Visualization: Abstractions & Idioms

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http://www.cs.ubc.ca/~tmm/talks.html#coimbra22

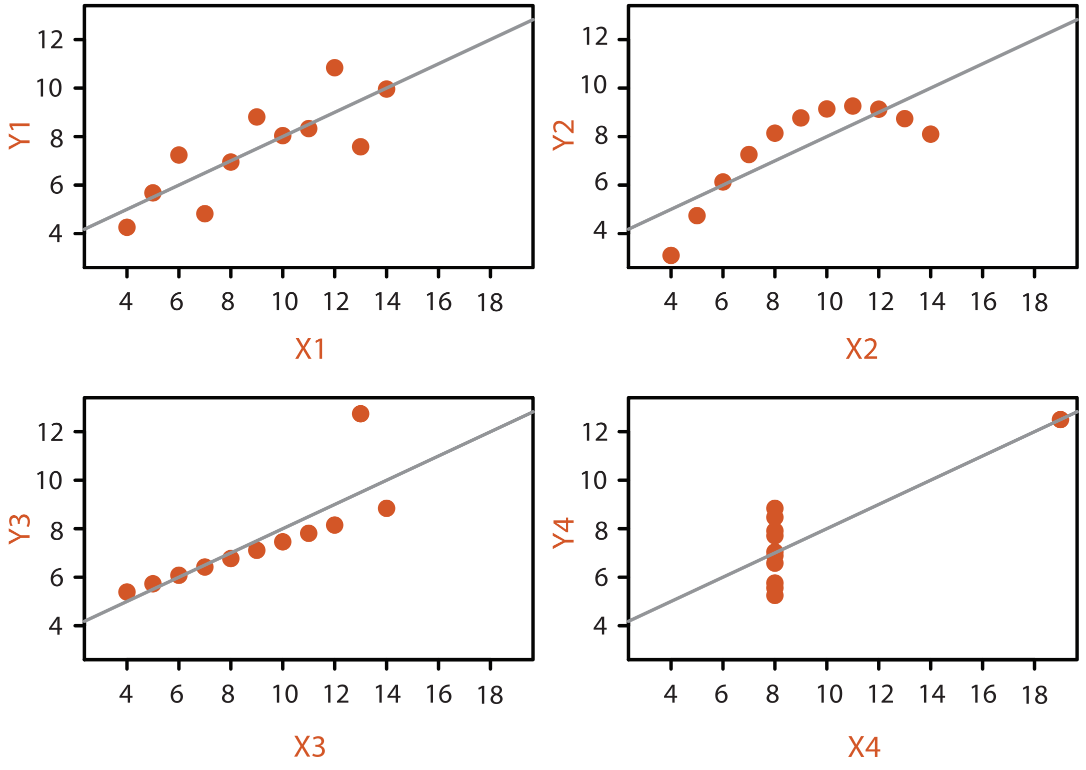
Visualization defined & motivated

Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.

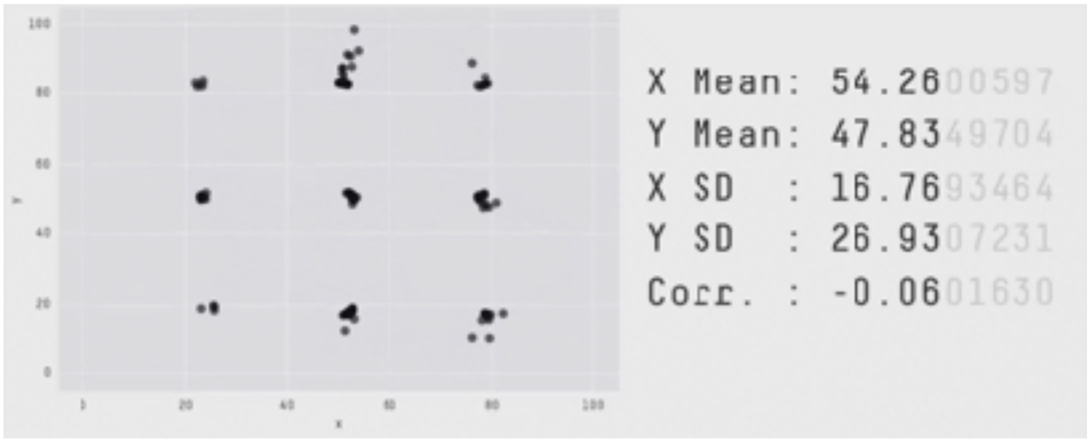
- suitable when human in the loop needs details
  - interplay between human judgement and automatic computation

Anscombe's Quartet

Identical statistics	
x mean	9
x variance	10
y mean	7.5
y variance	3.75
x/y correlation	0.816



Datasaurus Dozen



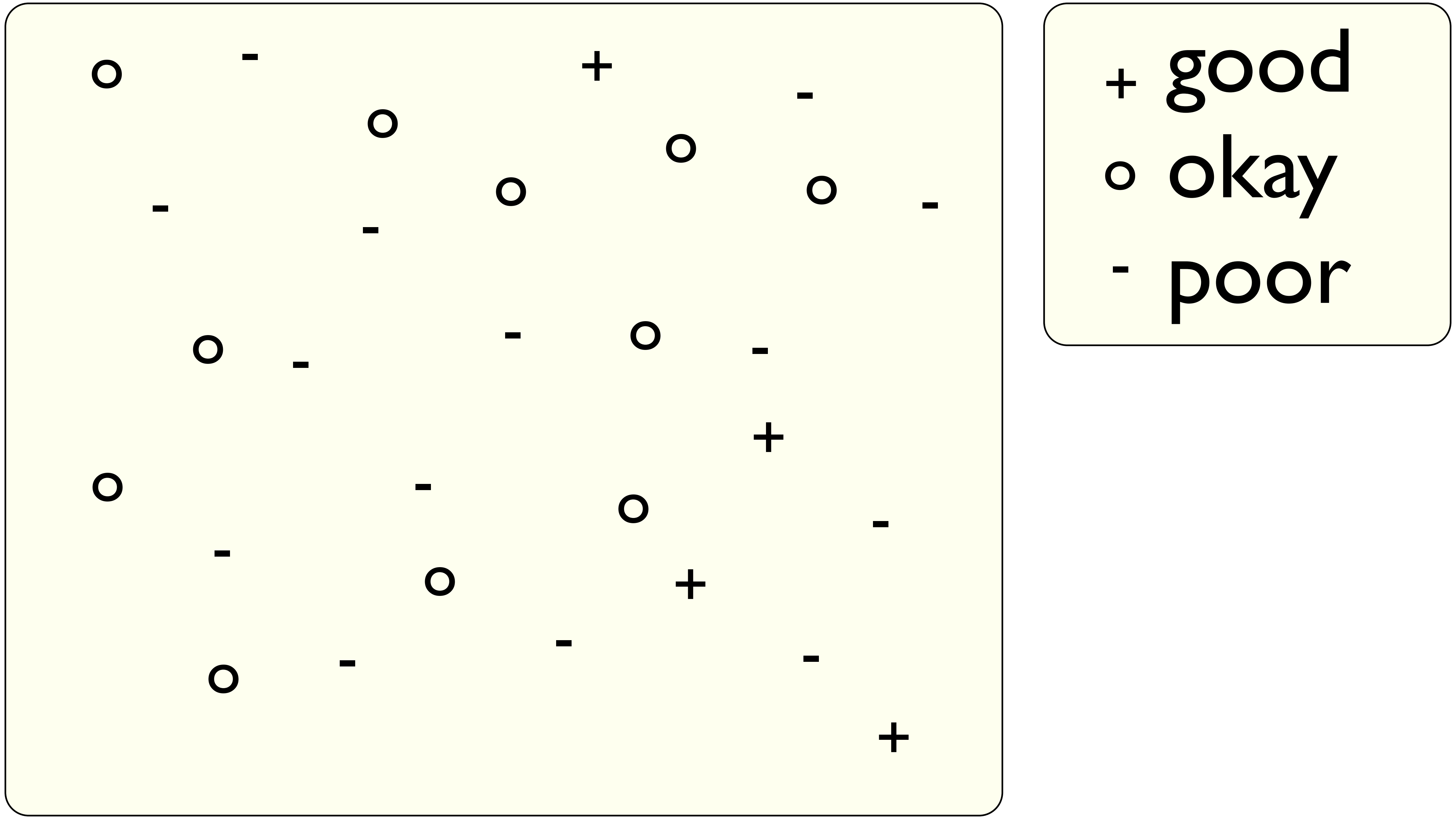
Same Stats, Different Graphs: Generating Datasets with Varied Appearance and Identical Statistics through Simulated Annealing. CHI 2017. Matejka & Fitzmaurice

Why focus on tasks and effectiveness?

Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.

- effectiveness requires match between data/task and representation
  - set of representations is huge
  - many are ineffective mismatch for specific data/task combo
  - increases chance of finding good solutions if you understand full space of possibilities

