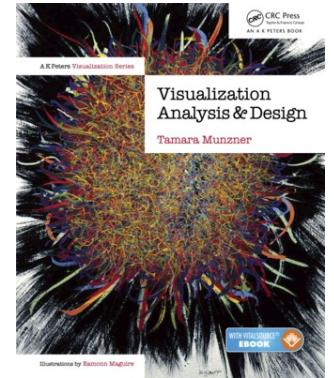


# Visualization Analysis & Design



## Data Abstraction (Ch 2)

Tamara Munzner

# What does data mean?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
  - two points far from each other in 3D space?

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
  - two points far from each other in 3D space?
  - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?

## What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
  - two points far from each other in 3D space?
  - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
  - something else??

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
  - two points far from each other in 3D space?
  - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
  - something else??

Basil, 7, S, Pear

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
  - two points far from each other in 3D space?
  - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
  - something else??

Basil, 7, S, Pear

- What about this data?

## What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
  - two points far from each other in 3D space?
  - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
  - something else??
- What about this data?
  - food shipment of produce (basil & pear) arrived in satisfactory condition on 7th day of month

## What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?
  - two points far from each other in 3D space?
  - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
  - something else??
- What about this data?
  - food shipment of produce (basil & pear) arrived in satisfactory condition on 7th day of month
  - Basil Point neighborhood of city had 7 inches of snow cleared by the Pear Creek Limited snow removal service

What does data mean?

14, 2.6, 30, 30, 15, 100001

- What does this sequence of six numbers mean?

- two points far from each other in 3D space?
  - two points close to each other in 2D space, with 15 links between them, and a weight of 100001 for the link?
  - something else??

Basil, 7, S, Pear

- What about this data?

- food shipment of produce (basil & pear) arrived in satisfactory condition on 7th day of month
  - Basil Point neighborhood of city had 7 inches of snow cleared by the Pear Creek Limited snow removal service
  - lab rat Basil made 7 attempts to find way through south section of maze, these trials used pear as reward food

## Now what?

- semantics: real-world meaning

Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

## Now what?

- semantics: real-world meaning

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

## Now what?

- semantics: real-world meaning
- data types: structural or mathematical interpretation of data
  - item, link, attribute, position, (grid)
  - different from data types in programming!

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

## Items & Attributes

- item: individual entity, discrete
  - eg patient, car, stock, city
  - "independent variable"

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

## Items & Attributes

- item: individual entity, discrete
  - eg patient, car, stock, city
  - "independent variable"

Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
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Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

## Items & Attributes

- item: individual entity, discrete
  - eg patient, car, stock, city
  - "independent variable"
- attribute: property that is measured, observed, logged...
  - eg height, blood pressure for patient
  - eg horsepower, make for car
  - "dependent variable"

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

item: person

## Items & Attributes

- item: individual entity, discrete
  - eg patient, car, stock, city
  - "independent variable"
- attribute: property that is measured, observed, logged...
  - eg height, blood pressure for patient
  - eg horsepower, make for car
  - "dependent variable"

attributes: name, age, shirt size, fave fruit

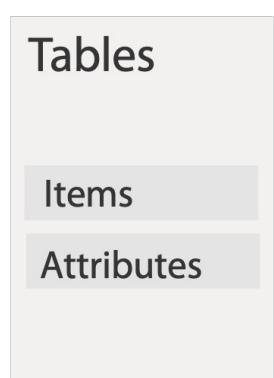
Name	Age	Shirt Size	Favorite Fruit
Amy	8	S	Apple
Basil	7	S	Pear
Clara	9	M	Durian
Desmond	13	L	Elderberry
Ernest	12	L	Peach
Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

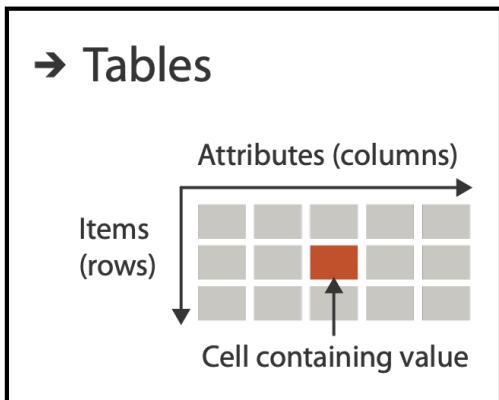
## Other data types

- **links**
  - express relationship between two items
  - eg 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

# Dataset types



- flat table
  - one item per row
  - each column is attribute
  - cell holds value for item-attribute pair

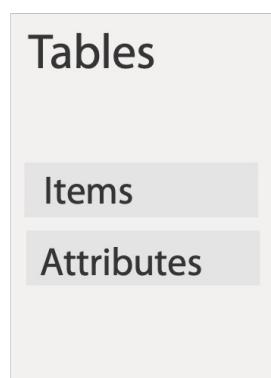


attributes: name, age, shirt size, fave fruit

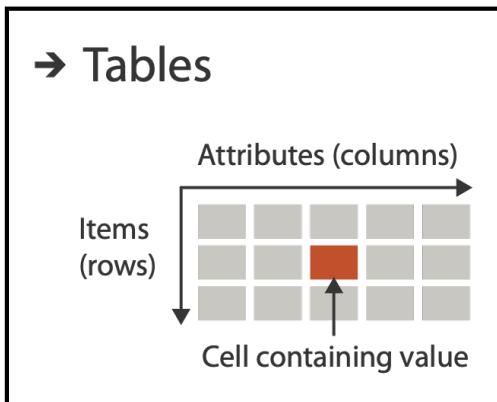
Name	Age	Shirt Size	Favorite Fruit
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Fanny	10	S	Lychee
George	9	M	Orange
Hector	8	L	Loquat
Ida	10	M	Pear
Amy	12	M	Orange

item: person

# Dataset types



- flat table
  - one item per row
  - each column is attribute
  - cell holds value for item-attribute pair
  - unique key (could be implicit)



attributes: name, age, shirt size, fave fruit

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

item: person

# Table

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	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	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	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Specified	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

