UNIVERSITÀ DI TORINO

Analisi e Visualizzazione di Reti Complesse

DV02 Nested Model
Data Abstraction
Task Abstraction

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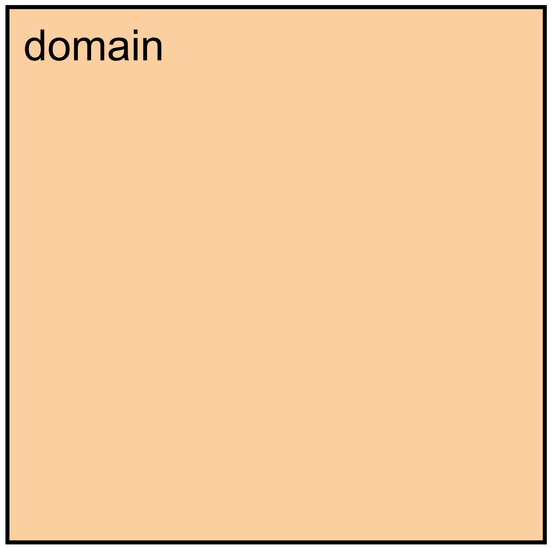
Nested Model

How to evaluate a visualization: So many methods, how to pick?

- Computational benchmarks?
  - quant: system performance, memory
- User study in lab setting?
  - quant: (human) time and error rates, preferences
  - qual: behavior/strategy observations
- Field study of deployed system?
  - quant: usage logs
  - qual: interviews with users, case studies, observations
- Analysis of results?
  - quant: metrics computed on result images
  - qual: consider what structure is visible in result images
- Justification of choices?
  - qual: perceptual principles, best practices

Analysis framework: Four levels, three questions

- **domain situation**
  - who are the target users?



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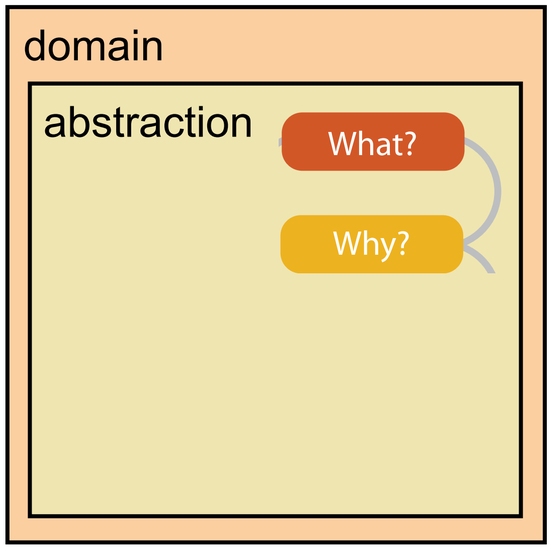
    - why is the user looking at it? task abstraction



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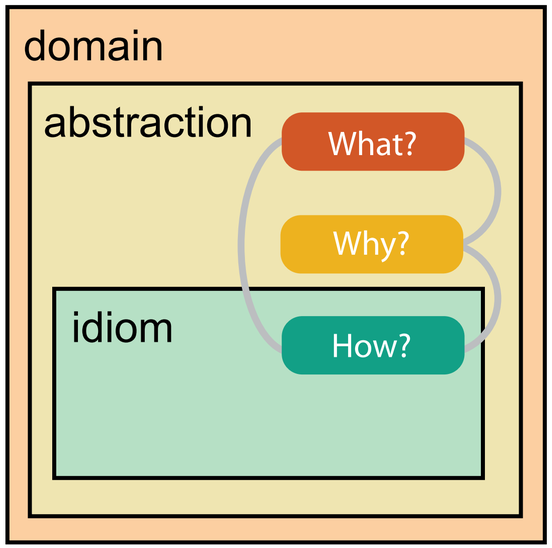
- **idiom**
  - how is it shown?
    - visual encoding idiom: how to draw
    - interaction idiom: how to manipulate



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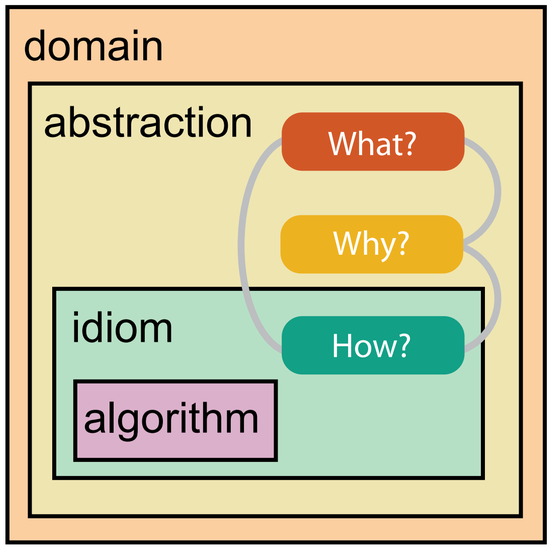
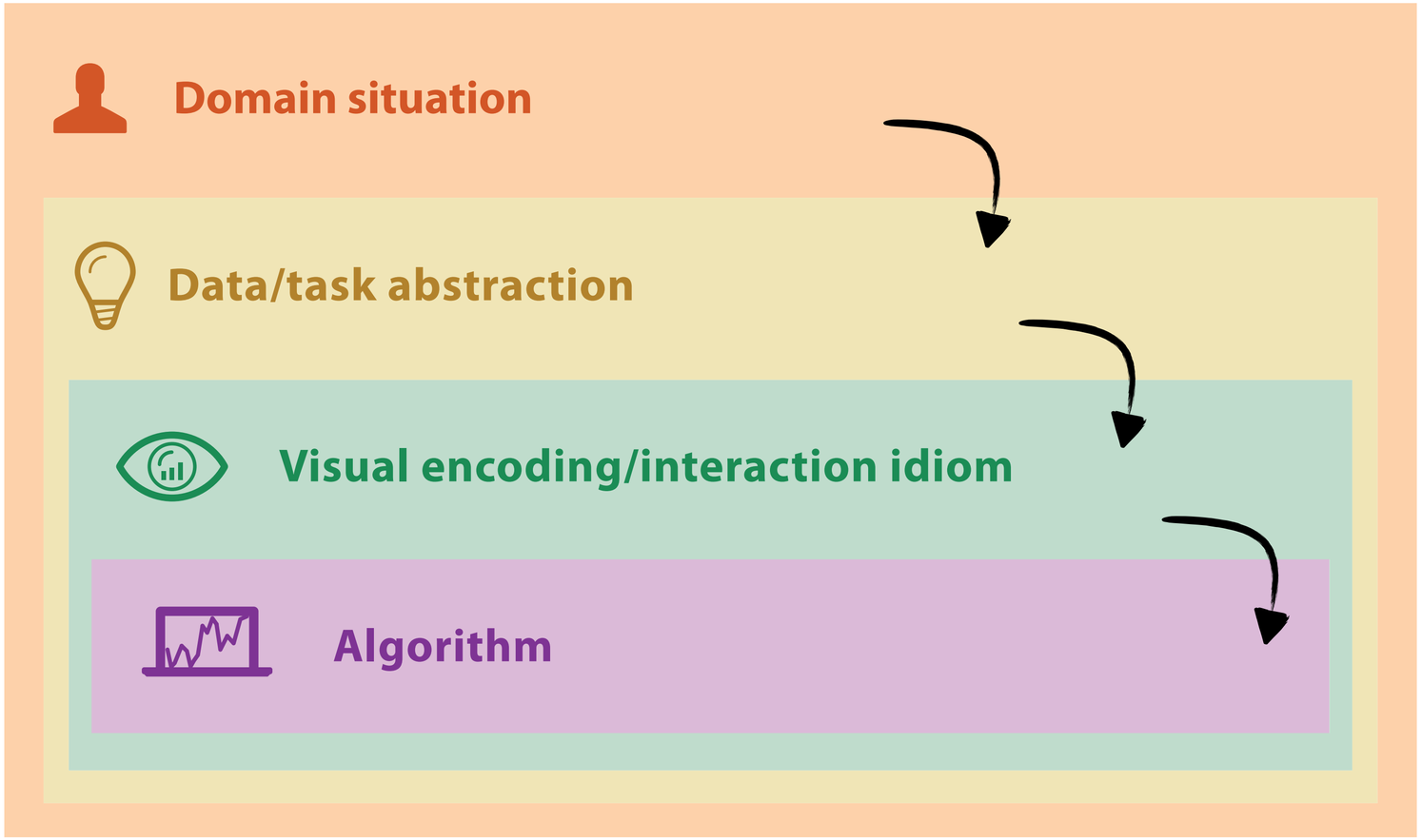
- **algorithm**
  - efficient computation



