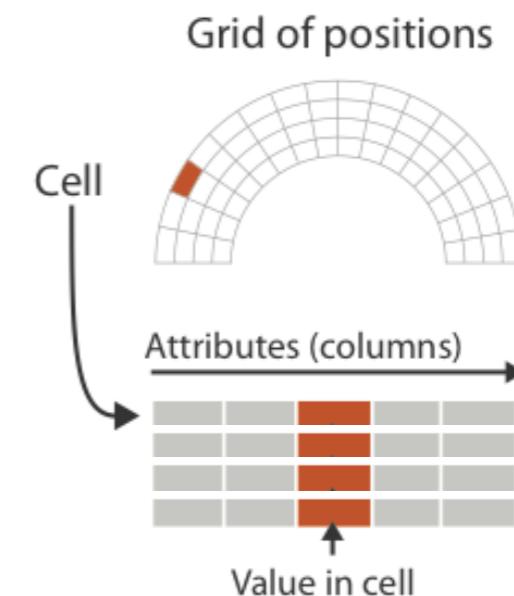
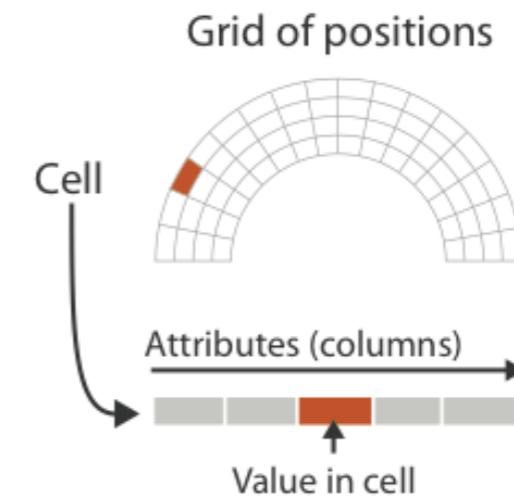
Tables