Table

item

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
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item

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193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
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attribute

Table

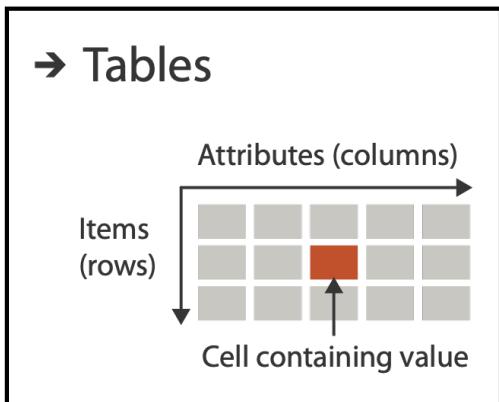
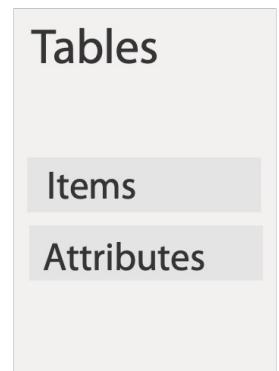
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Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
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35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
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66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
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194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

item

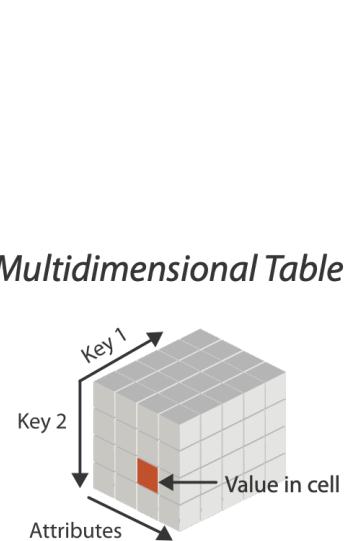
cell

attribute

# Dataset types



- **multidimensional tables**
  - indexing based on multiple keys
    - eg genes, patients

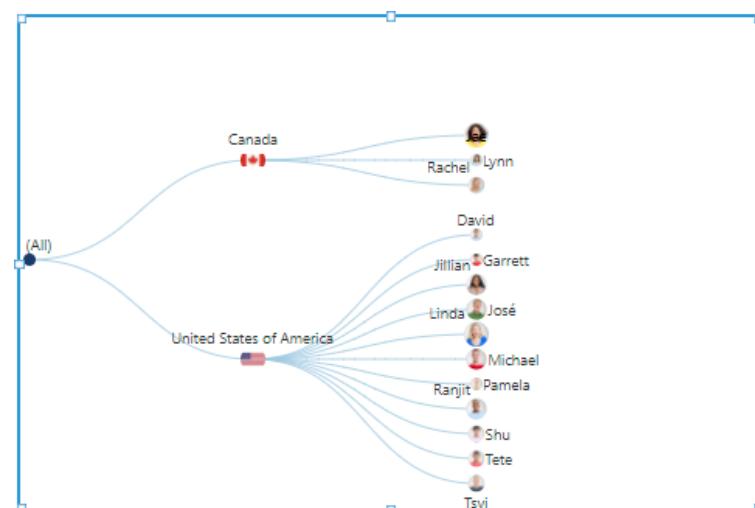
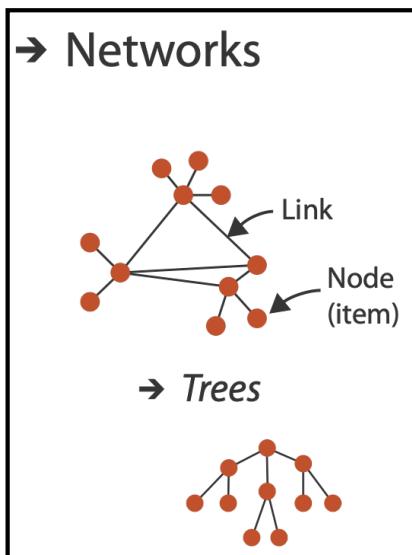
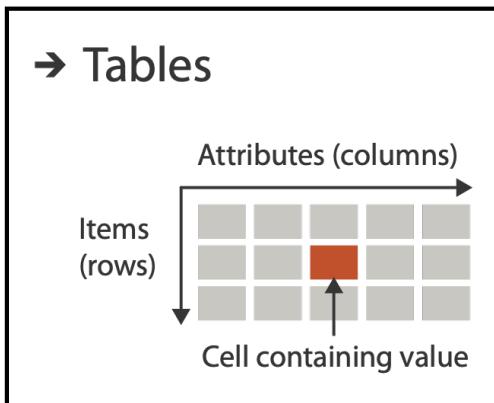