Nested model

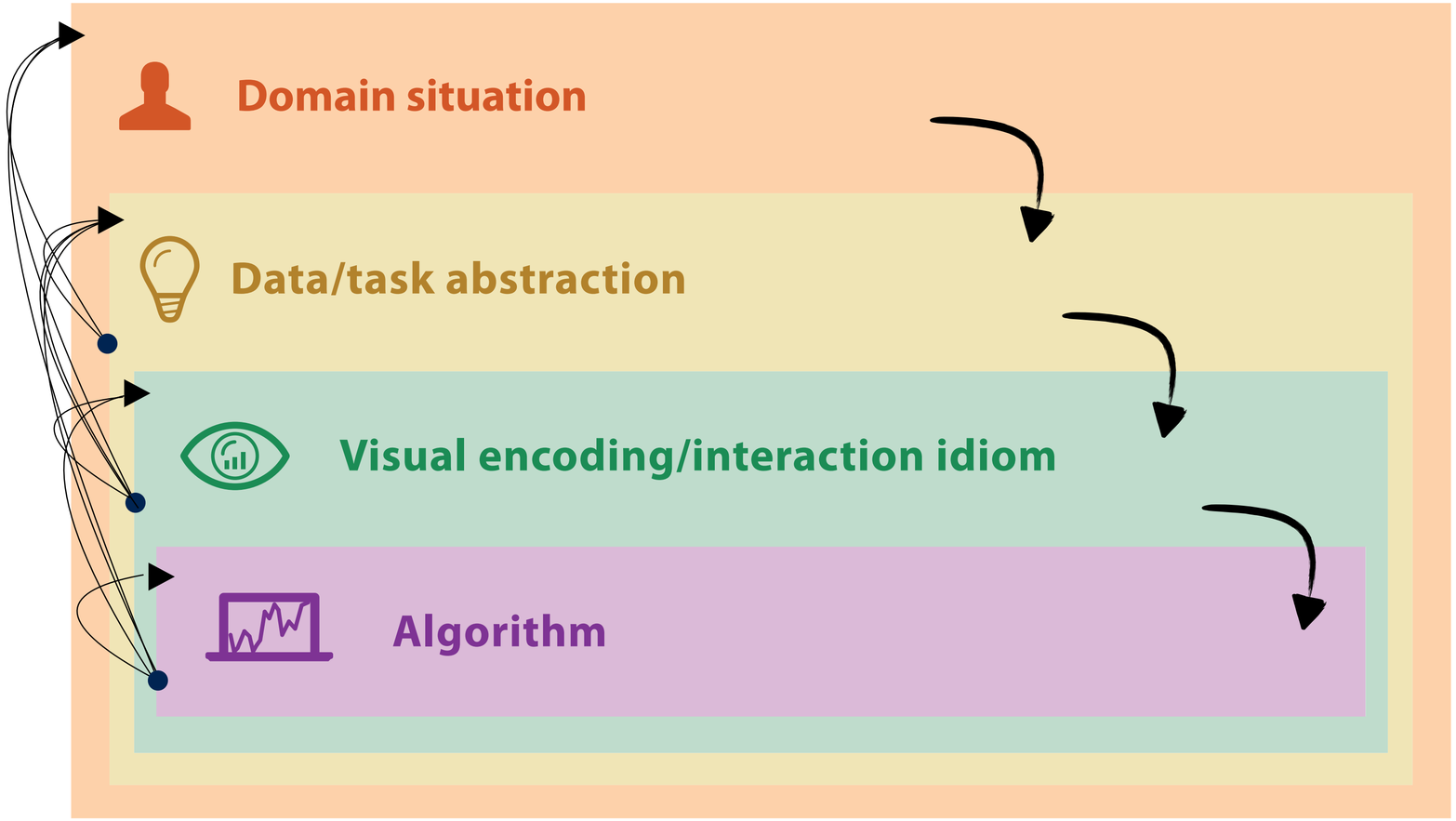
downstream: cascading effects



Nested model

downstream: cascading effects

upstream: iterative refinement



Why is validation difficult?

- different ways to get it wrong at each level

Why is validation difficult?

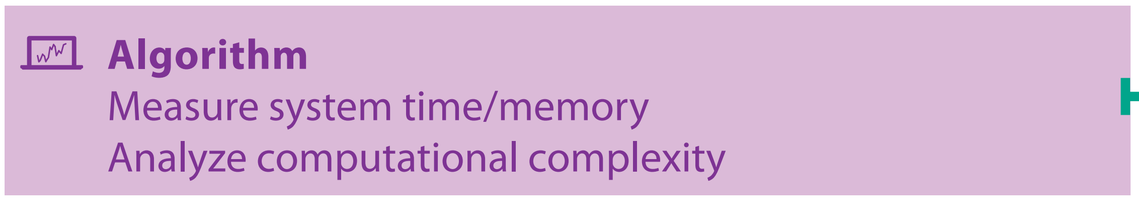
- solution: use methods from different fields at each level

Algorithm
Measure system time/memory
Analyze computational complexity

Why is validation difficult?

- solution: use methods from different fields at each level

computer science



→ technique-driven work

Why is validation difficult?

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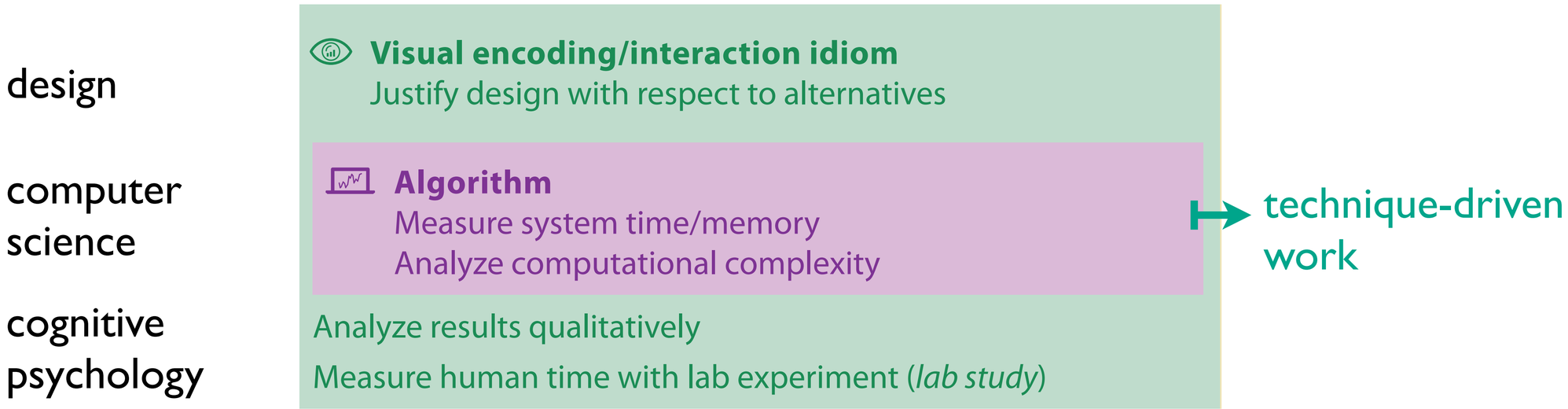

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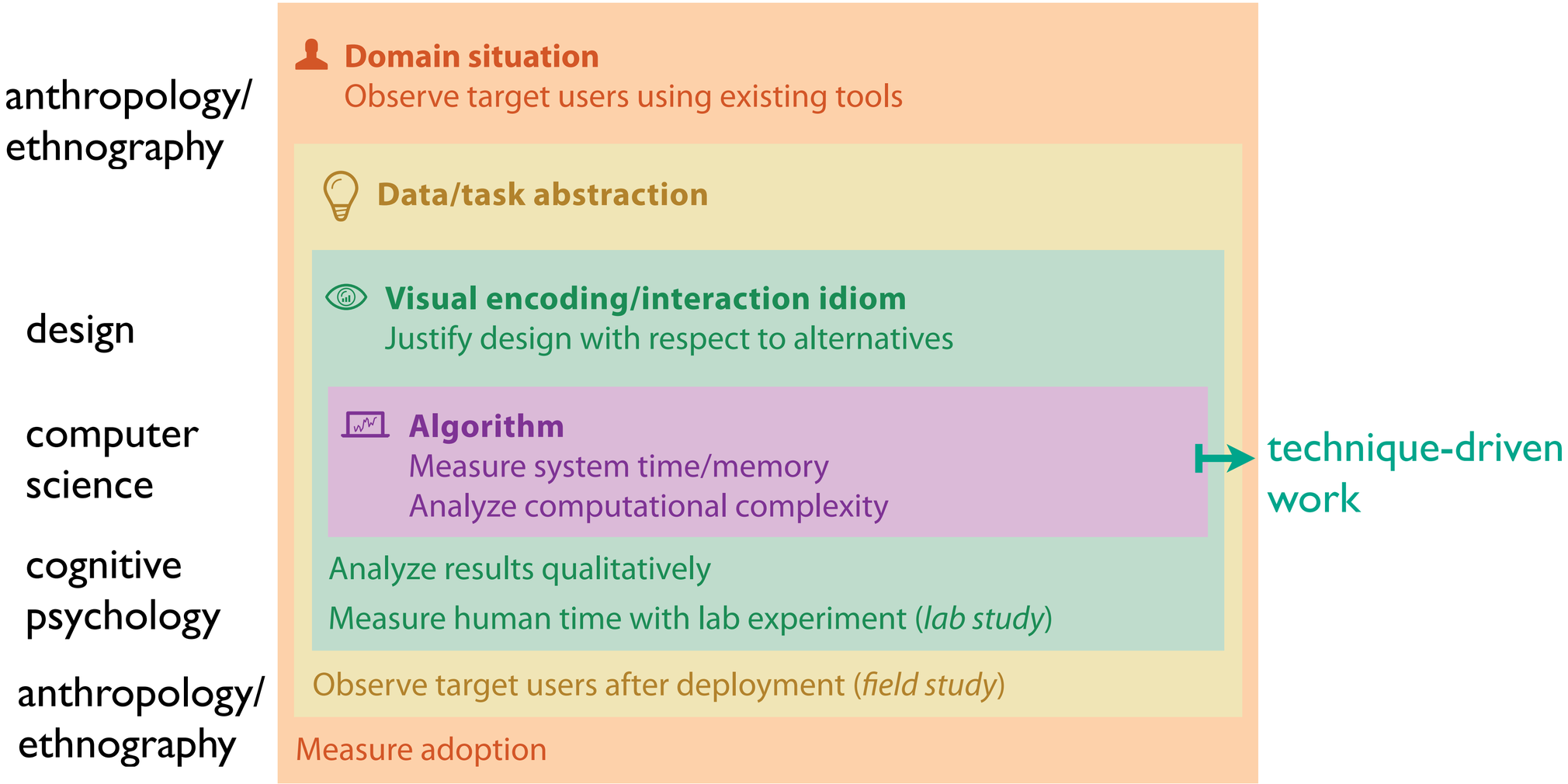