Metaphor: Design space



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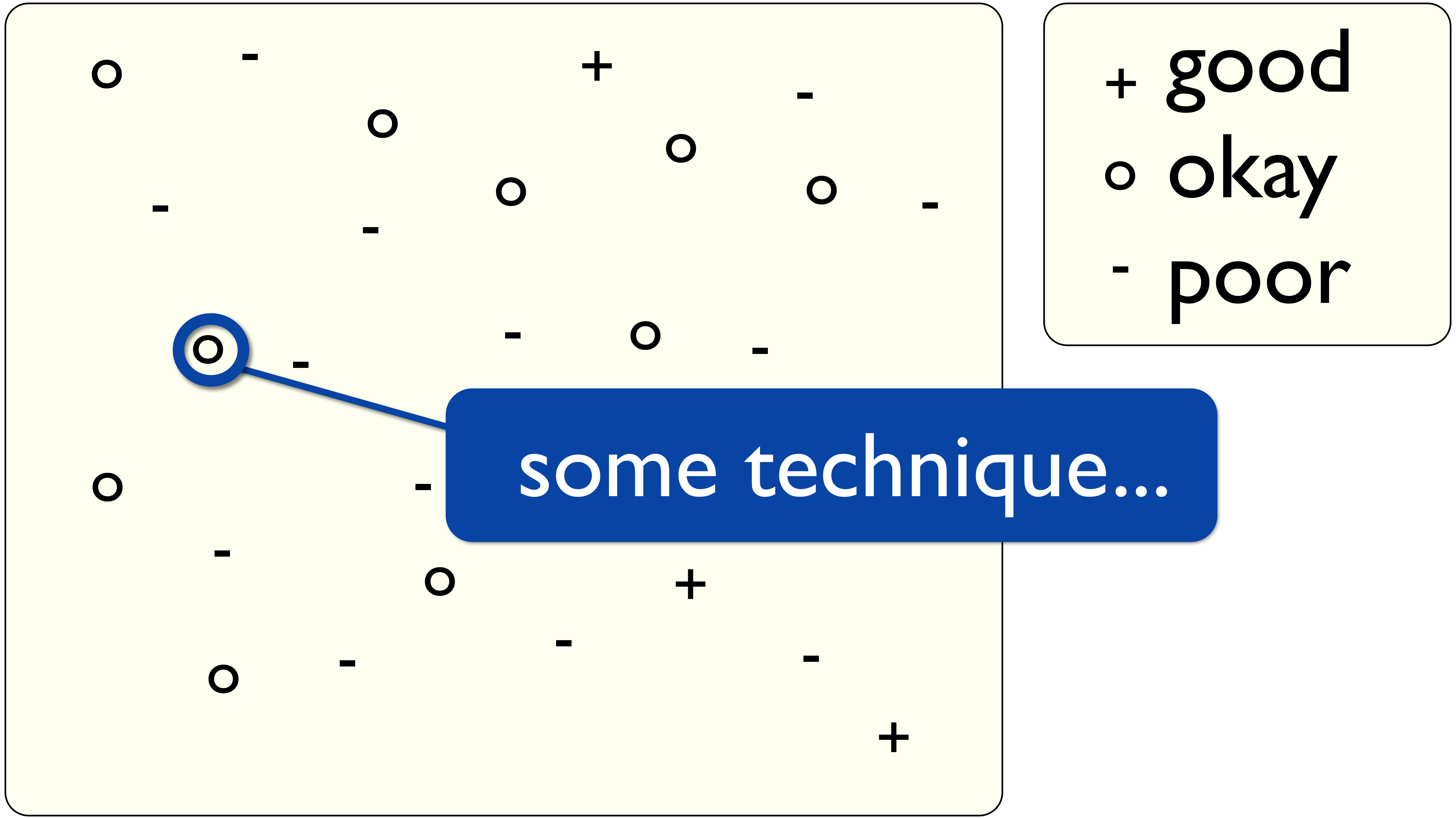

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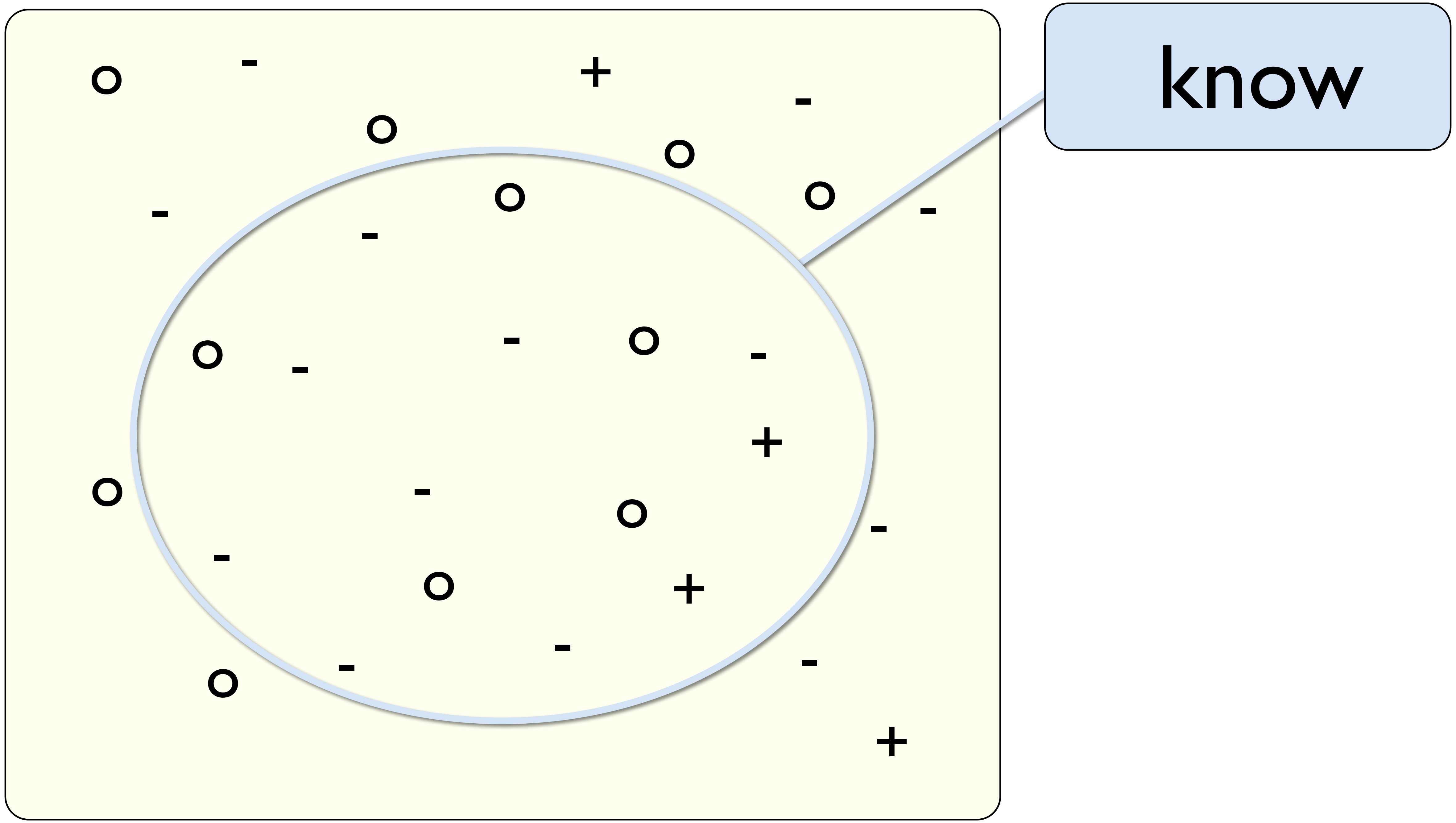

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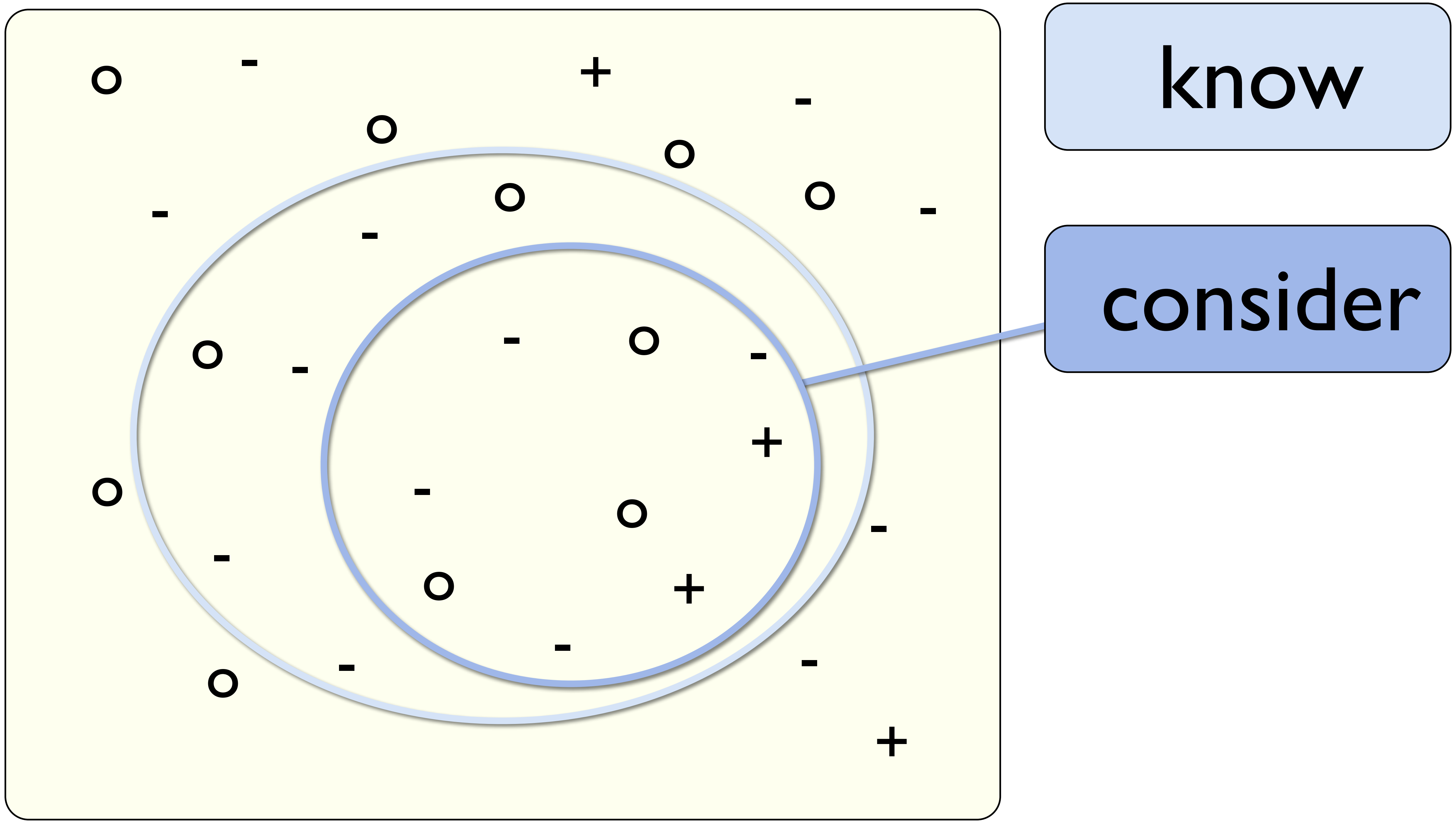