	A	B	C	D	E	
1	A	B	C	D	E	
2	1	#1.2				
3	2					
4	3	G 2	1500	529		
5	4	L 3				
6	5	F 4	L 3	GeneName	DESCRIPTION	TCGA-02-0001-01C-01R-0177-01
7	6	T 5	P 4	TCGA-02-0003-01A-01R-0177-01	TCGA-02-0004-01A-01R-0298-01	
8	7	H 6	LTF	LTF	-1.265728057	2.377012066
9	8	F 7	T 6	POSTN	POSTN	2.662411805
10	9	S 8	R 7	TMSL8	TMSL8	-3.082217838
11	10	C 9	S 8	HLA-DQA1	HLA-DQA1	-1.739664398
12	11	A 10	R 9	RP11-35N6.1	RP11-35N6.1	-3.346352968
13	12	I 11	D 9	STMN2	STMN2	-2.578511106
14	13	S 12	A 10	DCX	DCX	-2.26078976
15	14	I 13	IL 11	AGXT2L1	AGXT2L1	-2.639493611
16	15	C 14	SI 12	IL13RA2	IL13RA2	-2.93596915
17	16	M 13	V 13	SLN	SLN	-2.466718221
18	17	I 15	C 14	MEOX2	MEOX2	-2.395054066
19	18	F 16	N 15	COL11A1	COL11A1	1.211934832
20	19	C 17	F 16	NNMT	NNMT	0.703745164
21	20	I 18	C 17	F13A1	F13A1	0.664082419
22	21	M 18	V 18	CXCL14	CXCL14	-0.224094042
22	21	C 20	T 19	MBP	MBP	-3.1309694
22	G 21	K 20	T 19	TF	TF	-1.906390566
22	G 21	K 20	T 19	KCND2	KCND2	-4.334123292
22	G 21	K 20	T 19	KCND2	KCND2	-1.777692395
22	G 21	K 20	T 19	KCND2	KCND2	-2.100362021
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# Dataset types

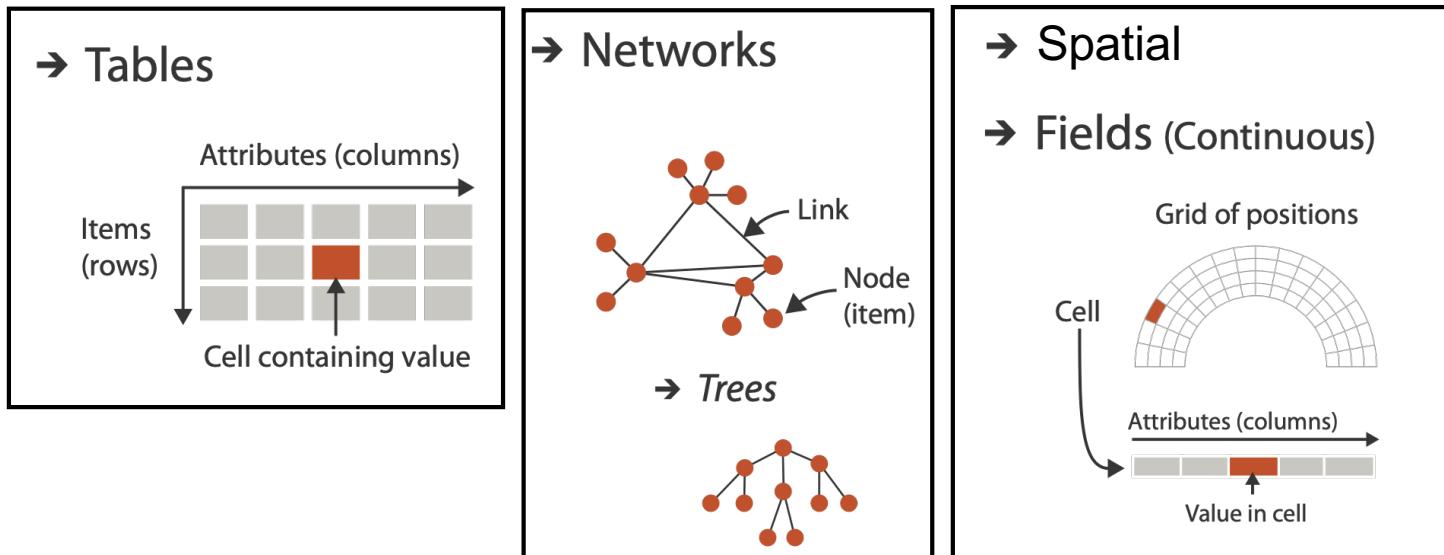
Tables	Networks & Trees
Items	Items (nodes)
Attributes	Links

- network/graph
  - nodes (vertices) connected by links (edges)
  - tree is special case: no cycles
- often have roots and are directed