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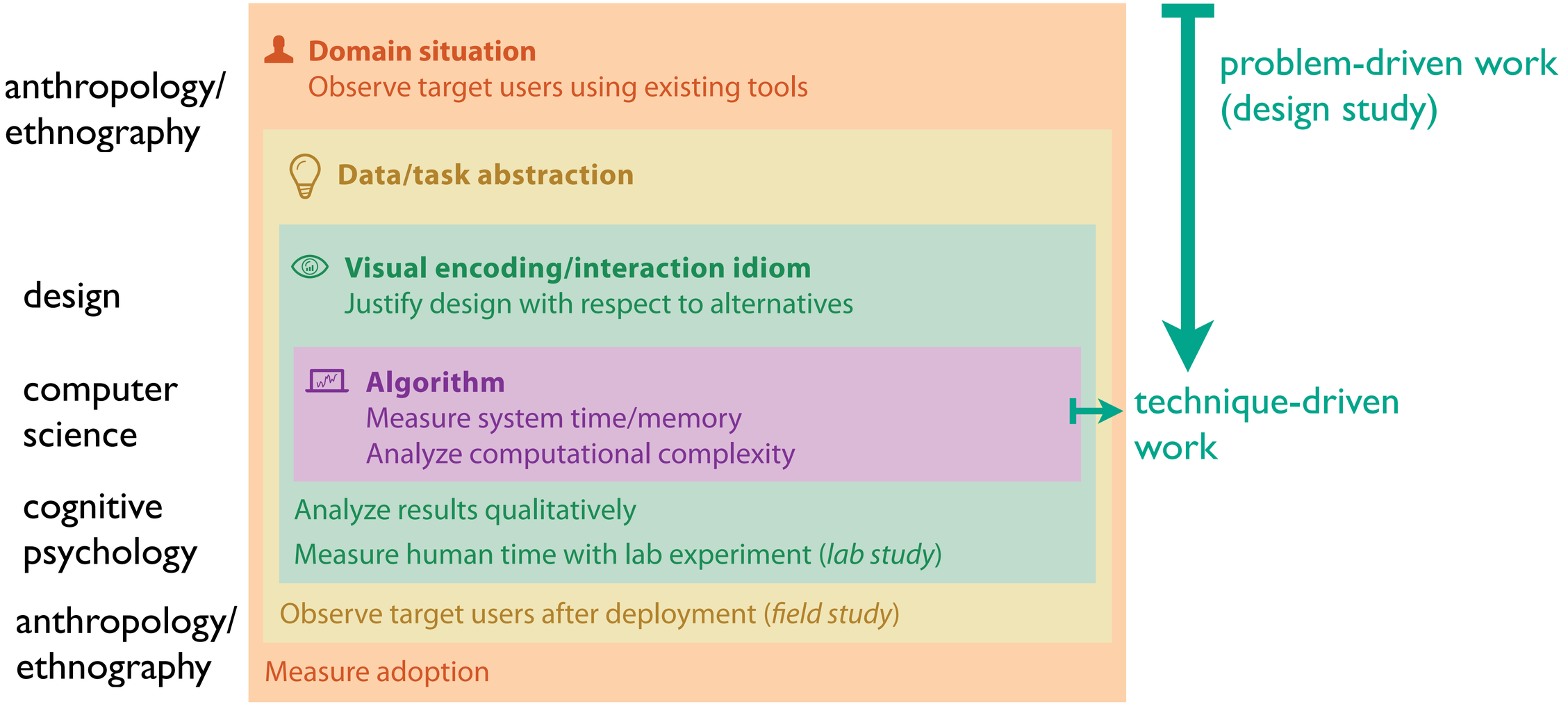
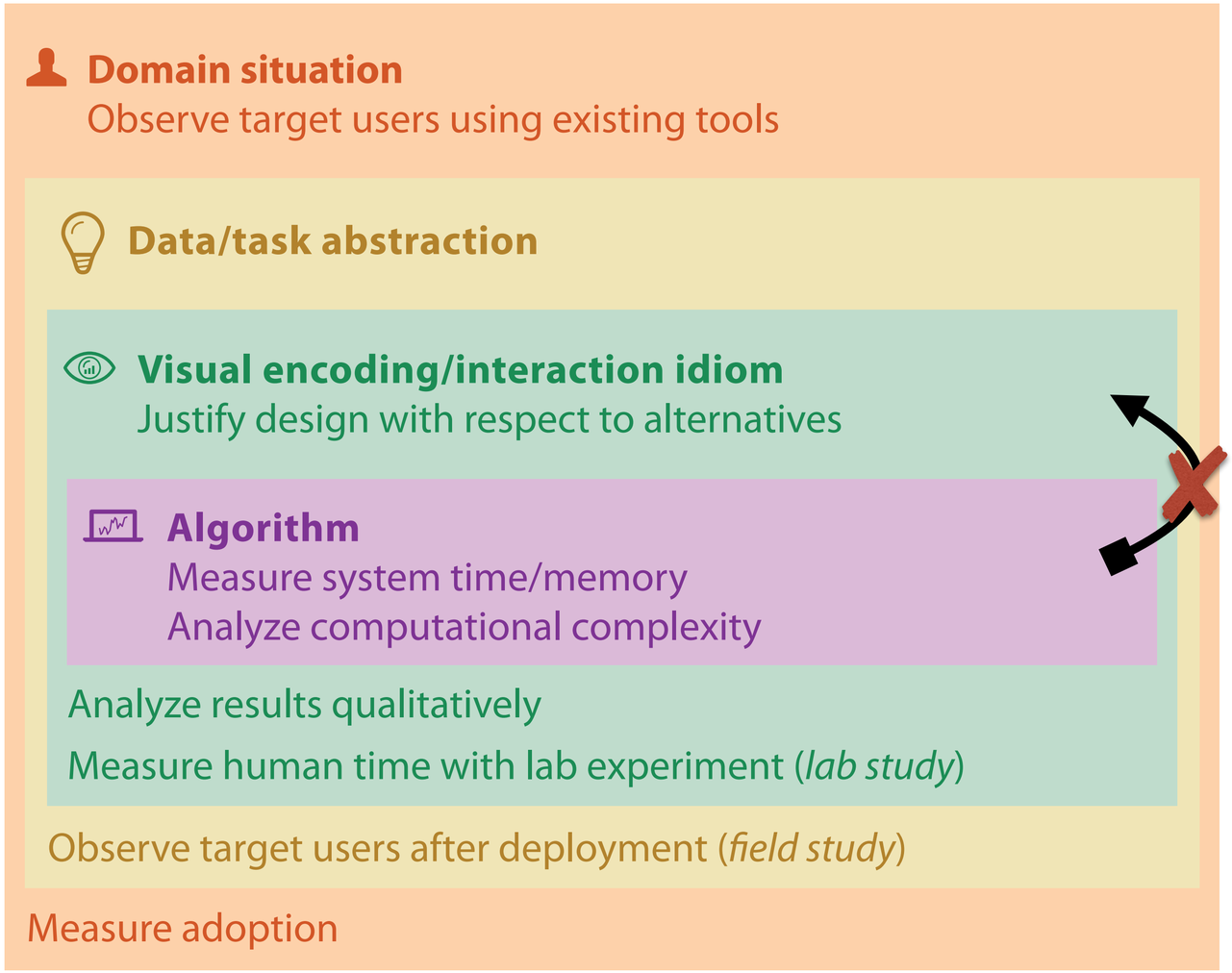
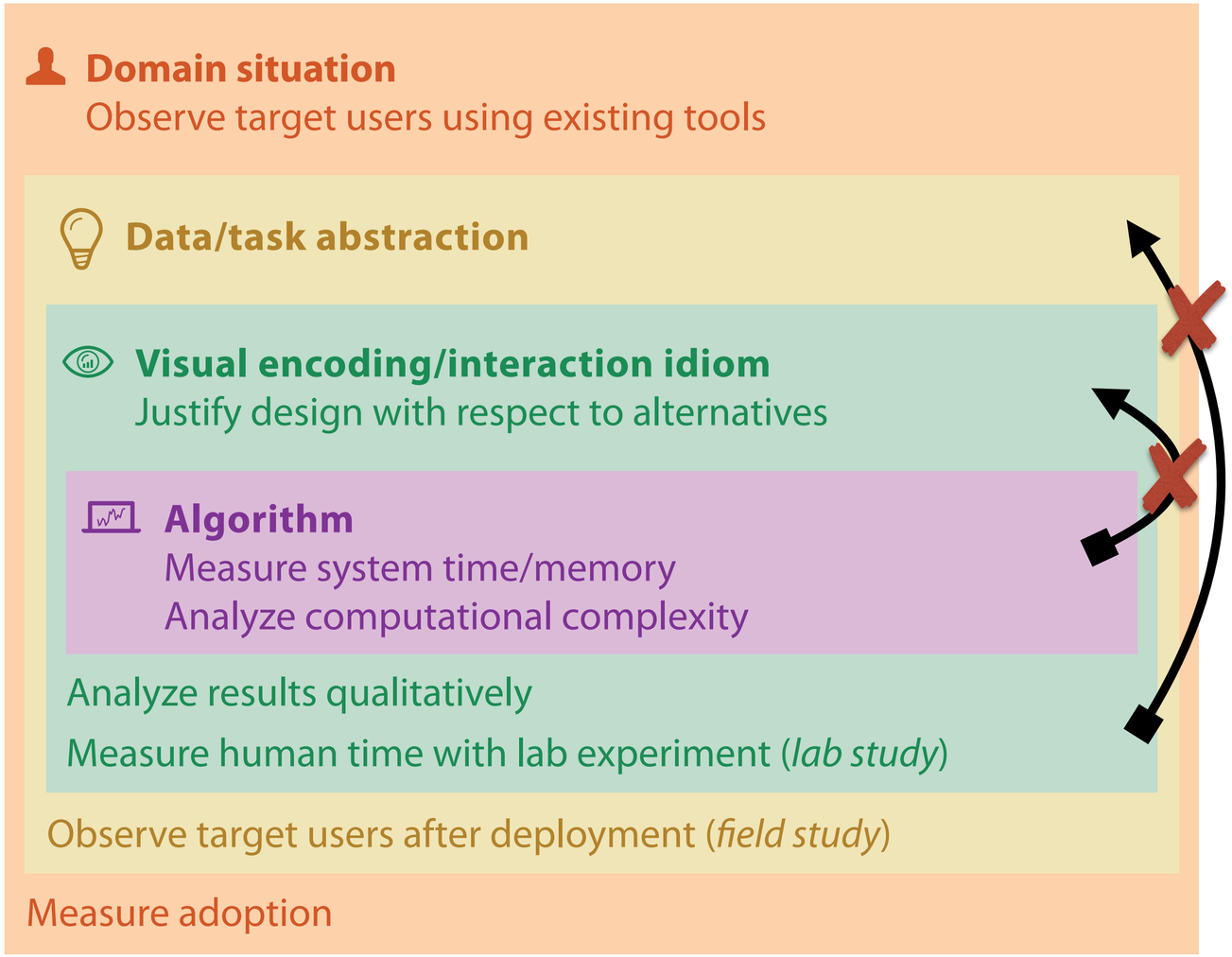