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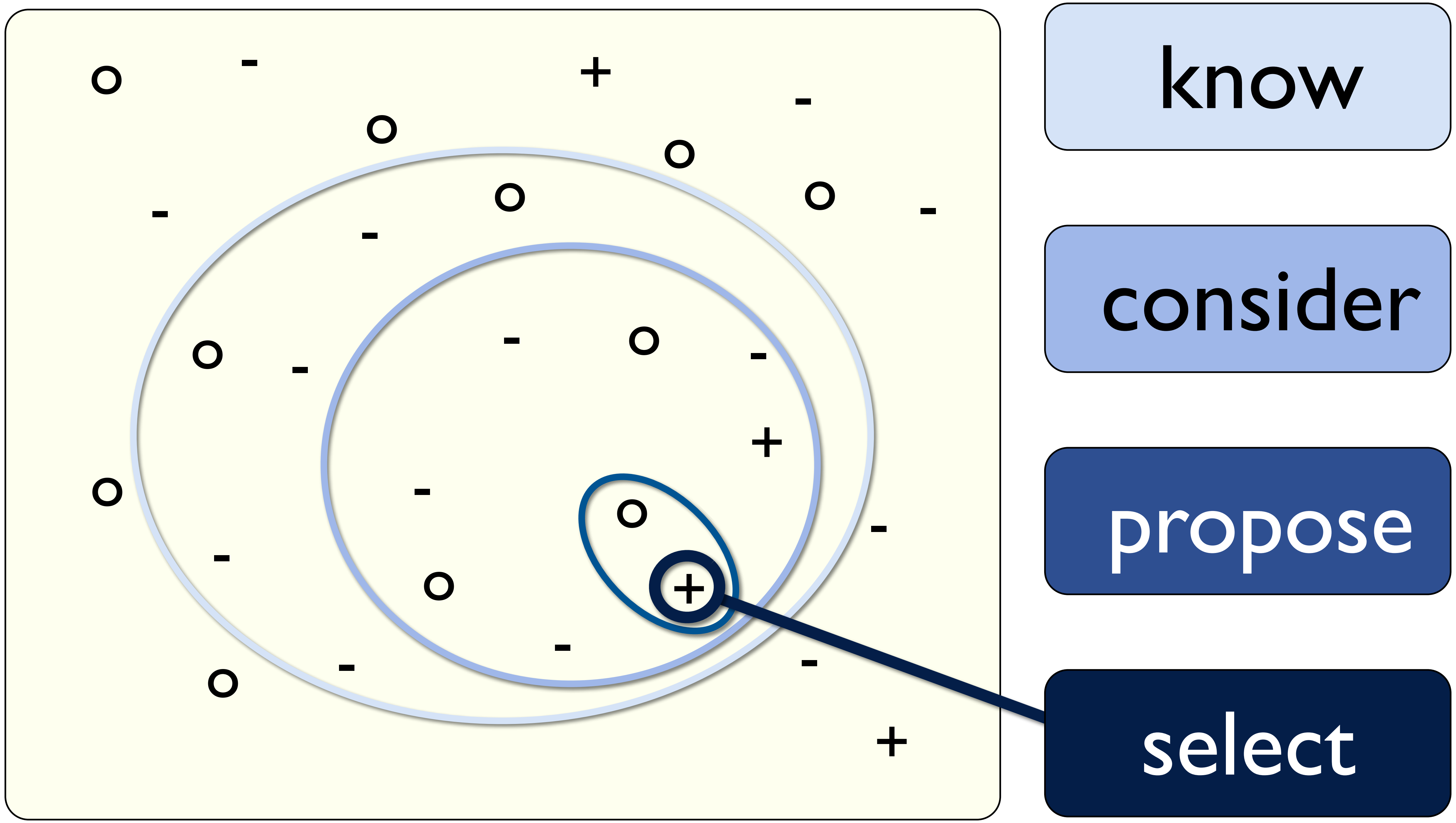

Metaphor: Design space

Think broad!

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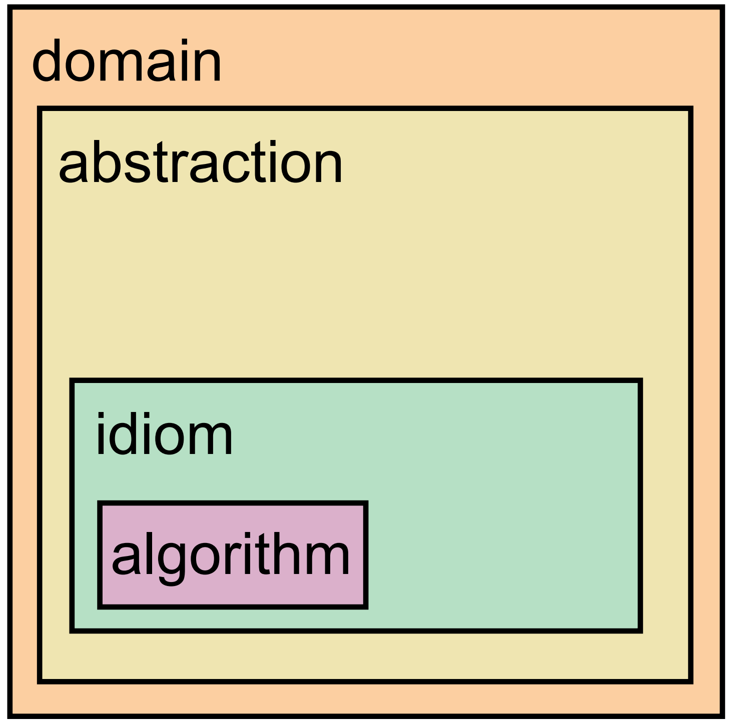
  - many are ineffective mismatch for specific data/task combo
  - increases chance of finding good solutions if you understand full space of possibilities
- what counts as effective?
  - novel: enable entirely new kinds of analysis
  - faster: speed up existing workflows
- how to validate effectiveness
  - many methods, must pick appropriate one for your context

Nested model: Four levels of visualization concerns



[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

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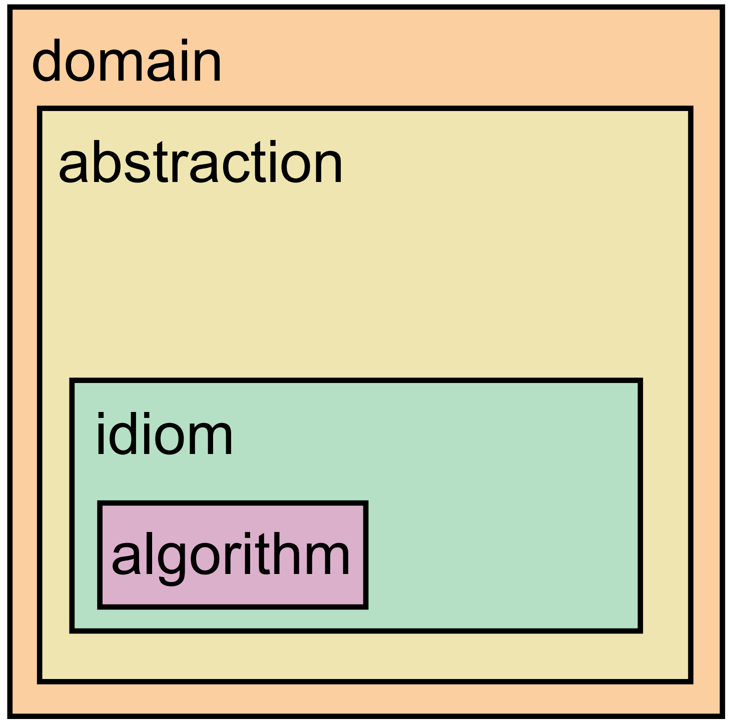
- *domain* situation
  - **who** are the target users?



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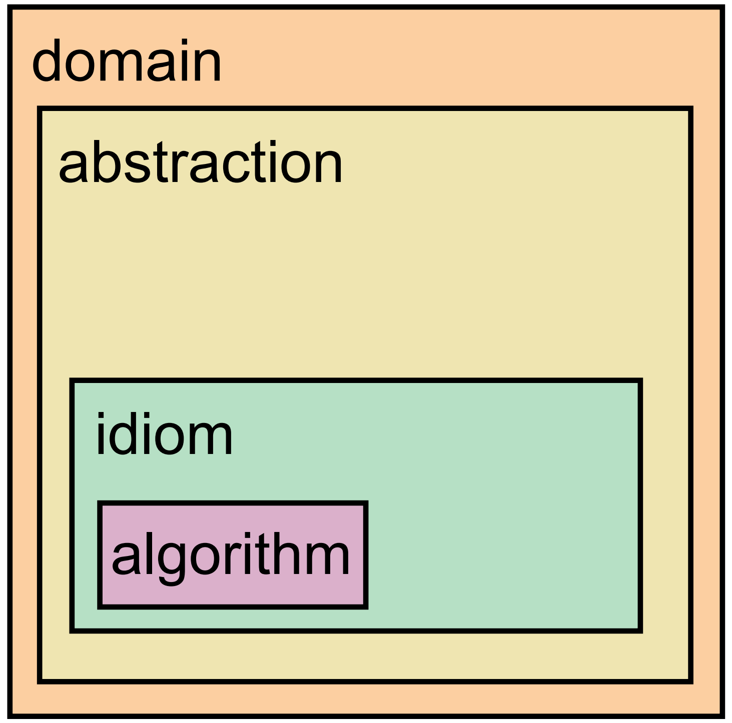

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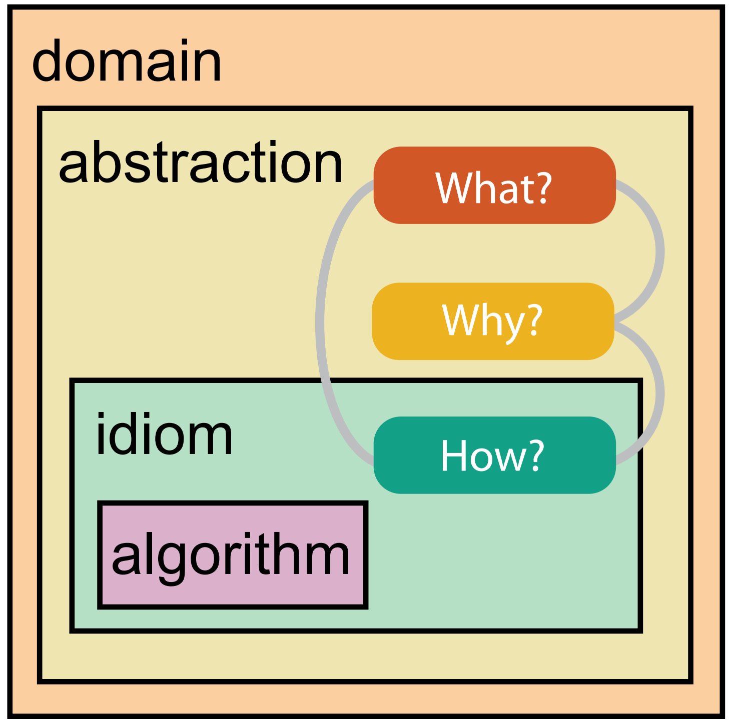