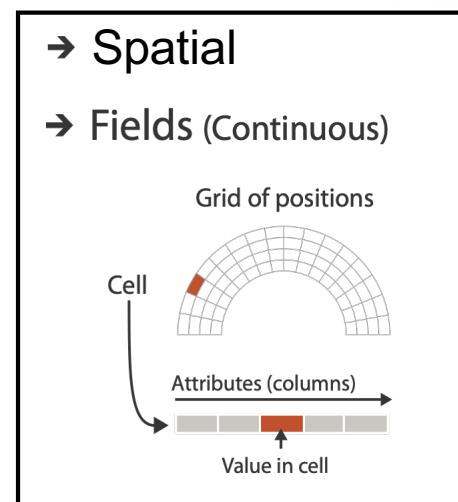
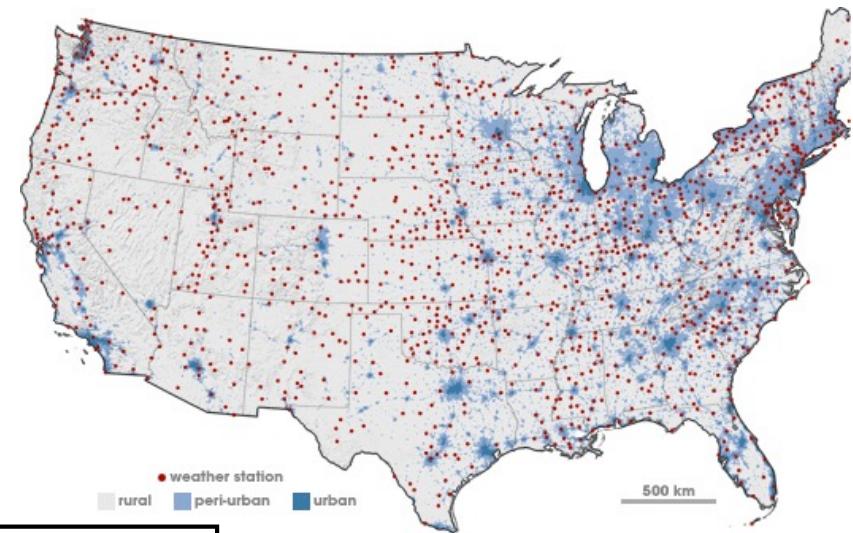
# Dataset types

Tables	Networks & Trees	Fields
Items	Items (nodes)	Grids
Attributes	Links	Positions
		Attributes



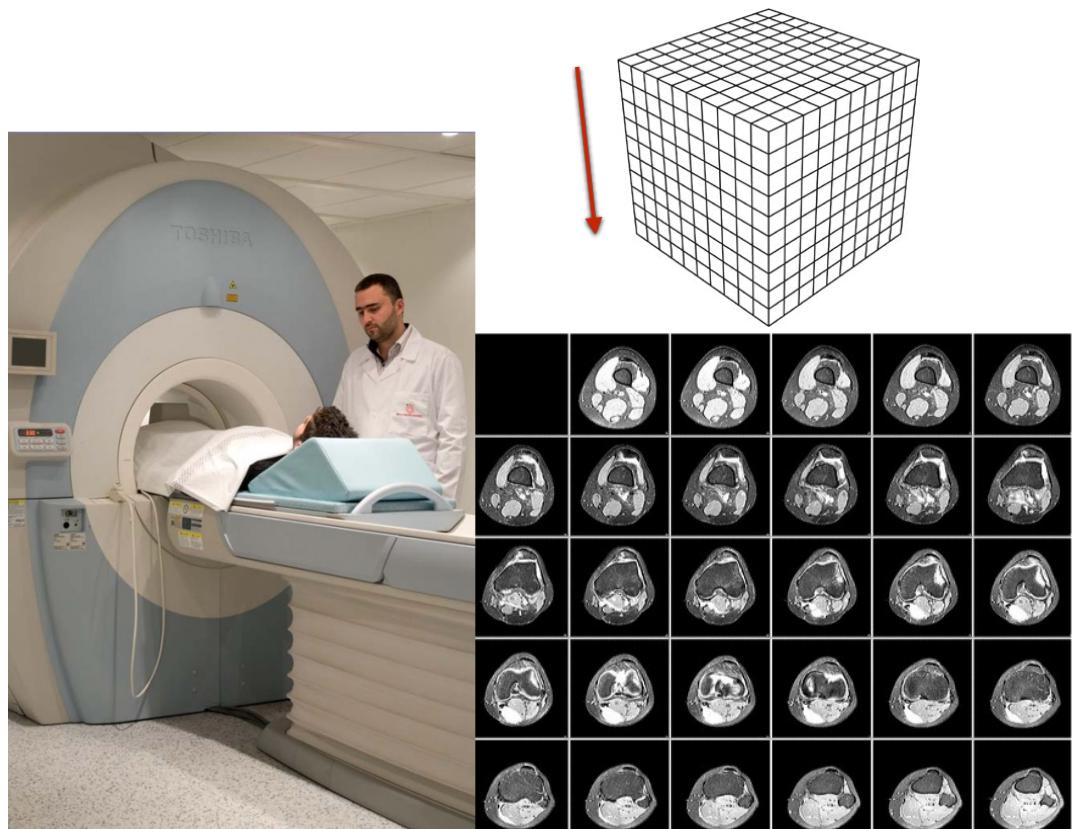
## Spatial fields

- attribute values associated w/ cells
- cell contains value from continuous domain
  - E.g., temperature, pressure, wind velocity
- measured or simulated