Avoid mismatches



computational benchmarks
do not confirm idiom design

Avoid mismatches



lab studies do not confirm task abstraction

computational benchmarks do not confirm idiom design

Reading Material

[dv3] **Chapter 4 - Analysis: Four Levels for Validation**

Data Abstraction

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 the 7th day of the month
  - Basil Point neighborhood of the city had 7 inches of snow cleared by the Pear Creek Limited snow removal service
  - lab rat Basil made 7 attempts to find a way through the south section of the maze, these trials used pear as reward food

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"

- **attribute:** property that is measured, observed, logged...
  - eg, height, blood pressure for a 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
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item: person

Other data types

- **links**
  - express the relationship between two items
  - e.g., 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

Tables

Items

Attributes

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

Name	Age	Shirt Size	Favorite Fruit
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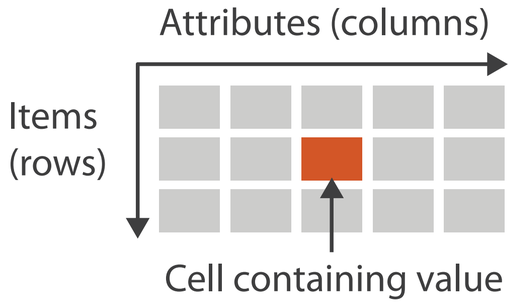
item: person

➔ Tables



Dataset types

Tables

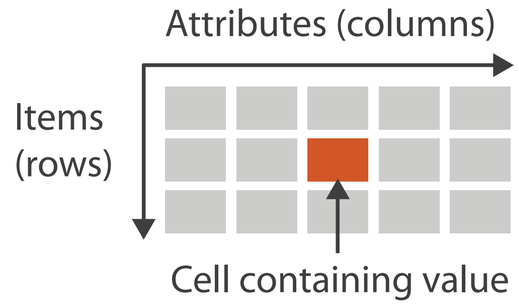
Items

Attributes

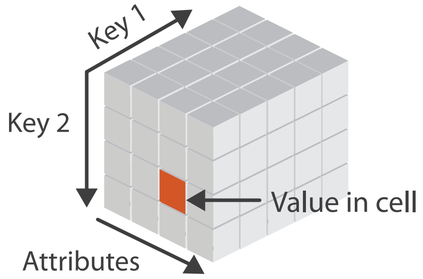
multidimensional tables

- indexing based on multiple keys
  - eg, genes, patients

➔ Tables



➔ *Multidimensional Table*



	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

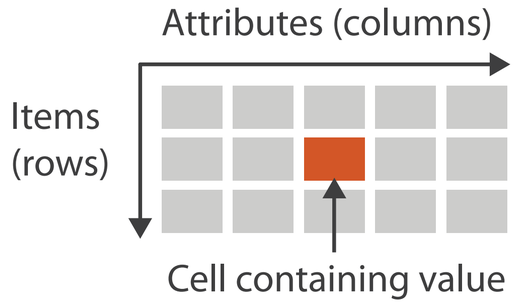
Dataset types

Tables	Networks & Trees
Items	Items (nodes)
Attributes	Links
	Attributes

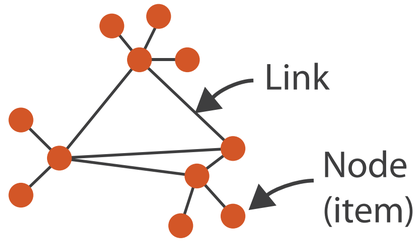
network/graph

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

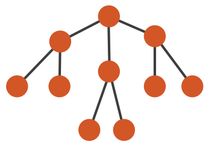
➔ Tables



➔ Networks



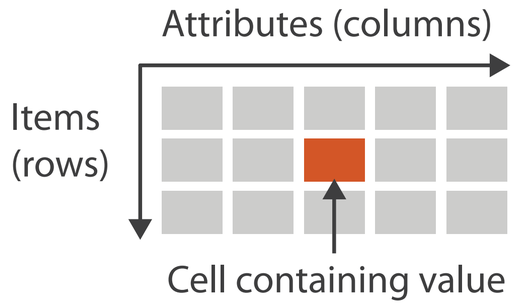
➔ *Trees*



Dataset types

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

➔ Tables



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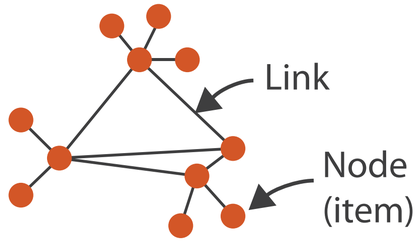

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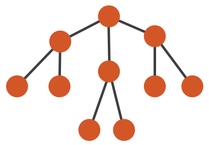
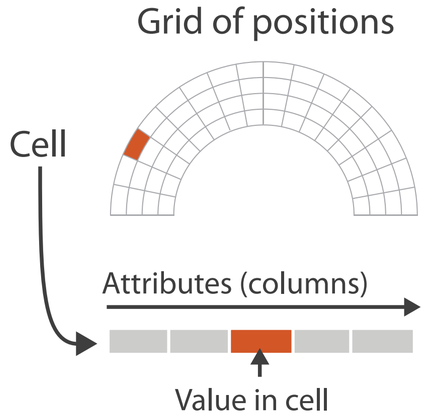


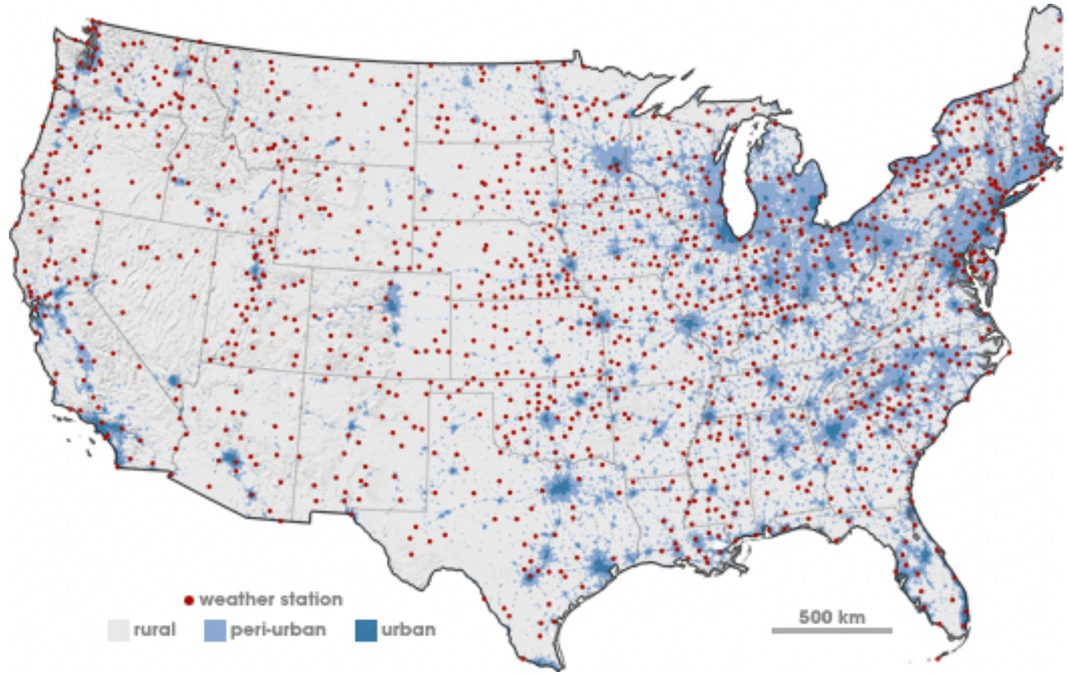
➔ Spatial

➔ Fields (Continuous)