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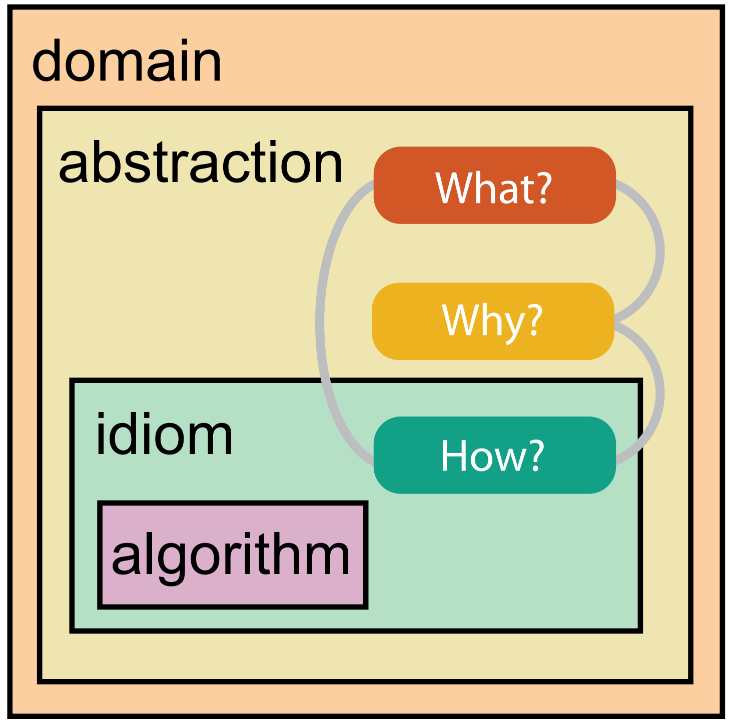

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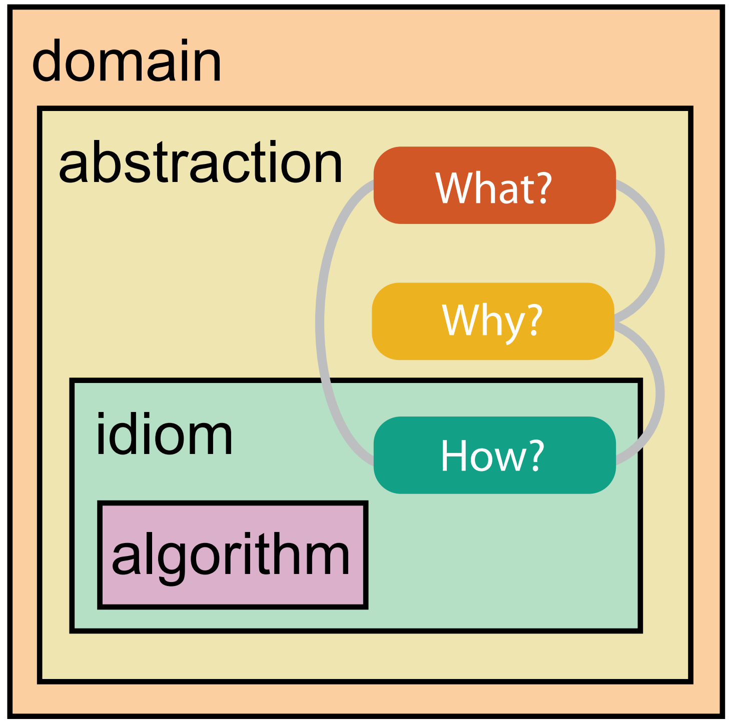

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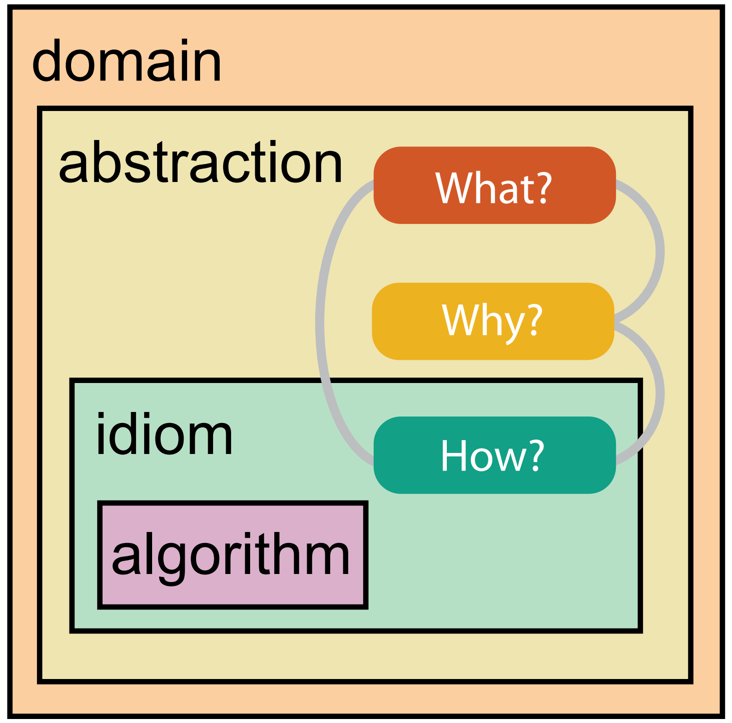

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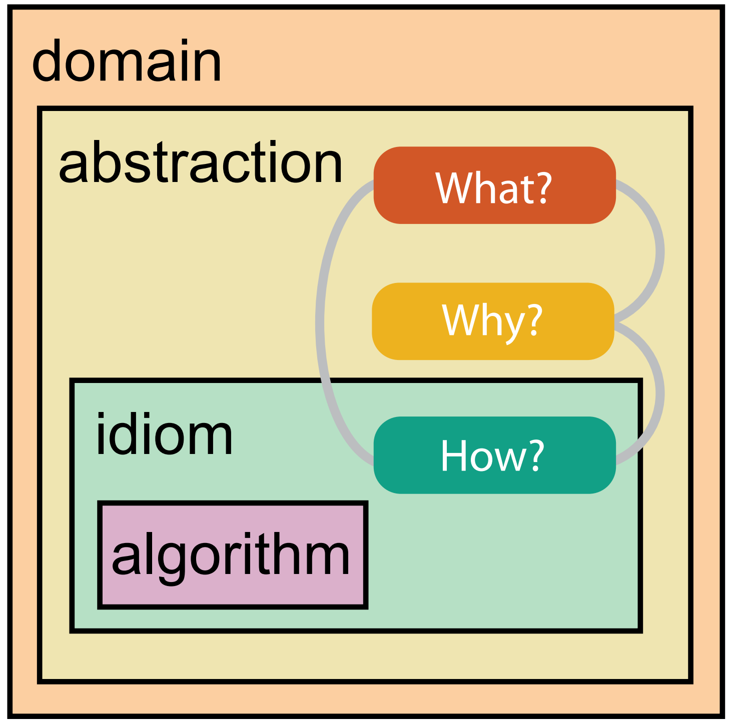
    - **visual encoding idiom**: how to draw



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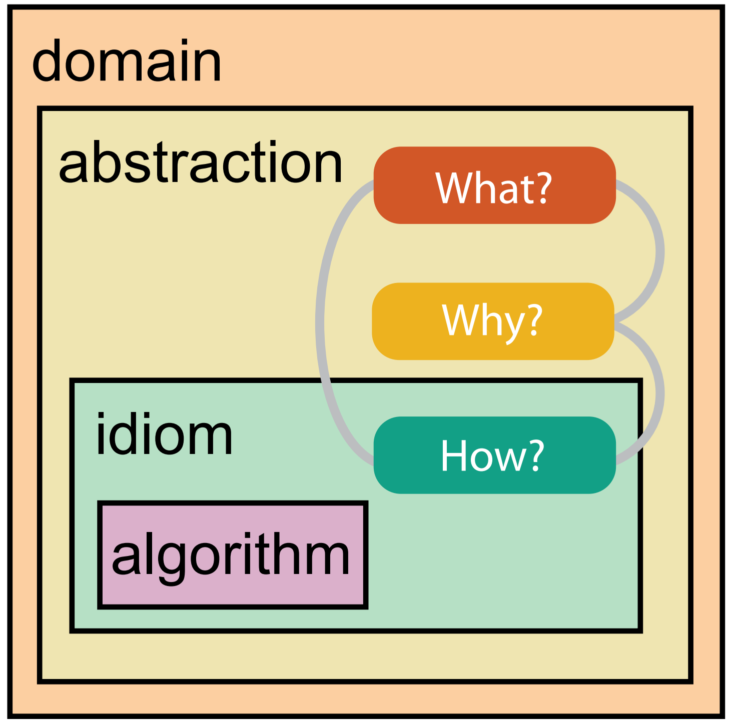

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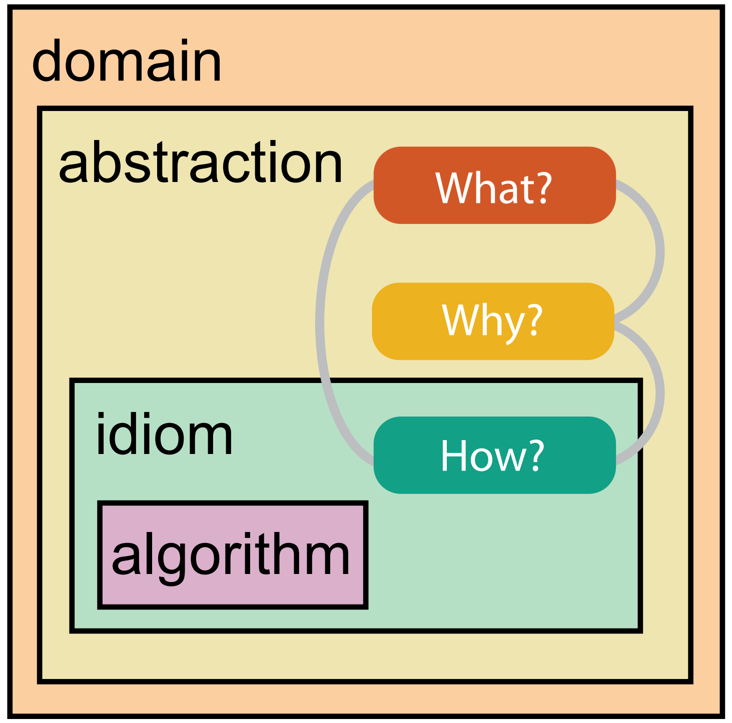
  - **how** is it shown?
    - **visual encoding idiom**: how to draw
    - **interaction idiom**: how to manipulate
- *algorithm*
  - efficient computation



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Why is validation difficult?

- different ways to get it wrong at each level

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Why is validation difficult?