Multidimensional

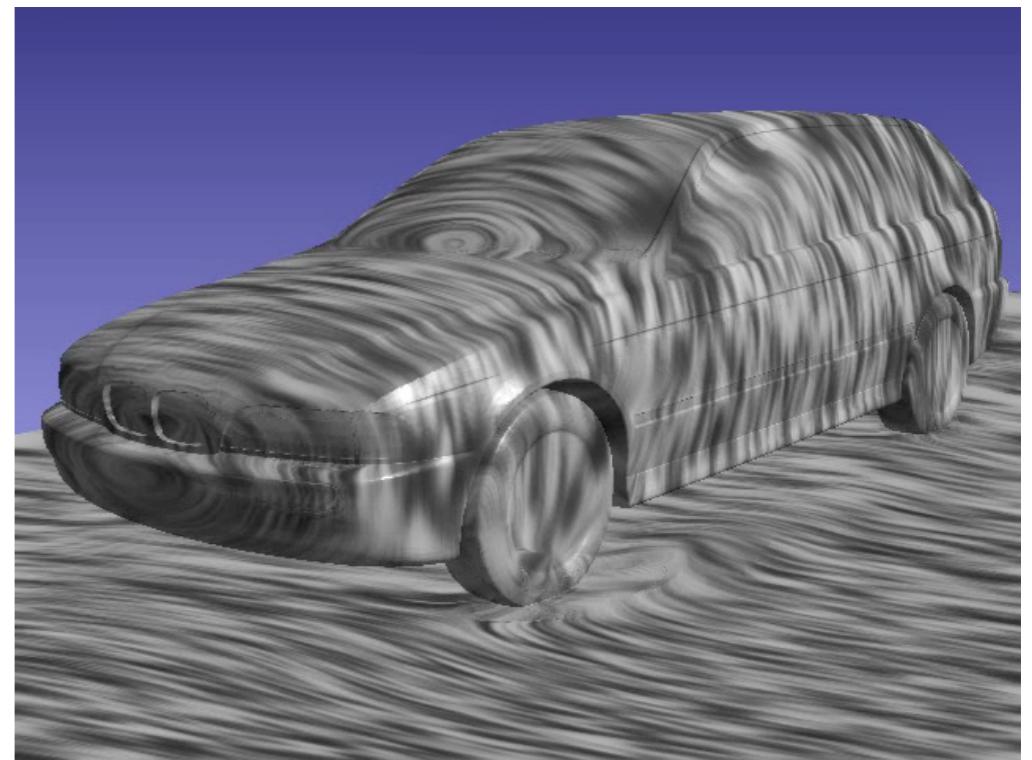
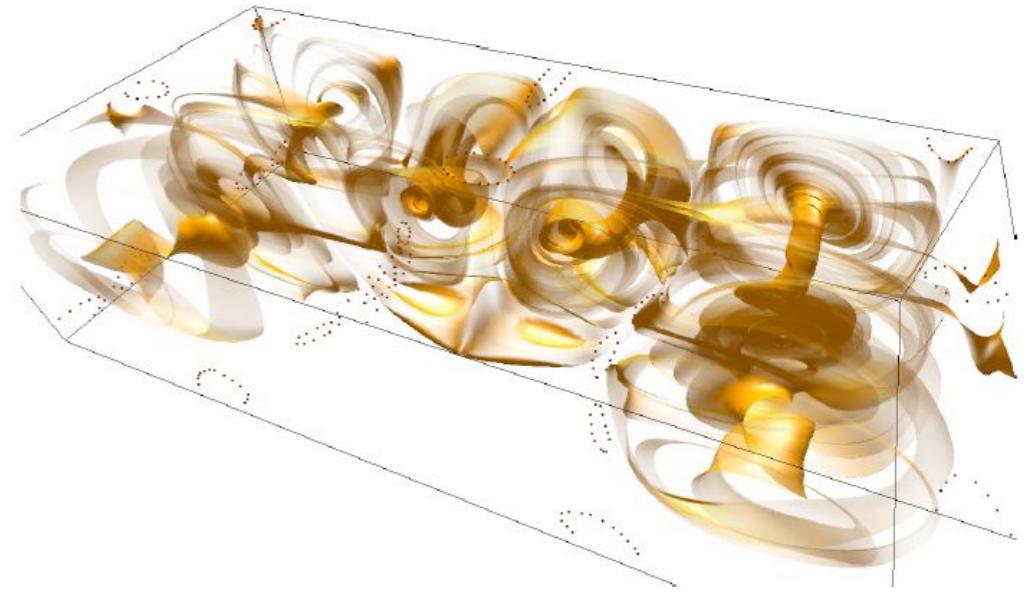