Spatial fields

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



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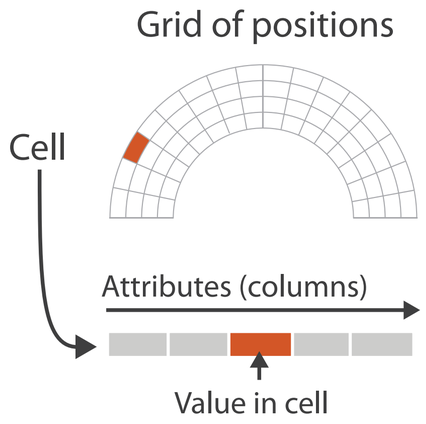
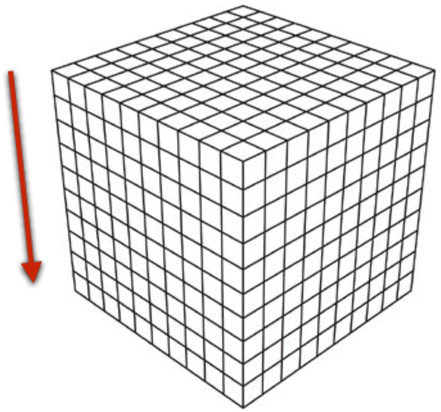
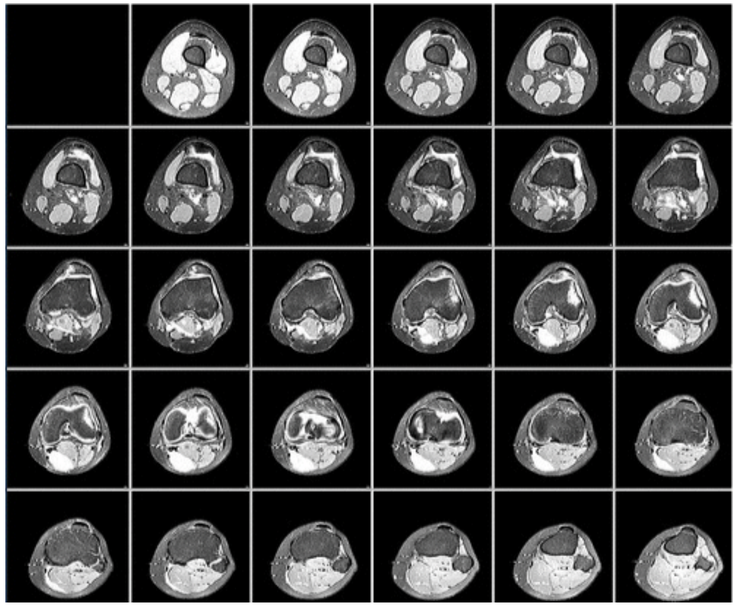


Spatial fields

- 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





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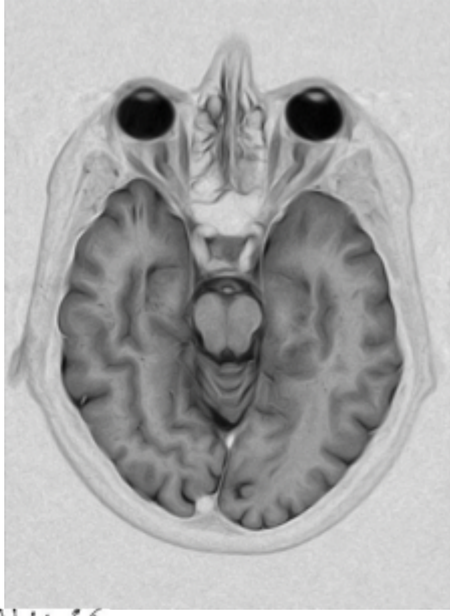
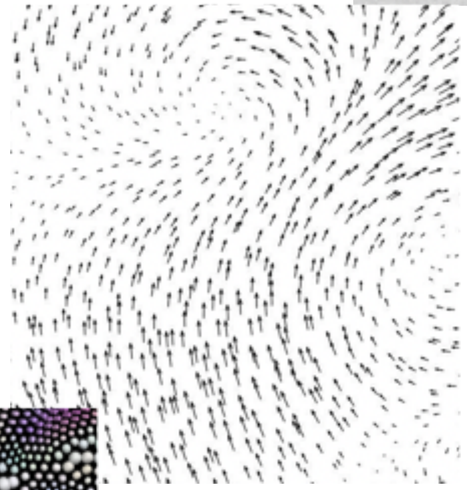
  - eg temperature, pressure, wind velocity
- measured or simulated
- major concerns
  - sampling:
    where attributes are measured
  - interpolation:
    how to model attributes elsewhere
  - grid types
- major divisions
  - attributes per cell:
    scalar (1), vector (2), tensor (many)

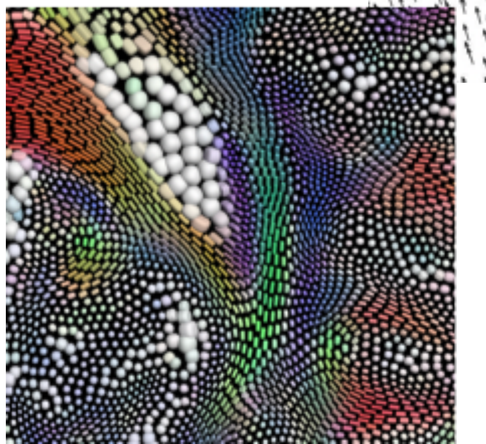
scalar



vector



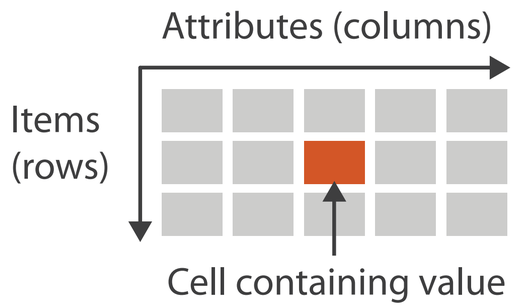
tensor



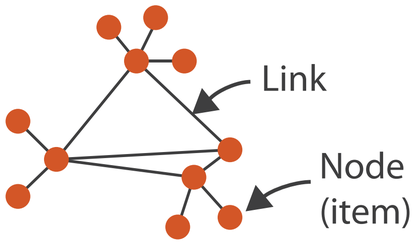
Dataset types

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

➔ Tables



➔ Networks



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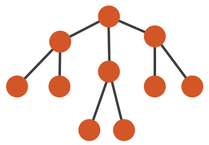
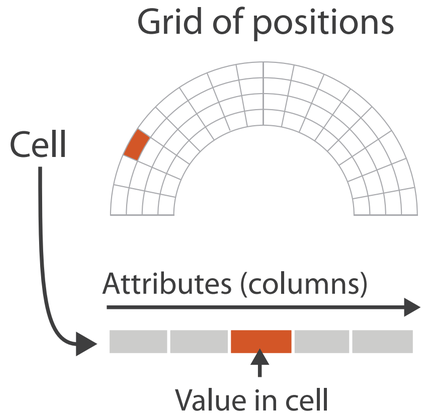
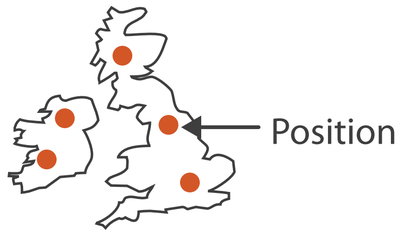


➔ Spatial

➔ Fields (Continuous)