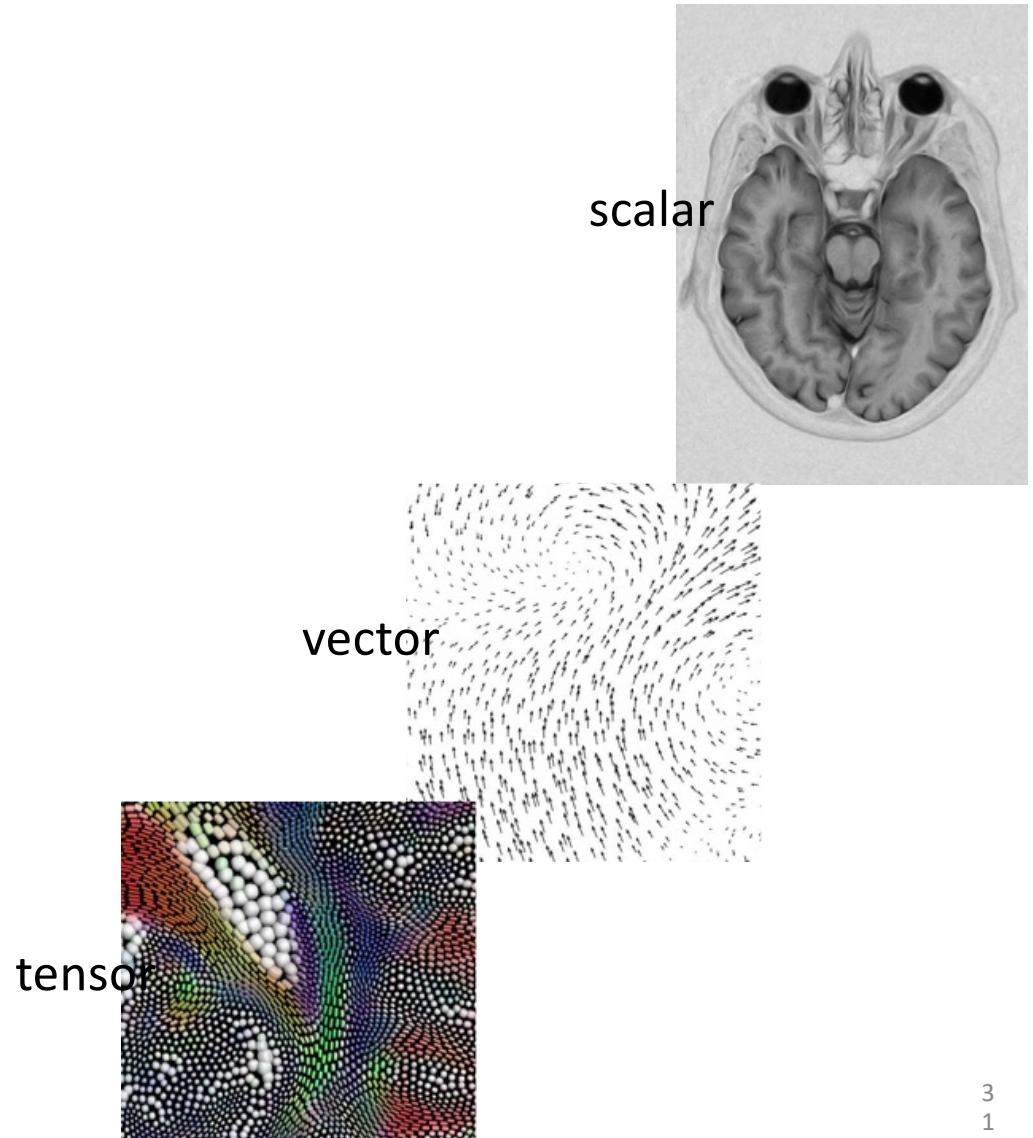
## Spatial fields

- attribute values associated w/ cells
- cell contains value from continuous domain
  - eg temperature, pressure, wind velocity
- measured or simulated
- major concerns
  - sampling: where attributes are measured
  - interpolation: how to model attributes elsewhere
  - grid types



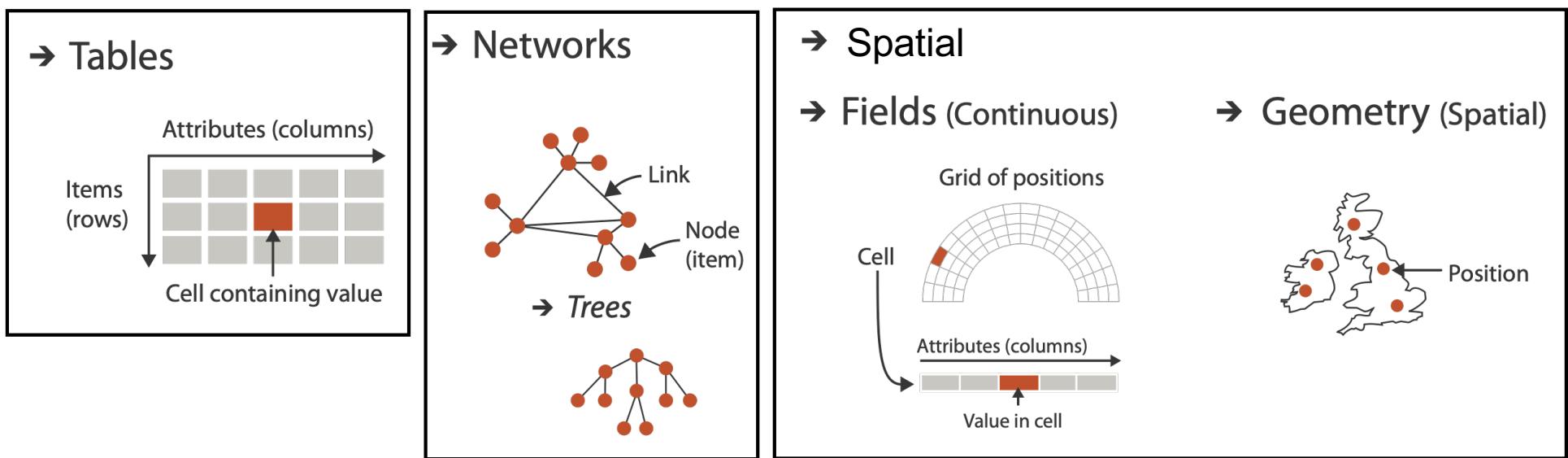
## Spatial fields

- attribute values associated w/ cells
- cell contains value from continuous domain
  - eg temperature, pressure, wind velocity
- measured or simulated
- major concerns
  - sampling:  
where attributes are measured
  - interpolation:  
how to model attributes elsewhere
  - grid types
- major divisions
  - attributes per cell:  
scalar (1), vector (2), tensor (many)