Fields



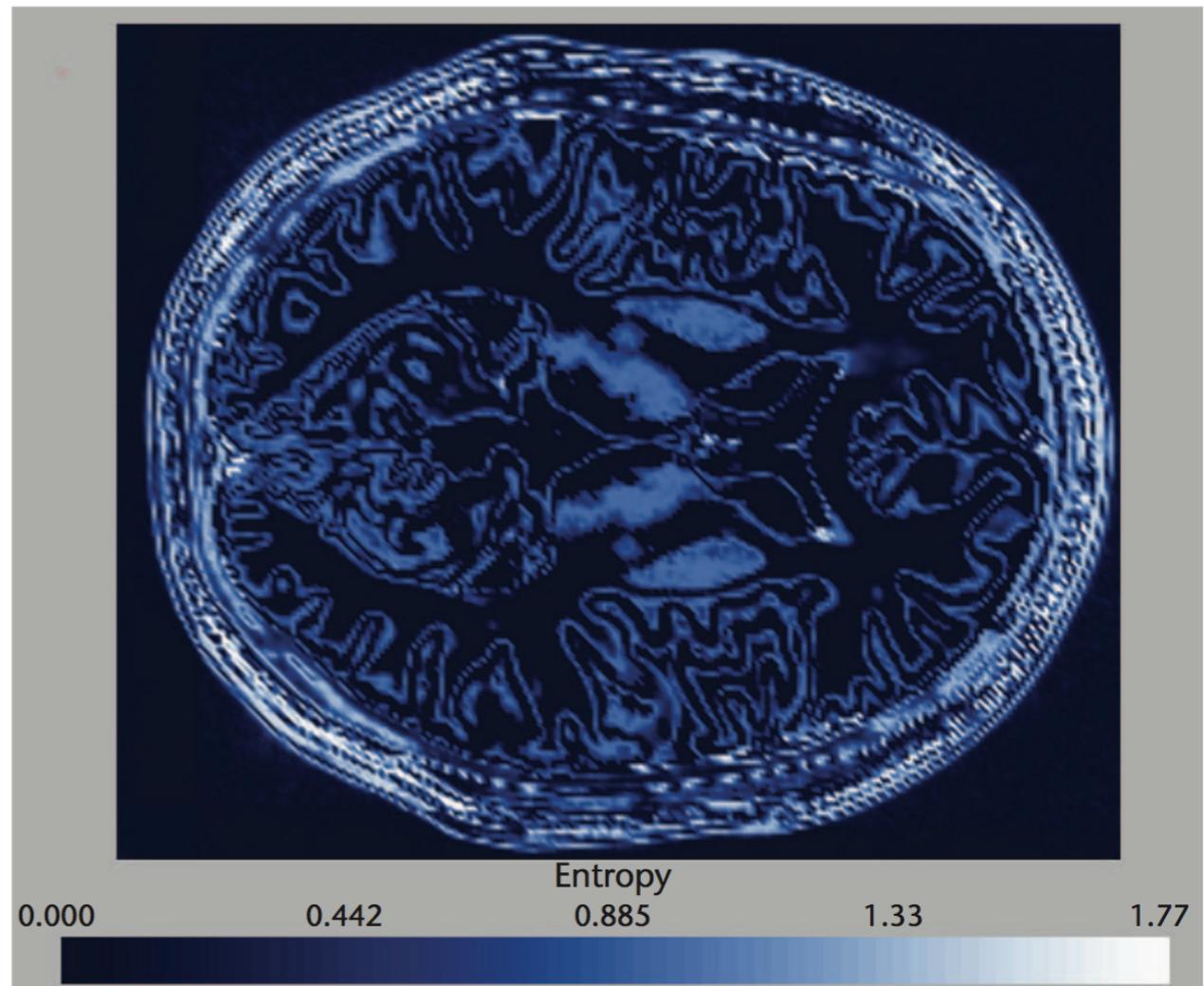
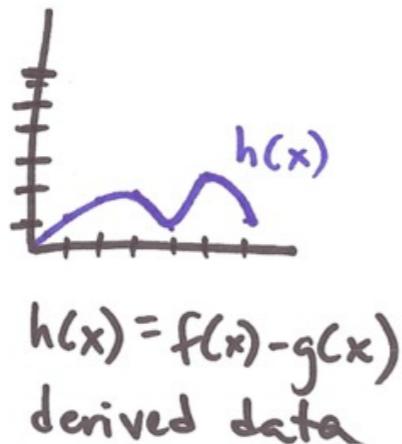
Example: Vector Fields

- A vector is represented at each position.
- Often used to represent velocities of wind/water, derivatives of scalar fields, magnetic fields, color (arguably)
 - In 2d, $f:\mathbb{R}^2 \rightarrow \mathbb{R}^2$ (a 2d vector)
 - In 3d, $f:\mathbb{R}^3 \rightarrow \mathbb{R}^3$ (a 3d vector)



Derived Attributes

- Conceptual model can motivate derived data
- Derived attributes: computed from originals
 - Simple change of type
 - Acquire additional data
 - Complex Transformation
 - Transformation is an abstract choice



Example: From Model to Attribute Type

From data model...

- 32.5, 54.0, -17.3, ... (floats)

...using conceptual model...

- Temperature

...to attribute type:

- Continuous to 4 significant figures (Q)
- Hot, warm, cold (O)
- Burned vs. Not burned (N)