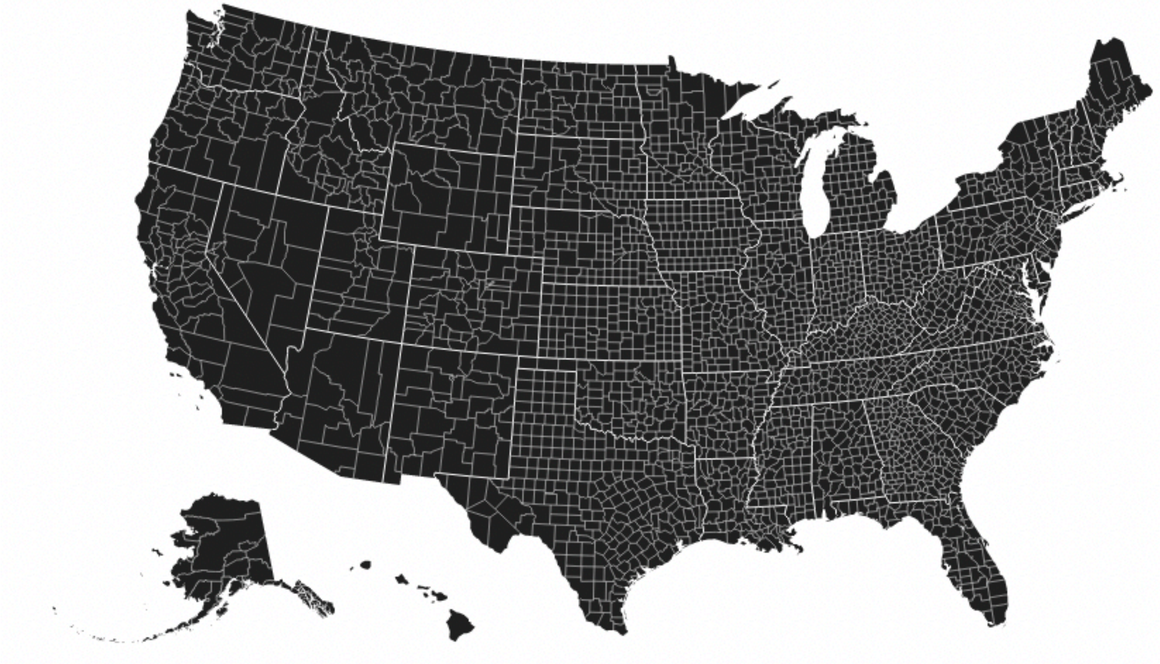


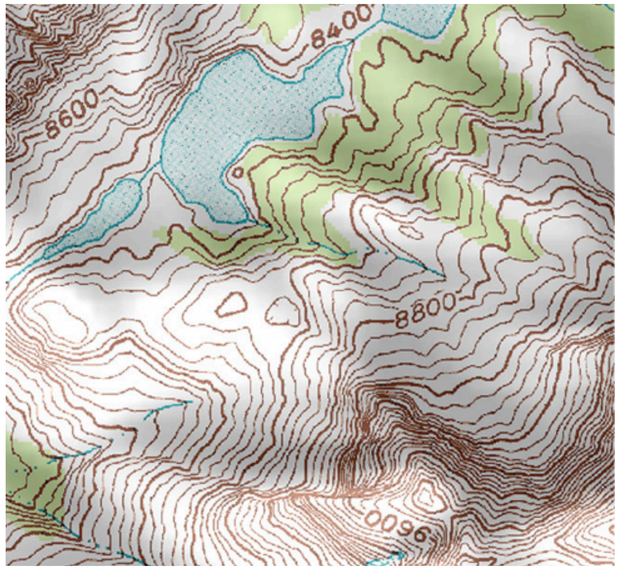
➔ Geometry (Spatial)



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

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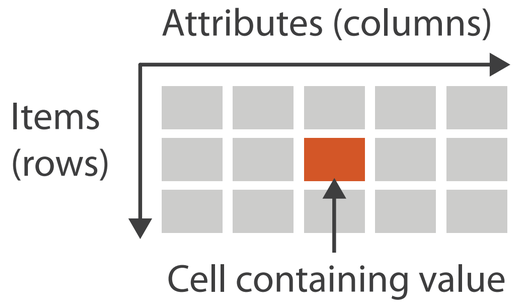
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

➔ Tables



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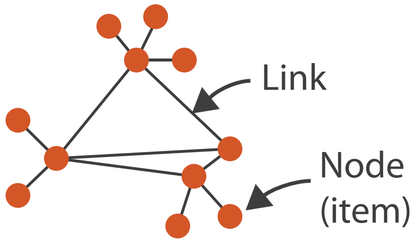

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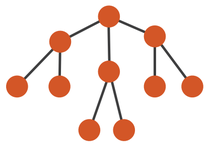
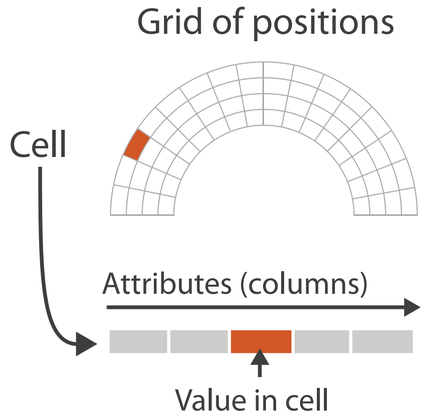
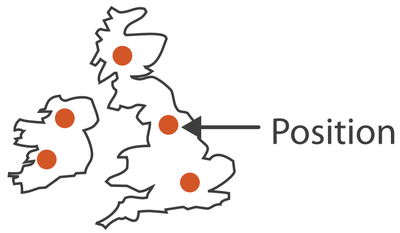


➔ Spatial

➔ Fields (Continuous)

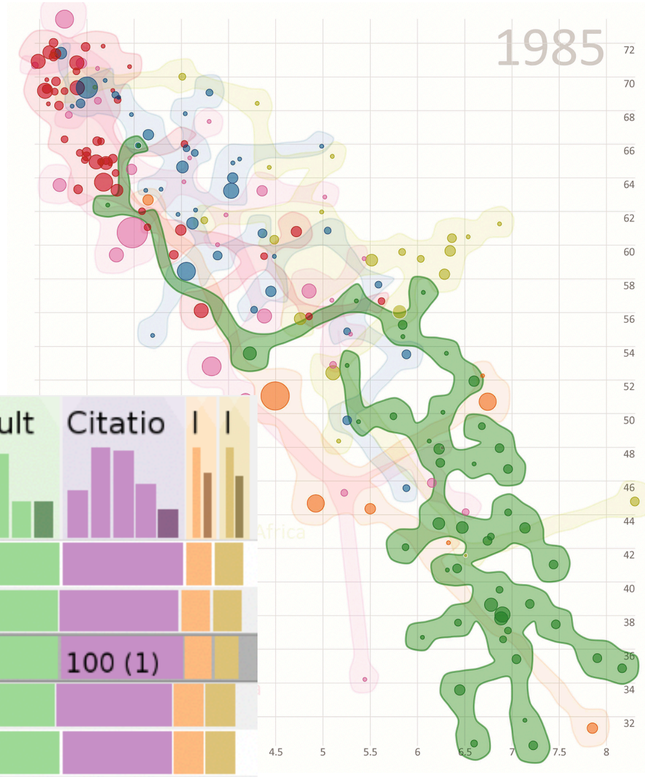


➔ Geometry (Spatial)

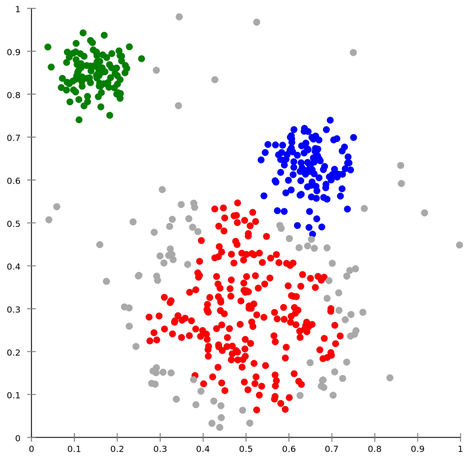


Collections

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



Data and Dataset Types

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

categorical
ordinal
quantitative

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

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!]

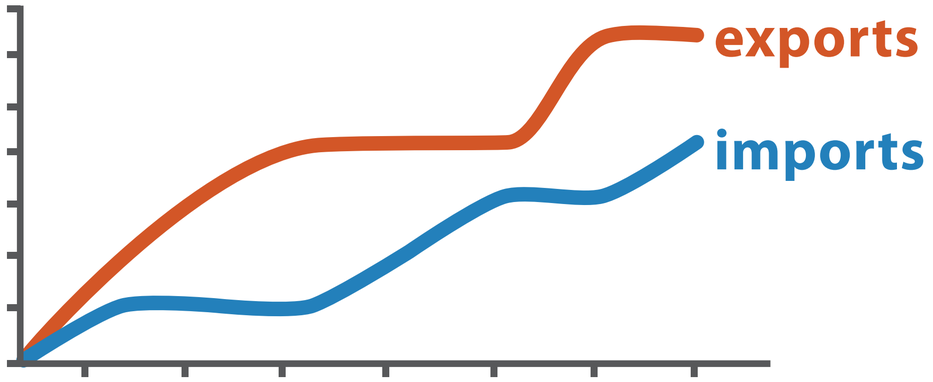
- data abstraction process relies on conceptual model
  - for transforming data if needed

Data vs conceptual model, example

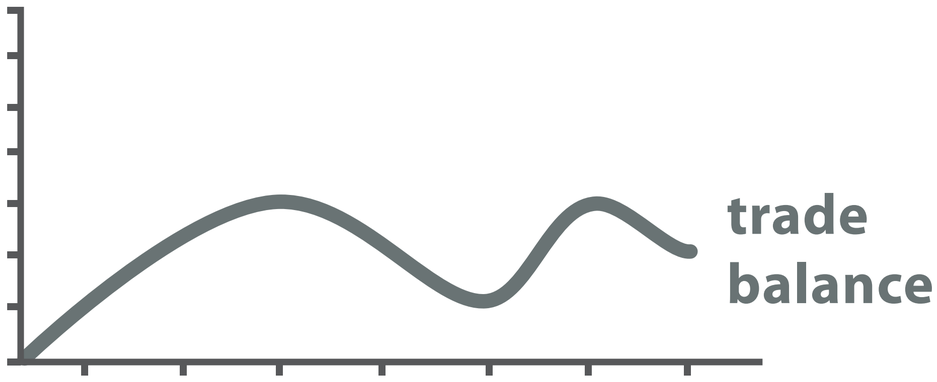
- data model: floats
  - 32.52, 54.06, -14.35, ...
- conceptual model
  - temperature
- multiple possible data abstractions
  - continuous to 2 significant figures: quantitative
    - task: forecasting the weather
  - hot, warm, cold: ordinal
    - task: deciding if bath water is ready
  - above freezing,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

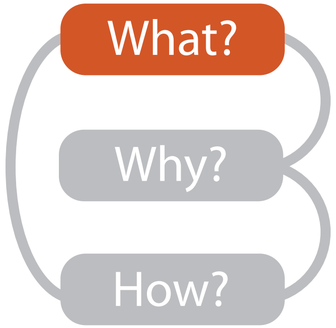


Original Data



trade balance = *exports* – *imports*

Derived Data



What?