# Dataset types

Tables	Networks & Trees	Fields	Geometry
Items	Items (nodes)	Grids	Items
Attributes	Links	Positions	Positions
	Attributes	Attributes	



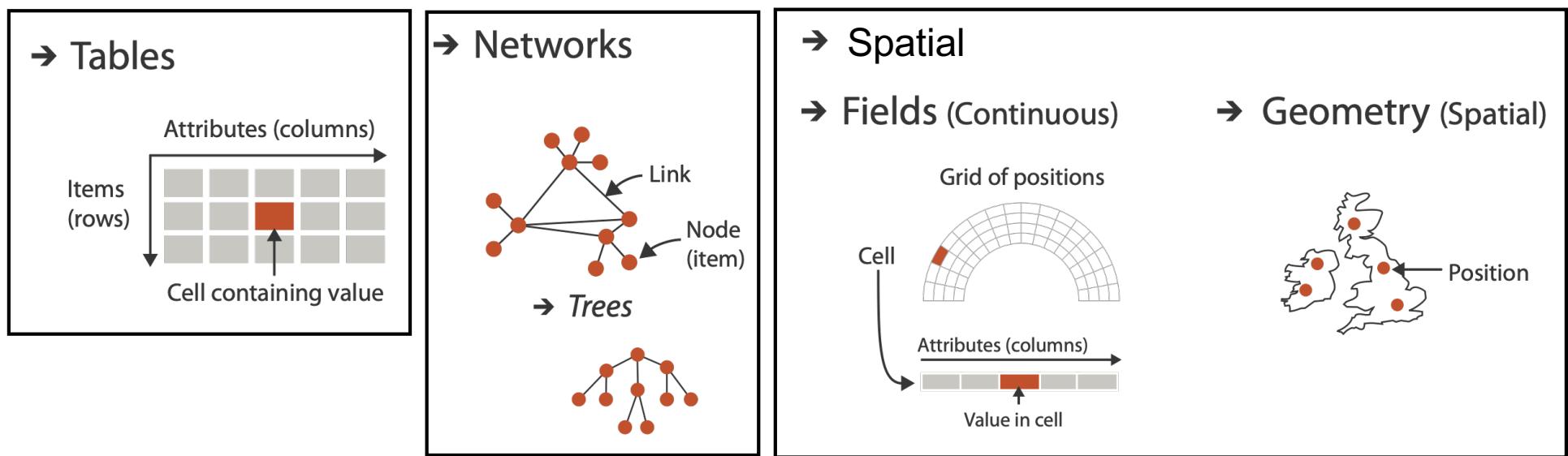
## Geometry

- shape of items
- explicit spatial positions / regions
  - points, lines, curves, surfaces, volumes
- boundary between computer graphics and visualization
  - graphics: geometry taken as given
  - vis: geometry is result of a design decision



# Dataset types

Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids Positions	Items	Items
Attributes	Links	Attributes	Positions	