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Domain situation
You misunderstood their needs

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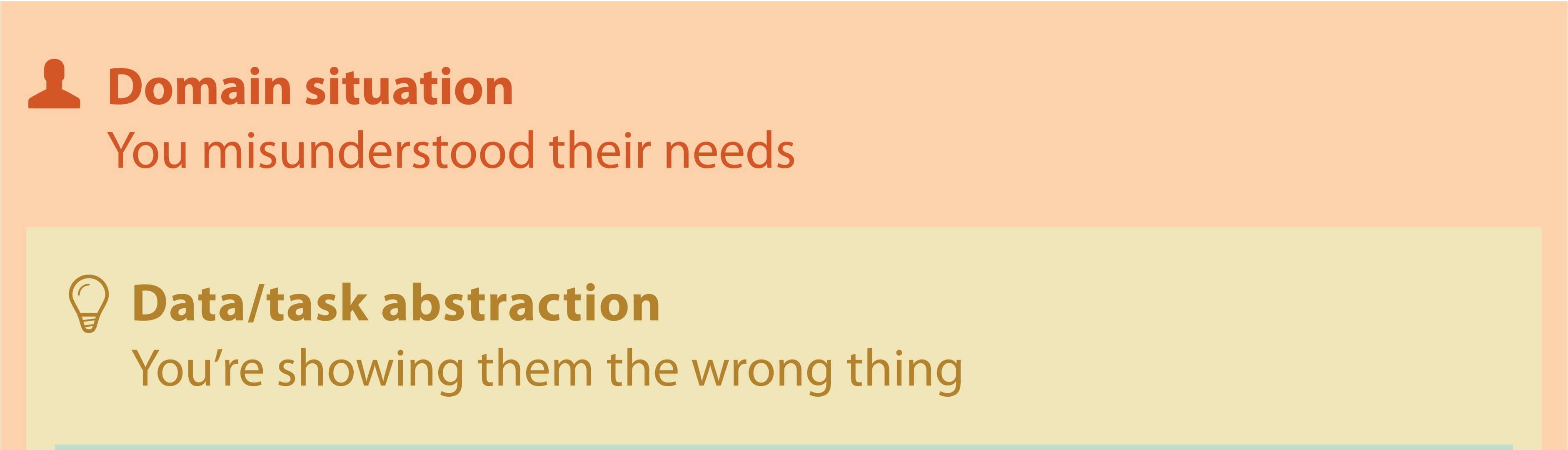

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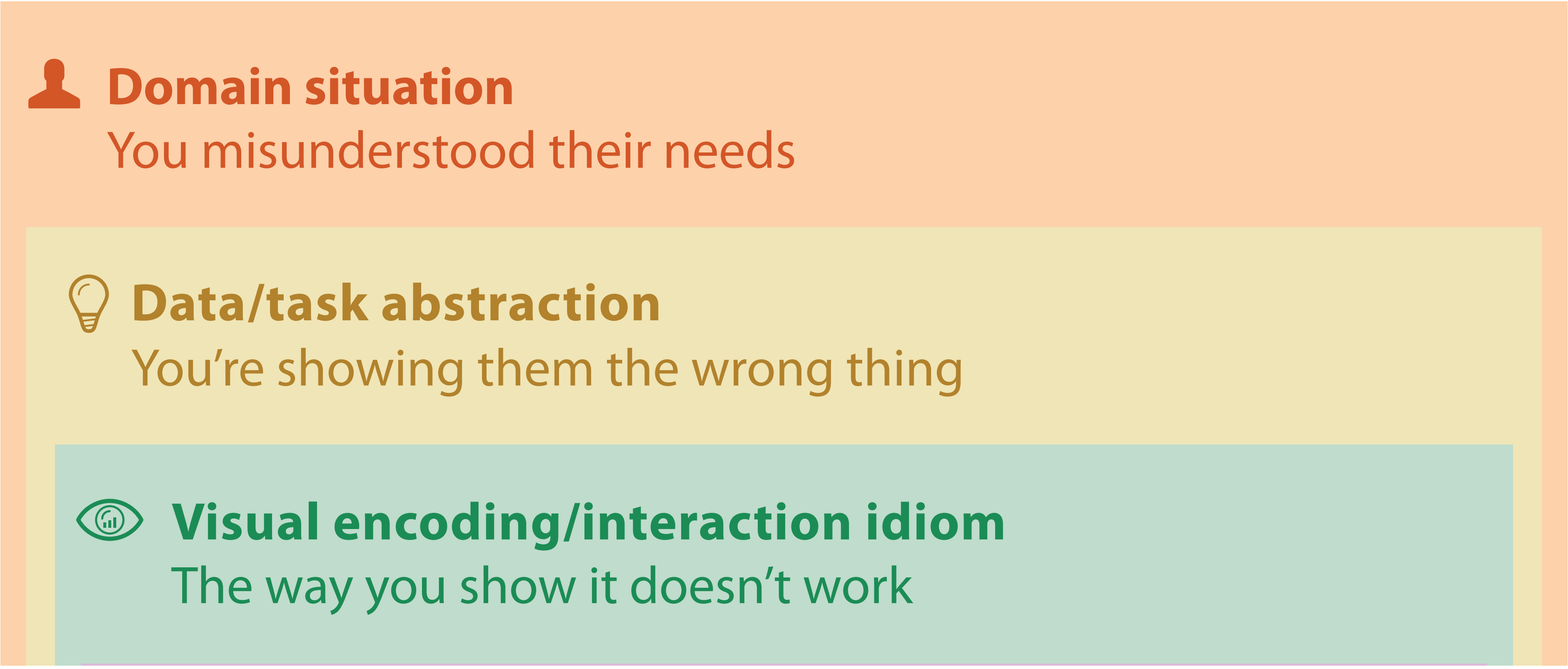

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Validation solution: use methods from appropriate fields at each level

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Validation solution: use methods from appropriate fields at each level

computer
science

Algorithm
Measure system time/memory
Analyze computational complexity

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Measure system time/memory
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technique-driven
work

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Validation solution: use methods from appropriate fields at each level

design

computer science

cognitive psychology

Visual encoding/interaction idiom
Justify design with respect to alternatives

Algorithm
Measure system time/memory
Analyze computational complexity

Analyze results qualitatively

Measure human time with lab experiment (*lab study*)

technique-driven work

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Validation solution: use methods from appropriate fields at each level

anthropology/
ethnography

design

computer
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cognitive
psychology

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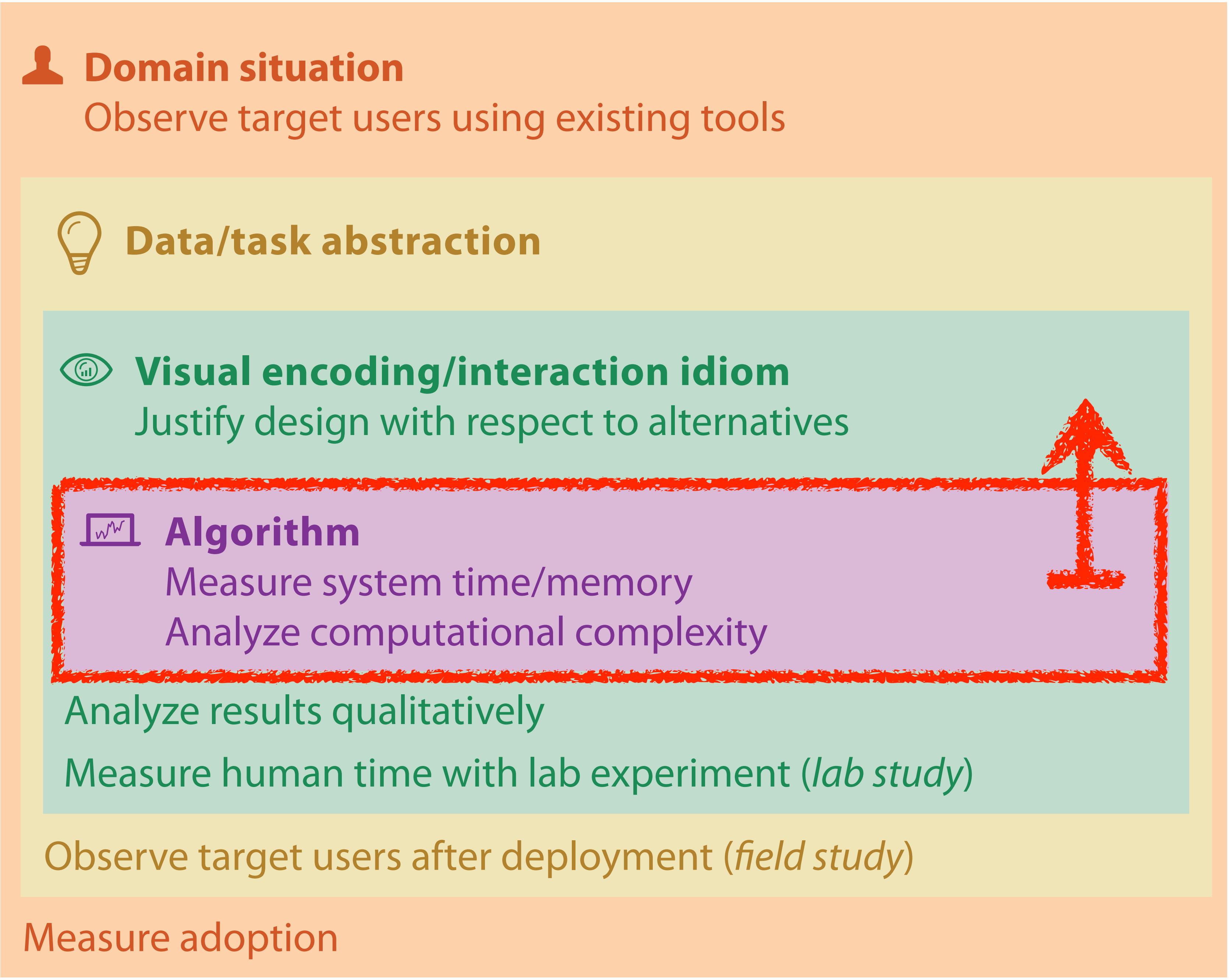

technique-driven
work

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Validation solution: use methods from appropriate fields at each level

anthropology/ ethnography

Domain situation
Observe target users using existing tools

Data/task abstraction

design

Visual encoding/interaction idiom
Justify design with respect to alternatives

computer science

Algorithm
Measure system time/memory
Analyze computational complexity

cognitive psychology

Analyze results qualitatively

Measure human time with lab experiment (*lab study*)

anthropology/ ethnography

Observe target users after deployment (*field study*)