Datasets

Data Types

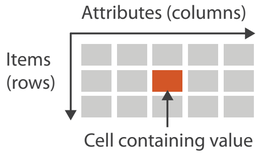
→ Items → Attributes → Links → Positions → Grids

Data and Dataset Types

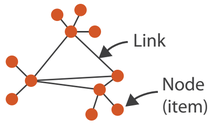
Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

Dataset Types

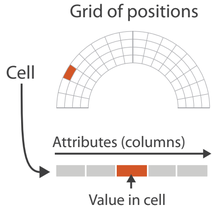
→ Tables



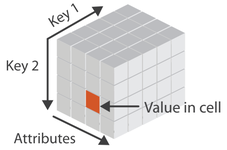
→ Networks



→ Fields (Continuous)



→ *Multidimensional Table*



→ *Trees*

→ Geometry (Spatial)

Dataset Availability

→ Static

→ Dynamic

Attributes

Attribute Types

→ Categorical

→ Ordered

→ *Ordinal*

→ *Quantitative*

Ordering Direction

→ Sequential

→ Diverging

→ Cyclic

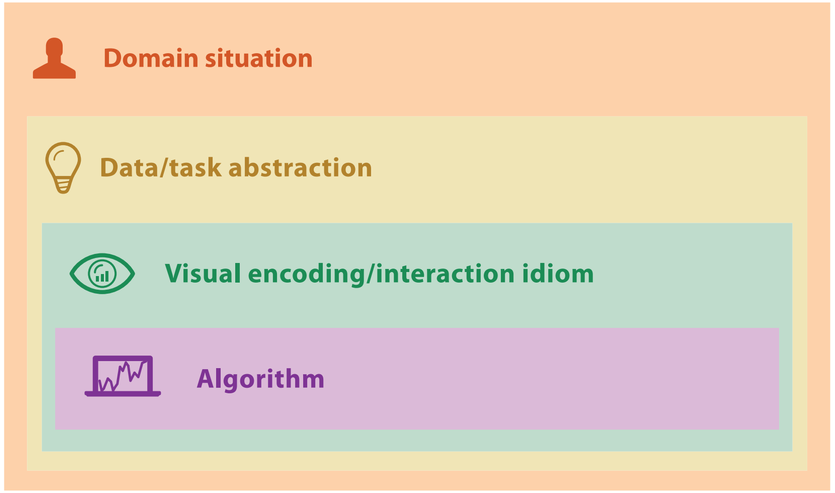
Reading Material

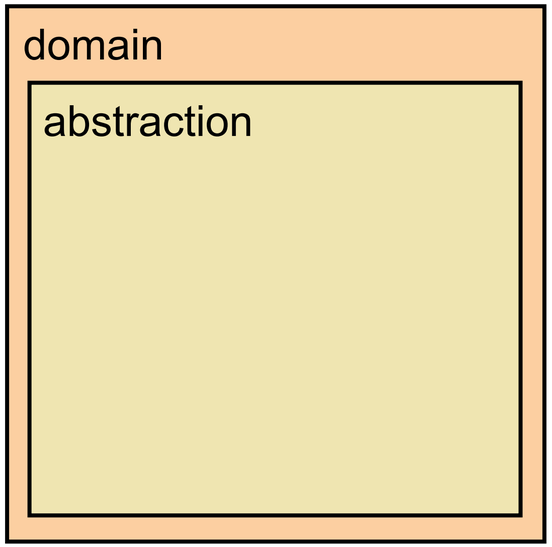
[dv3] **Chapter 2 - What: Data Abstraction**

Task Abstraction

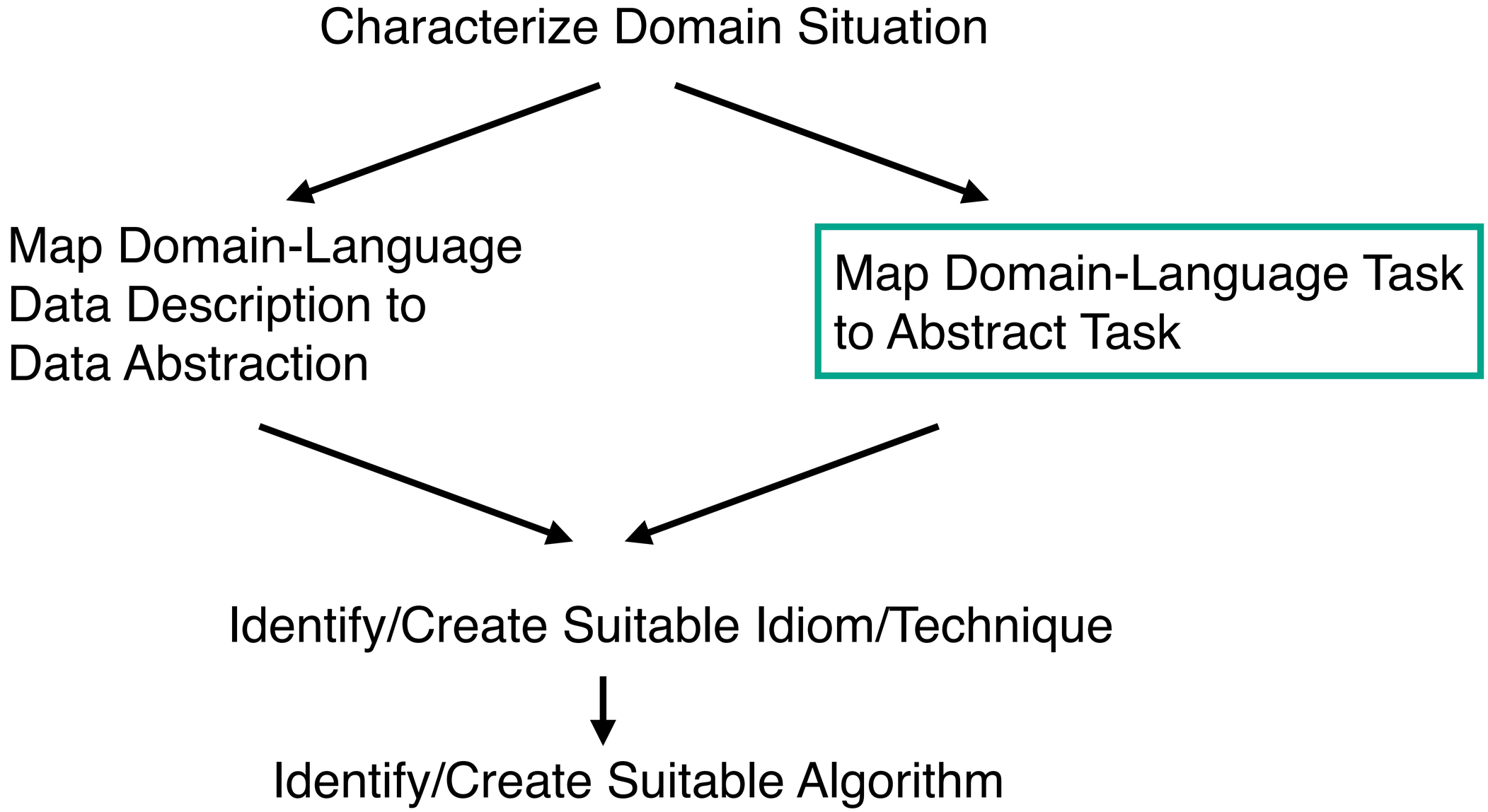
From domain to abstraction

- **domain characterization:** details of application domain
  - group of users, target domain, their questions & data
    - varies wildly by domain
    - must be specific enough to get traction
  - domain questions/problems
    - break down into simpler abstract tasks
- **abstraction:** data & task
  - map what and why into generalized terms
    - identify tasks that users wish to perform, or already do
    - find data types that will support those tasks
      - possibly transform /derive if need be





Design process



Task abstraction
Actions and targets

- **very high-level pattern**

- **actions**
  - analyze
    - high-level choices
  - search
    - find a known/unknown item
  - query
    - find out about the characteristics of the item
- **targets**
  - what is being acted on

{action, target} pairs

- discover distribution
- compare trends
- locate outliers
- browse topology

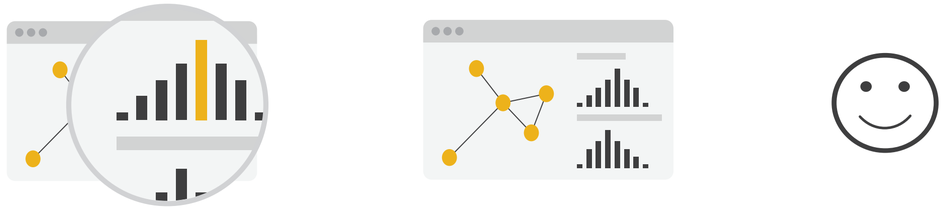
Actions: Analyze

- **consume**
  - discover vs present
    - classic split
    - aka explore vs explain
  - enjoy
    - newcomer
    - aka casual, social
- **produce**
  - annotate, record
  - derive
    - crucial design choice