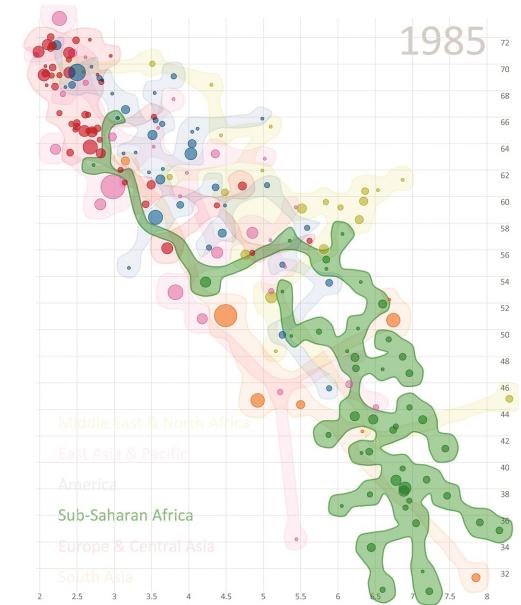


## Collections

- how we group items

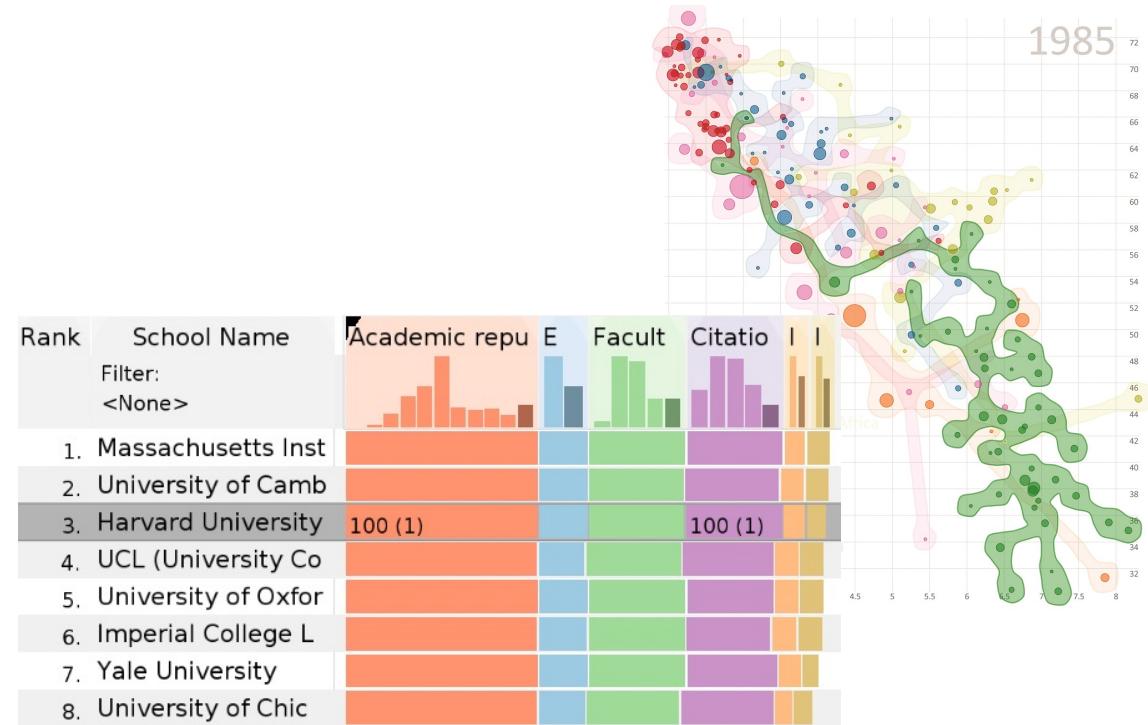
# Collections

- how we group items
- sets
  - unique items, unordered



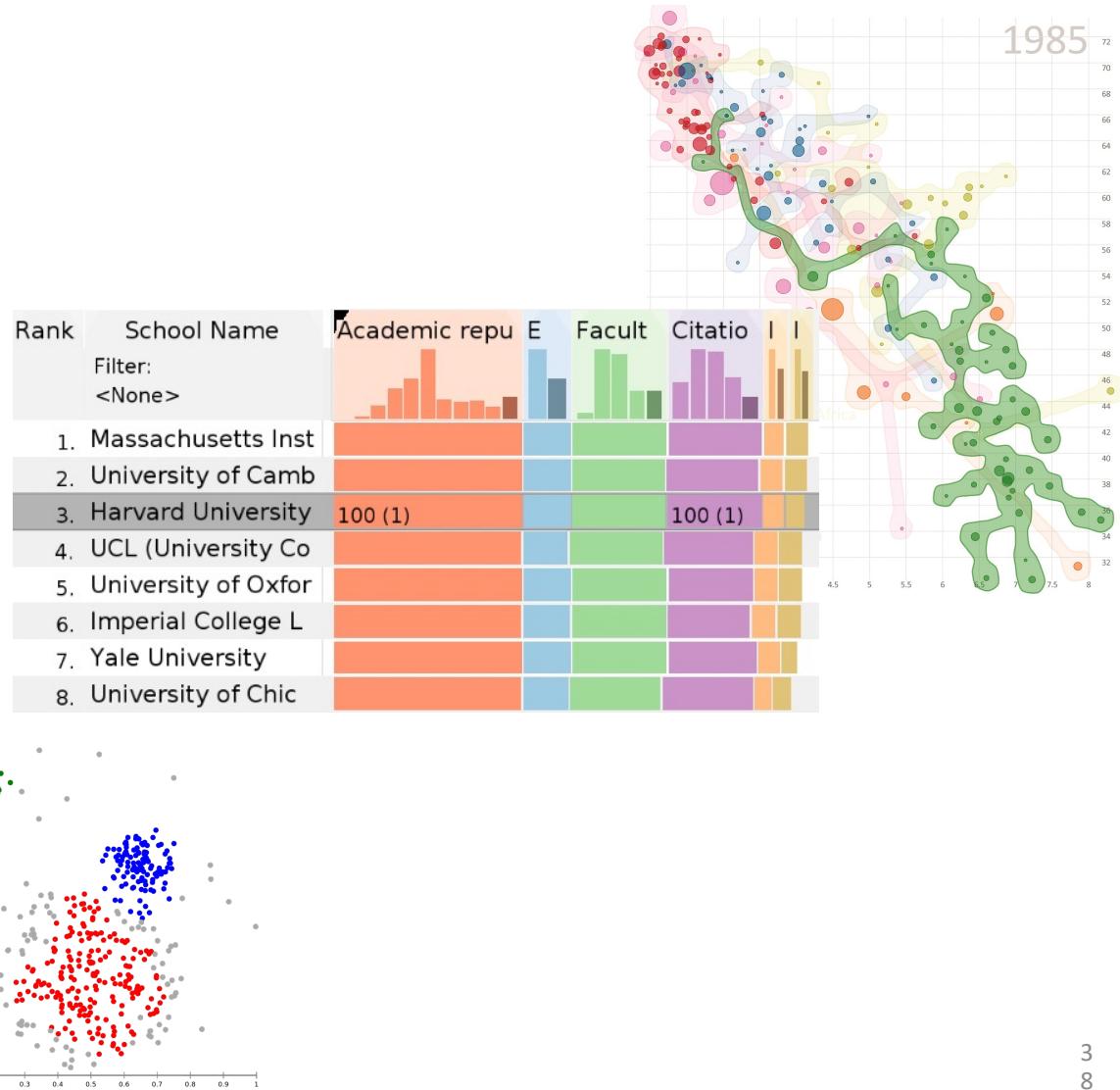
# Collections

- how we group items
- sets
  - unique items, unordered
- lists
  - ordered, duplicates possible