Measure adoption

problem-driven work

technique-driven work

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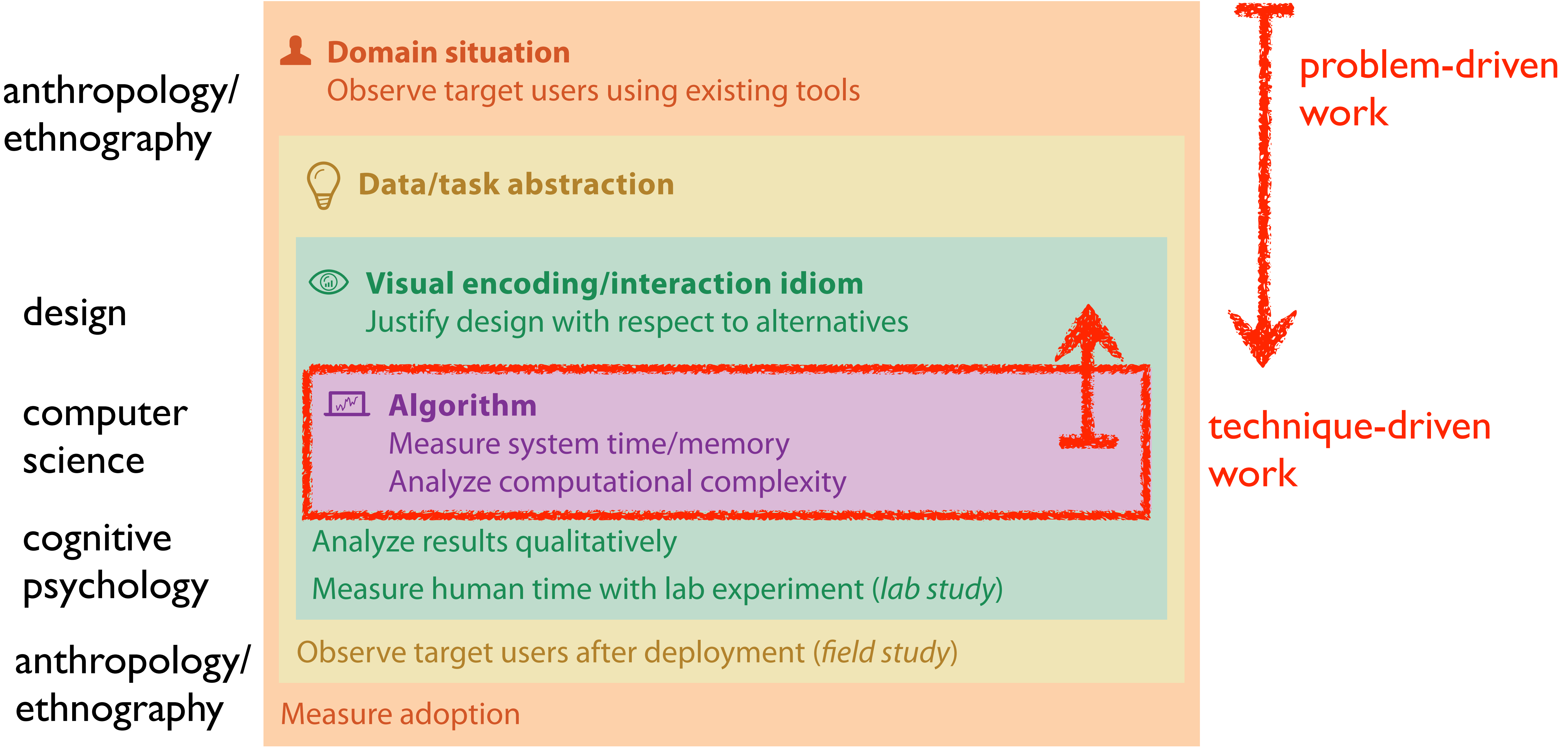
Validation solution: use methods from appropriate fields at each level

- avoid mismatches between level and validation



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Visualization: Angles of attack

problem-driven work

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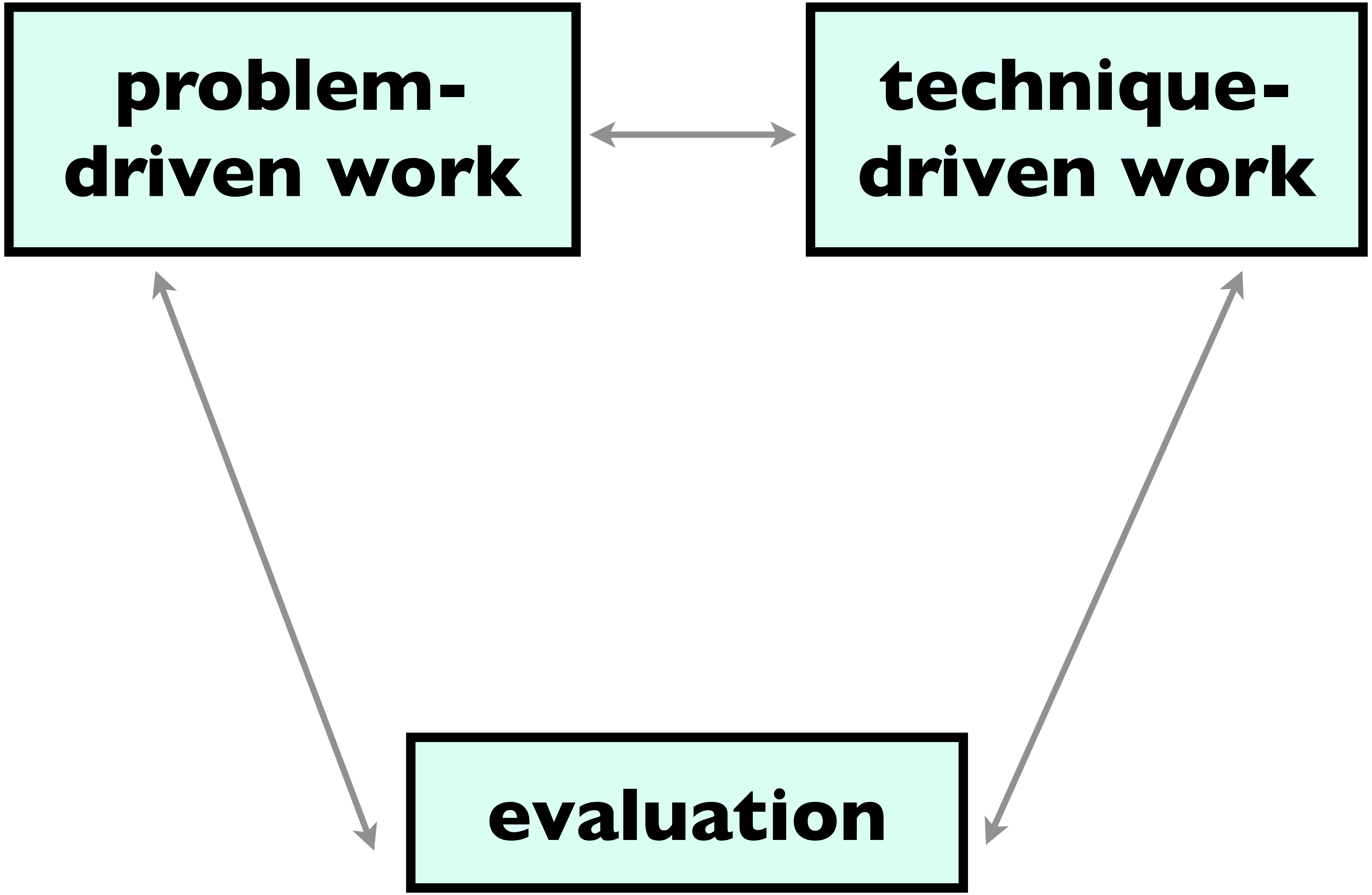
problem-driven work ⟷ **technique-driven work**

Visualization: Angles of attack



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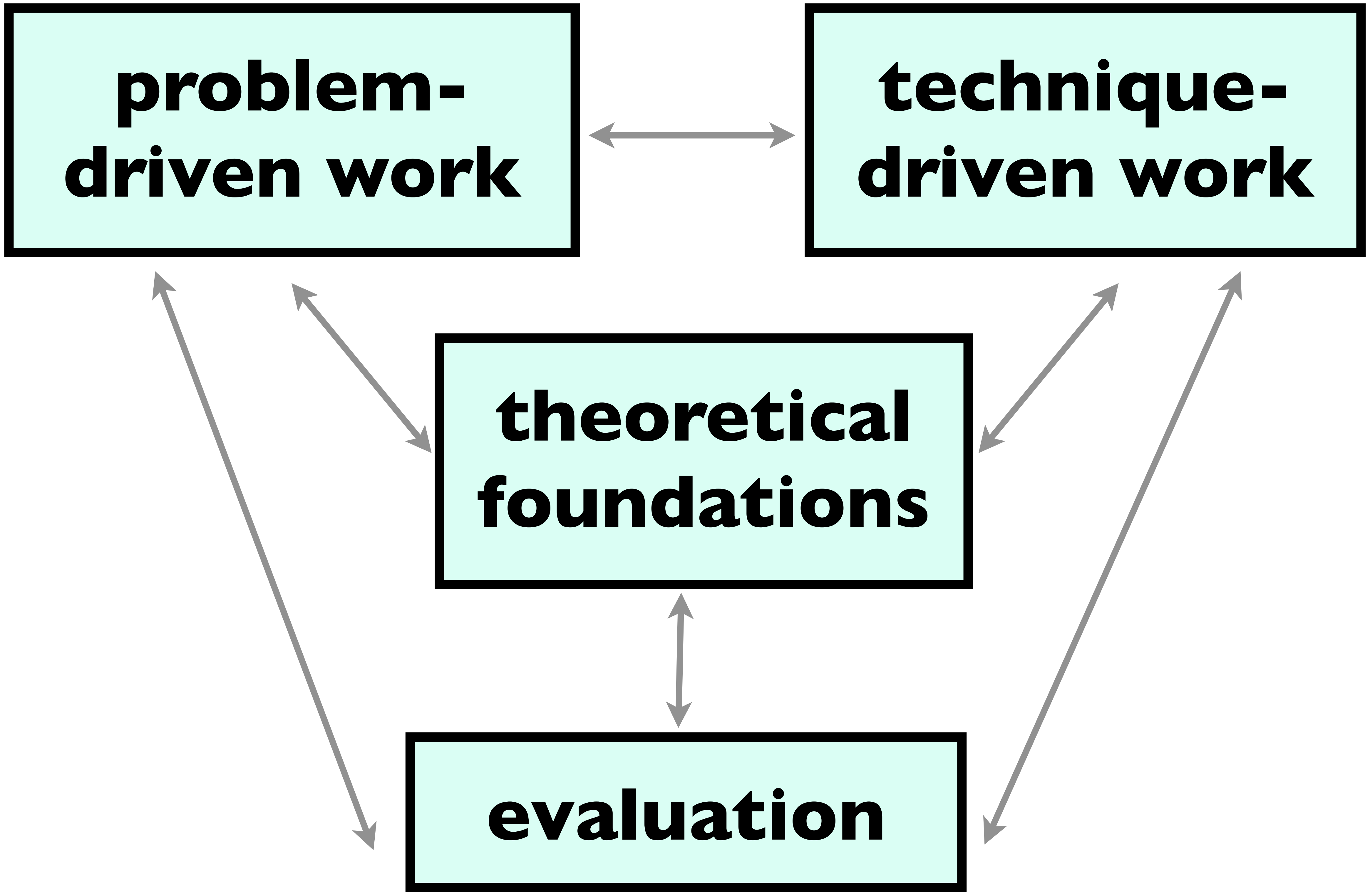