➔ **Analyze**

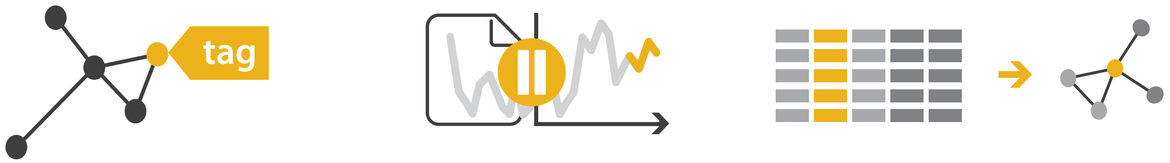
➔ Consume

➔ *Discover* ➔ *Present* ➔ *Enjoy*



➔ Produce

➔ *Annotate* ➔ *Record* ➔ *Derive*



Actions: Search

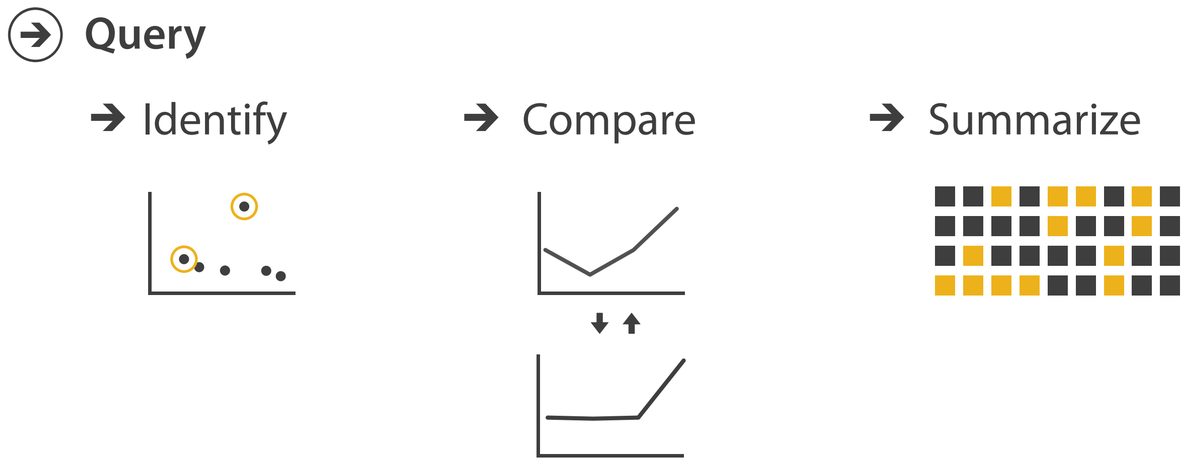
- what does user know?
  - target, location
- lookup
  - ex: word in dictionary
    - alphabetical order
- locate
  - ex: keys in your house
  - ex: node in network
- browse
  - ex: books in bookstore
- explore
  - ex: find cool neighborhood in new city

Search

	Target known	Target unknown
Location known	*Lookup*	*Browse*
Location unknown	*Locate*	*Explore*

Actions: Query

- **how much of the data matters?**
  - one: identify
  - some: compare
  - all: summarize



Actions

- **independent choices for each of these three levels**
  - analyze, search, query
  - mix and match

Actions

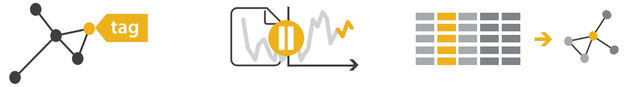
Analyze

→ Consume

→ *Discover* → *Present* → *Enjoy*

→ Produce

→ *Annotate* → *Record* → *Derive*

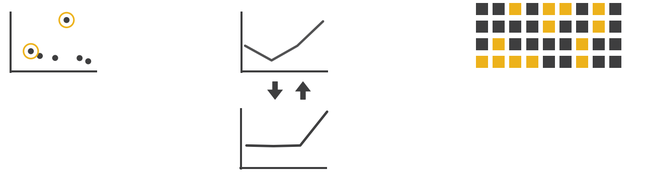


Search

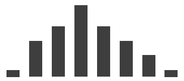
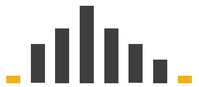
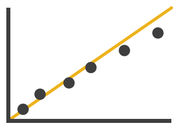
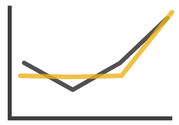
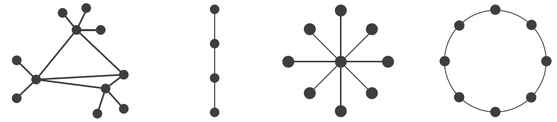
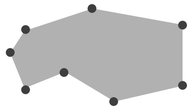
	Target known	Target unknown
Location known	*Lookup*	*Browse*
Location unknown	*Locate*	*Explore*

Query

→ Identify → Compare → Summarize



Task abstraction: Targets

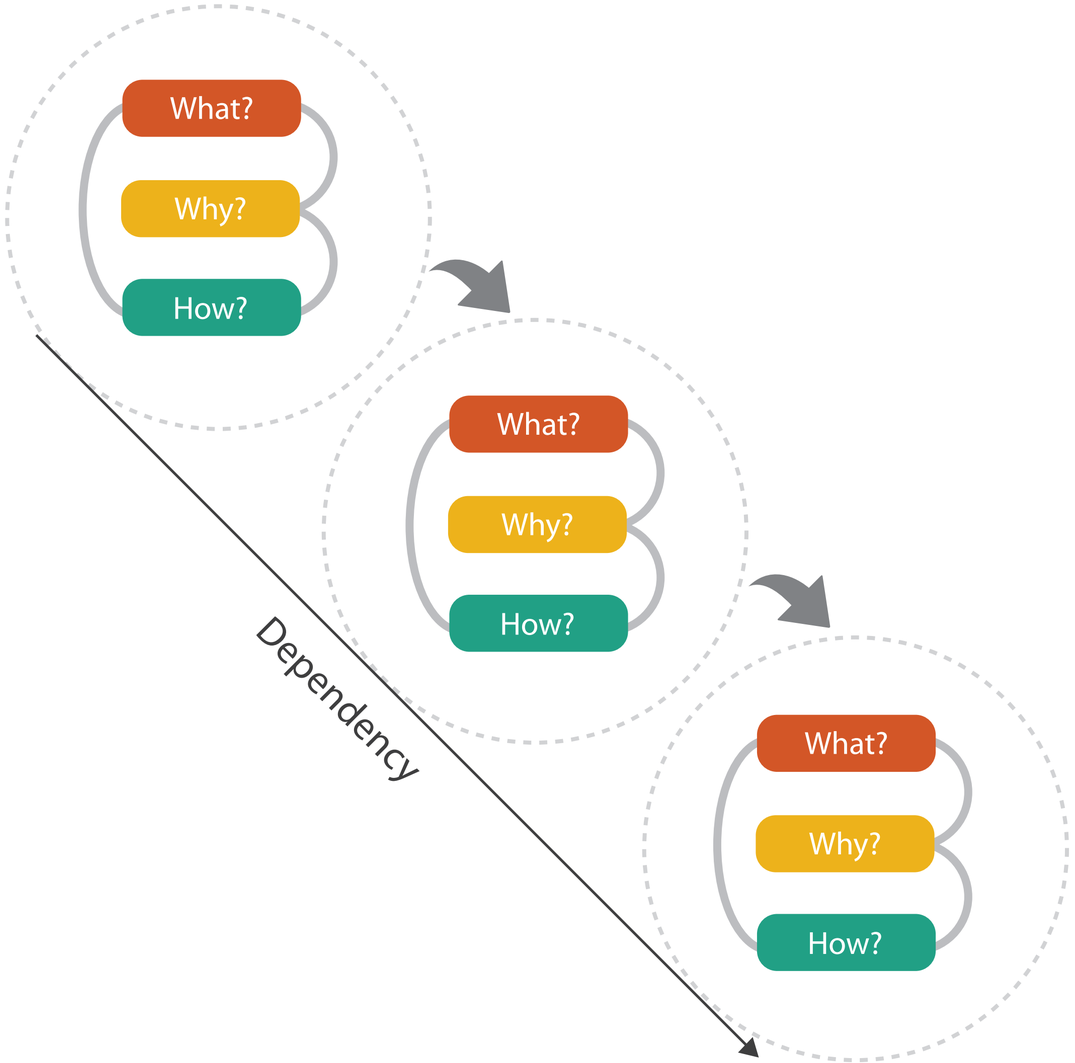
- **All Data**
  - Trends 
  - Outliers 
  - Features 
- **Attributes**
  - One
    - *Distribution* 
    - *Extremes* 
  - Many
    - *Dependency*
    - *Correlation* 
    - *Similarity* 
- **Network Data**
  - Topology 
  - *Paths* 
- **Spatial Data**
  - Shape 

Abstraction

- these {action, target} pairs are good starting point for vocabulary
  - but sometimes you'll need more precision!
- rule of thumb
  - systematically remove all domain jargon

- interplay: task and data abstraction
  - need to use data abstraction within task abstraction
    - to specify your targets!
    - but task abstraction can lead you to transform the data
  - iterate back and forth
    - first pass data, first pass task, second pass data, ...

Means and ends



{action, target} pairs

- discover distribution
- compare trends
- locate outliers
- browse topology

Why?

Actions

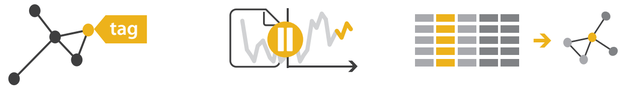
Analyze

→ Consume

→ *Discover* → *Present* → *Enjoy*

→ Produce

→ *Annotate* → *Record* → *Derive*

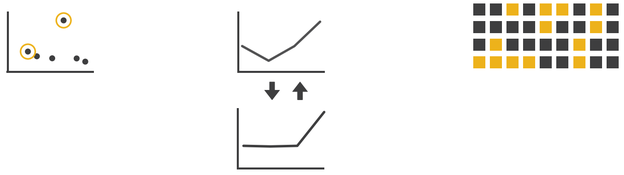


Search

	Target known	Target unknown
Location known	*Lookup*	*Browse*
Location unknown	*Locate*	*Explore*

Query

→ Identify → Compare → Summarize



Targets

All Data

→ Trends → Outliers → Features

Attributes

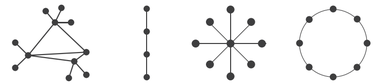
→ One → Many

→ *Distribution* → *Dependency* → *Correlation* → *Similarity*

→ *Extremes*

Network Data

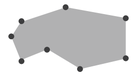
→ Topology



→ *Paths*

Spatial Data

→ Shape



Reading Material

[dv3] **Chapter 3 - Why: Task Abstraction**

Questions?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