Wind: 3 mph ↑

Humidity: 21%

Dew Pt: 23°

UV Index: 4

Visibility: 10+ mi

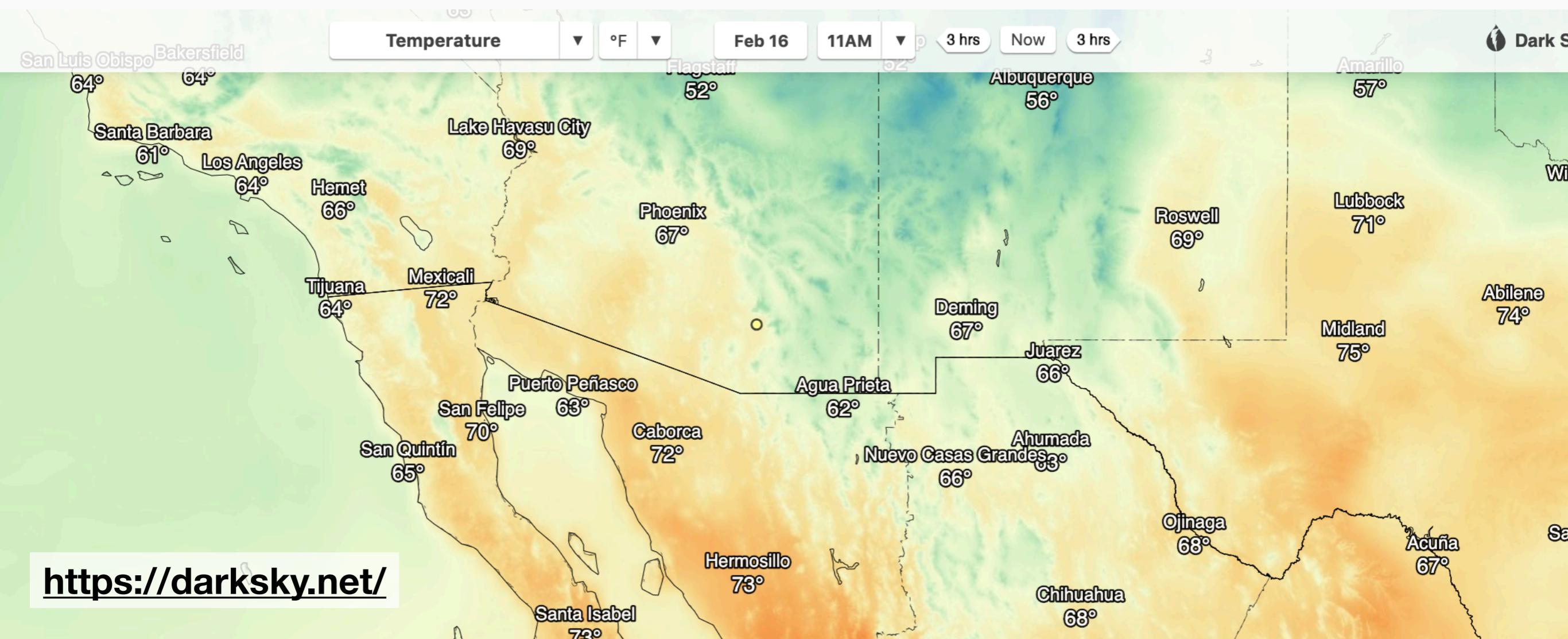
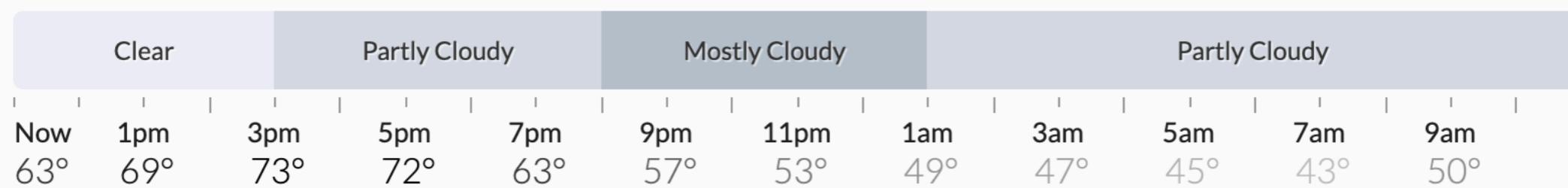
Pressure: 1019 mb