# Collections

- how we group items
- sets
  - unique items, unordered
- lists
  - ordered, duplicates possible
- clusters
  - groups of similar items



# Dataset and data types

## → Data and Dataset Types

Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids Positions Attributes	Items Positions	Items
Attributes	Links Attributes			

## → Data Types

→ Items

→ Attributes

→ Links

→ Positions

→ Grids

## Attribute types

- which classes of values & measurements?
- categorical (nominal)
  - compare equality
  - no implicit ordering
- ordered
  - ordinal
    - less/greater than defined
  - quantitative
    - meaningful magnitude
    - arithmetic possible

### ⇒ Attribute Types

→ Categorical



→ Ordered

→ *Ordinal*



→ *Quantitative*



# Table

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	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	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	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Specified	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

A	B	C	D	E	F	G
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	
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35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07	
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193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06	

categorical  
ordinal  
quantitative

# Other data concerns

## → Attribute Types

→ Categorical

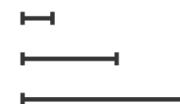


→ Ordered



→ Ordinal

→ Quantitative



## → Ordering Direction

→ Sequential



→ Diverging



→ Cyclic



## → Dataset Availability

→ Static



→ Dynamic



## Data abstraction: Three operations

- translate from domain-specific language to generic visualization language
- identify dataset type(s), attribute types
- identify cardinality
  - how many items in the dataset?
  - what is cardinality of each attribute?
    - number of levels for categorical data
    - range for quantitative data
- consider whether to transform data
  - guided by understanding of task

## Data vs conceptual models

- data model
  - mathematical abstraction
    - sets with operations, eg floats with \* / - +
    - variable data types in programming languages
- conceptual model
  - mental construction (semantics)
  - supports reasoning
  - typically based on understanding of tasks [stay tuned!]
- data abstraction process relies on conceptual model
  - for transforming data if needed

## Data vs conceptual model, example

## Data vs conceptual model, example

- data model: floats  
–32.52, 54.06, -14.35, ...

## Data vs conceptual model, example

- data model: floats
  - 32.52, 54.06, -14.35, ...
- conceptual model
  - temperature

## Data vs conceptual model, example

- data model: floats
  - 32.52, 54.06, -14.35, ...
- conceptual model
  - temperature
- multiple possible data abstractions

## Data vs conceptual model, example

- data model: floats
  - 32.52, 54.06, -14.35, ...
- conceptual model
  - temperature
- multiple possible data abstractions
  - continuous to 2 significant figures: quantitative
    - task: forecasting the weather

## Data vs conceptual model, example

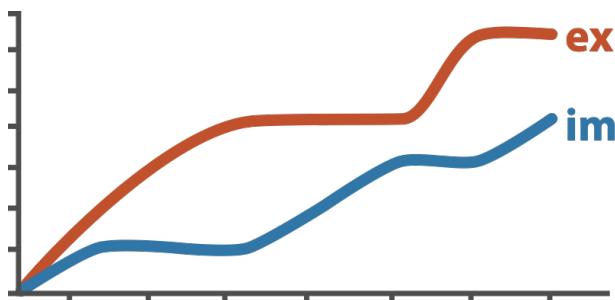
- data model: floats
  - 32.52, 54.06, -14.35, ...
- conceptual model
  - temperature
- multiple possible data abstractions
  - continuous to 2 significant figures: quantitative
    - task: forecasting the weather
  - hot, warm, cold: ordinal
    - task: deciding if bath water is ready

## Data vs conceptual model, example

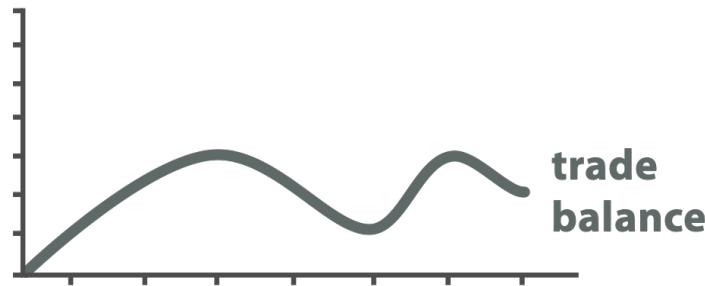
- data model: floats
  - 32.52, 54.06, -14.35, ...
- conceptual model
  - temperature
- multiple possible data abstractions
  - continuous to 2 significant figures: quantitative
    - task: forecasting the weather
  - hot, warm, cold: ordinal
    - task: deciding if bath water is ready
  - above freezing, below freezing: categorical
    - task: decide if I should leave the house today

## Derived attributes

- derived attribute: compute from originals
  - simple change of type
  - acquire additional data
  - complex transformation



Original Data



$$\text{trade balance} = \text{exports} - \text{imports}$$

Derived Data

# Analysis example: Derive one attribute

- Strahler number

- centrality metric for trees/networks
- derived quantitative attribute
- draw top 5K of 500K for good skeleton

[Using Strahler numbers for real time visual exploration of huge graphs. Auber.  
Proc. Intl. Conf. Computer Vision and Graphics, pp. 56–69, 2002.]