Three case studies: Abstractions & idioms

- e-commerce

- facilities management

- biology

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- e-commerce

- facilities management

- biology

e commerce by shashank singh from the Noun Project   Biology by tezar tantular from the Noun Project   Business by Colourcreatype from the Noun Project

Kim Dextras-Romagnino

Segmentifier

Interactive Refinement of Clickstream Data

http://www.cs.ubc.ca/labs/imager/tr/2019/segmentifier

Segmentifier: Interactive Refinement of Clickstream Data.
Dextras-Romagnino and Munzner. Computer Graphics Forum (Proc. EuroVis 2019) 38(3):623–634 2019

E-commerce: mobile apps for large companies

What are the **Data and Task Abstractions** for *Clickstream Data Analysis?*

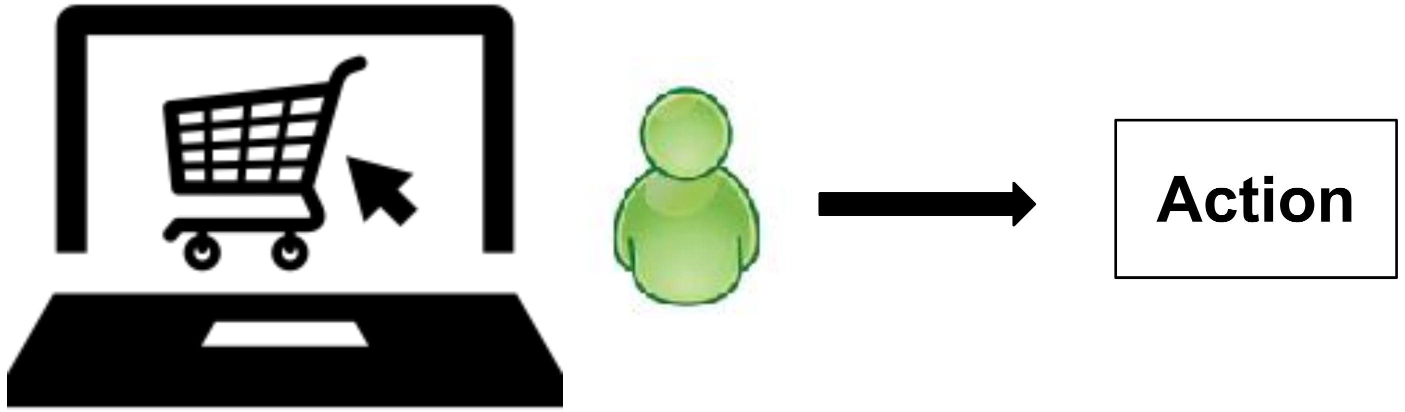
Clickstream Data

Clickstream Analysis Tasks

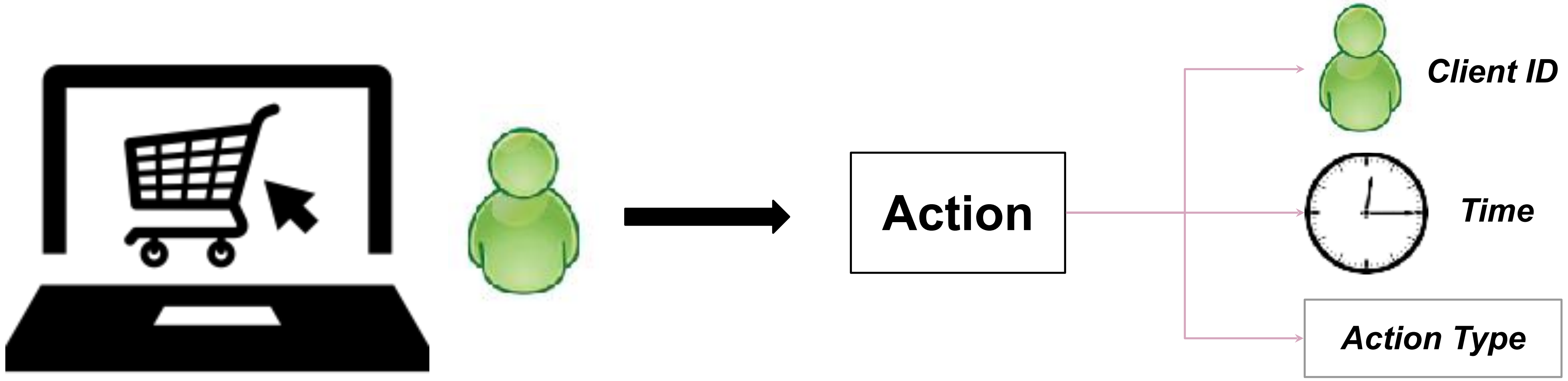
Segmentifier Analysis Model

What is ***Clickstream Data***?