Abstraction Exercise

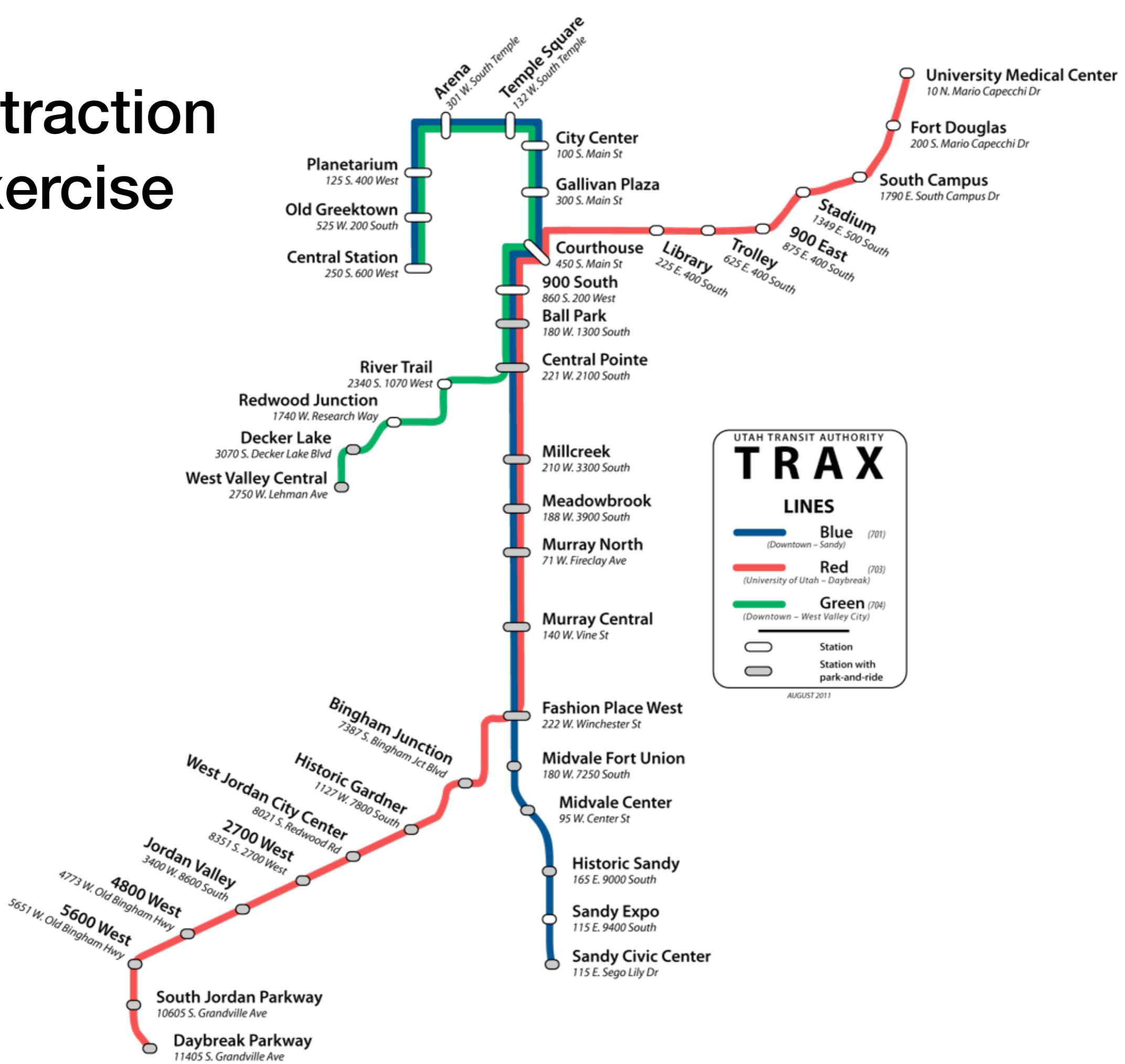
**63° Clear.**

Feels Like: 63° Low: 39° High: 74°

Clear throughout the day.



Abstraction Exercise



Lec08 Reading

- Munzner, Ch. 5, 6.3-6.6, 6.9
- Automating the Design of Graphical Presentations of Relational Information. Jock Mackinlay. ACM TOG 5(2), 1986.

Assignment 02

Assigned: Monday, February 6

Due: Monday, February 20, 4:59:59 pm

Reminder

Project Milestone 01

Assigned: Monday, January 25

Due: Wednesday, February 22, 4:59:59 pm