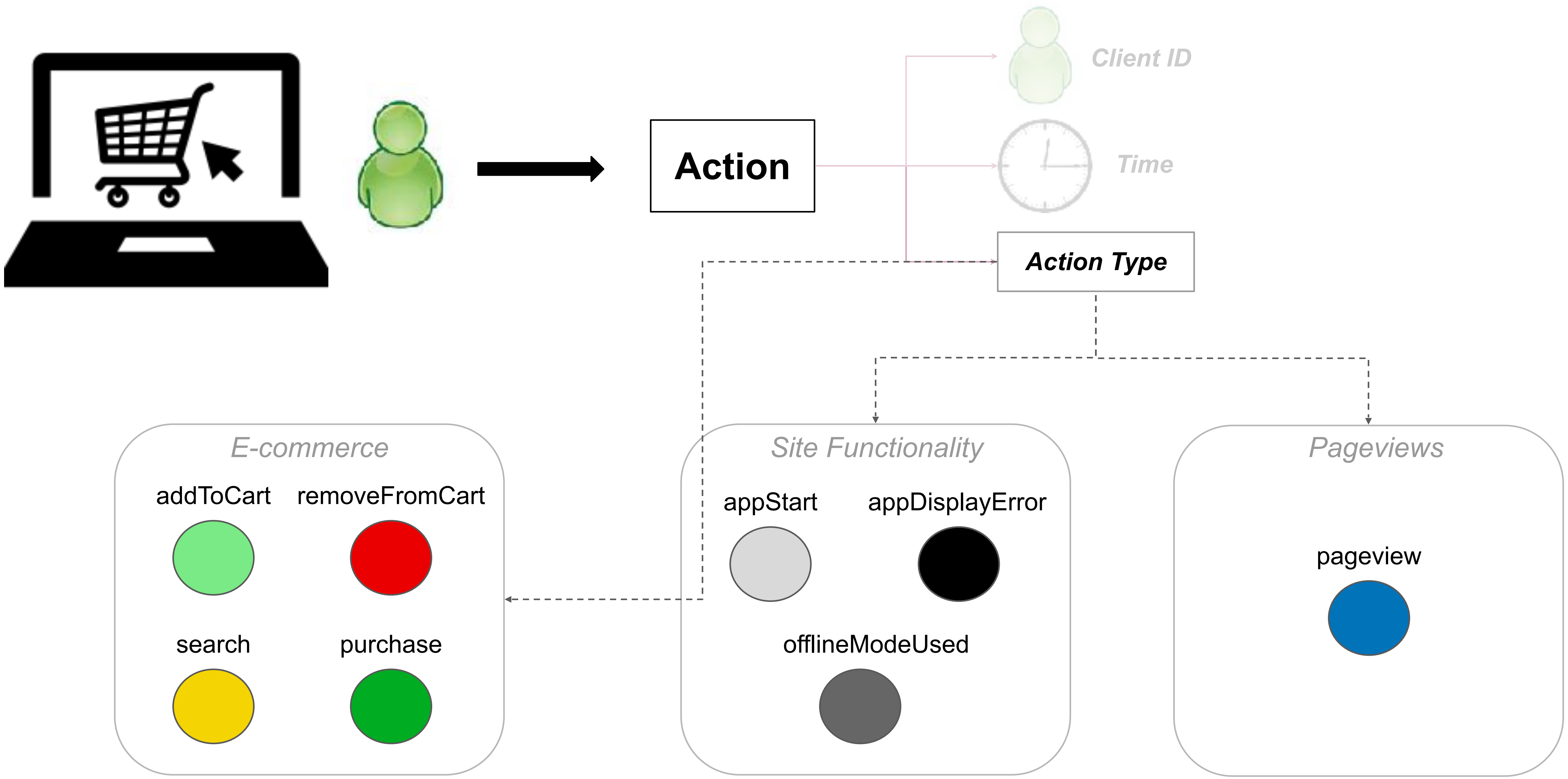
Data: *Actions*



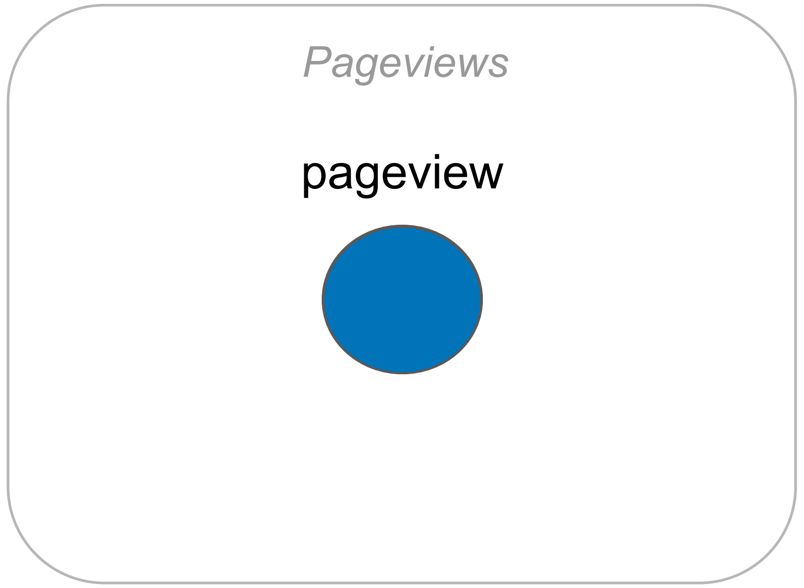
Data: *Action Attributes*



Data: *Action Types*



Action Hierarchy



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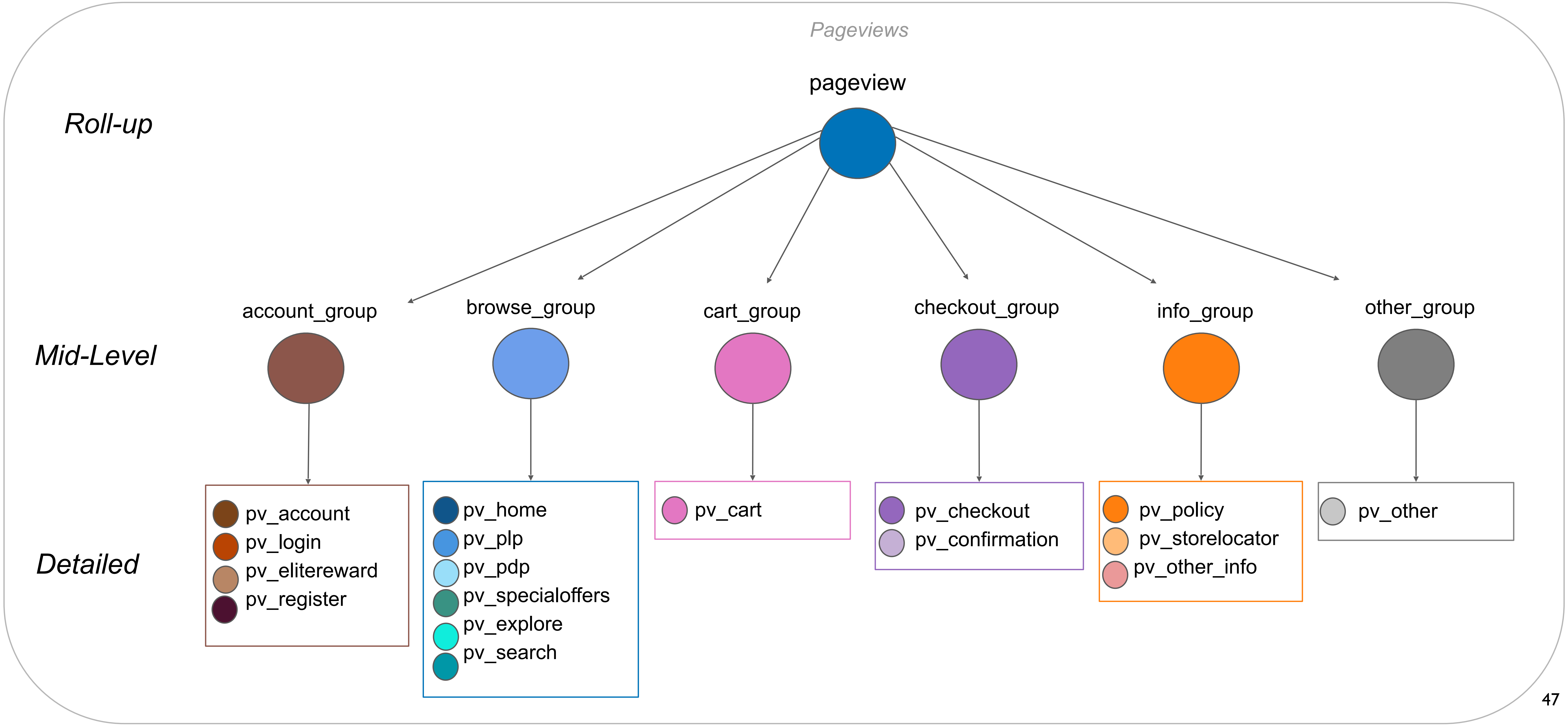
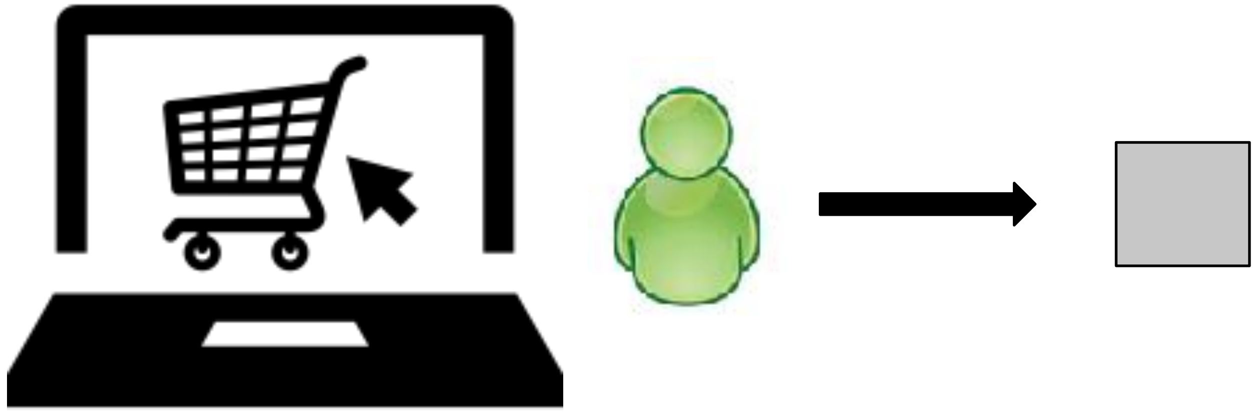
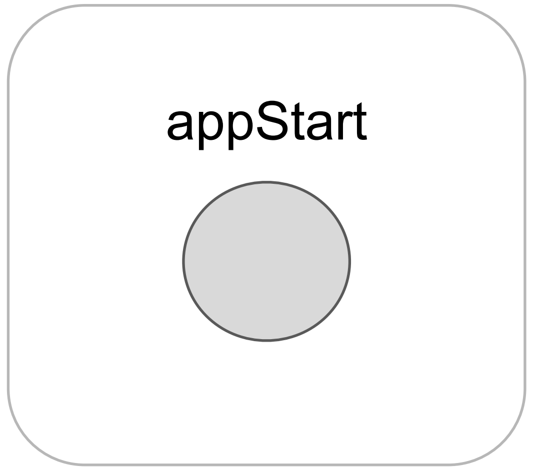


Data: *Sequences*





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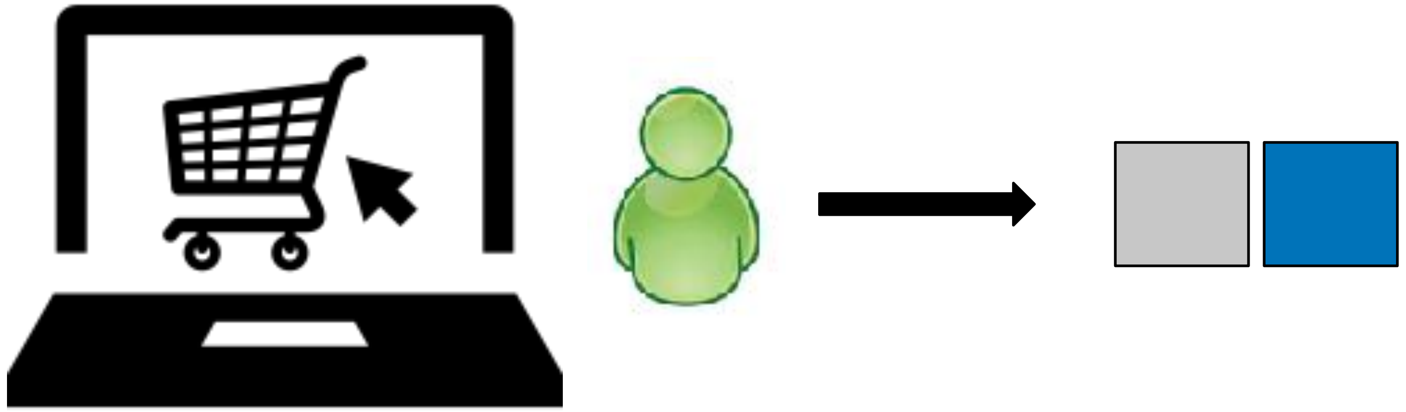
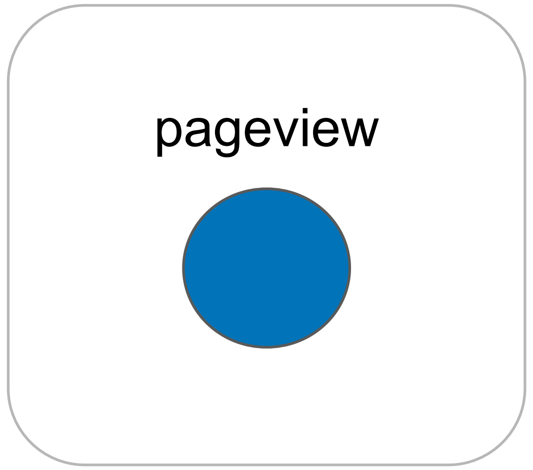
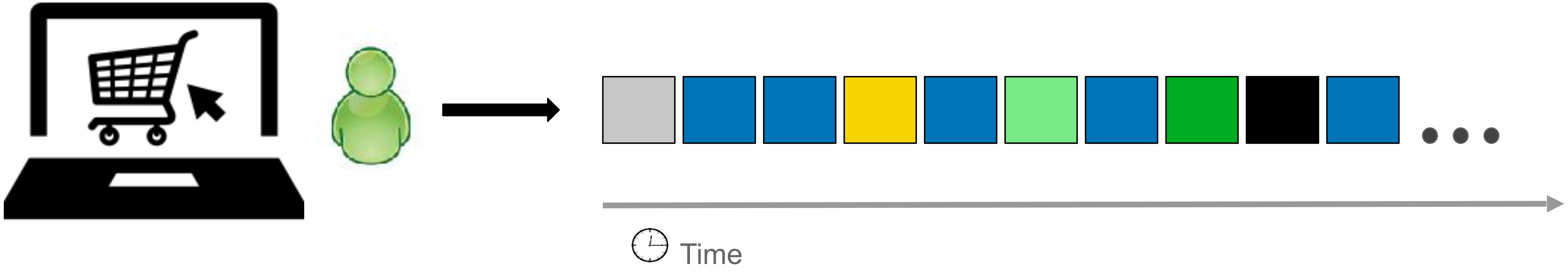


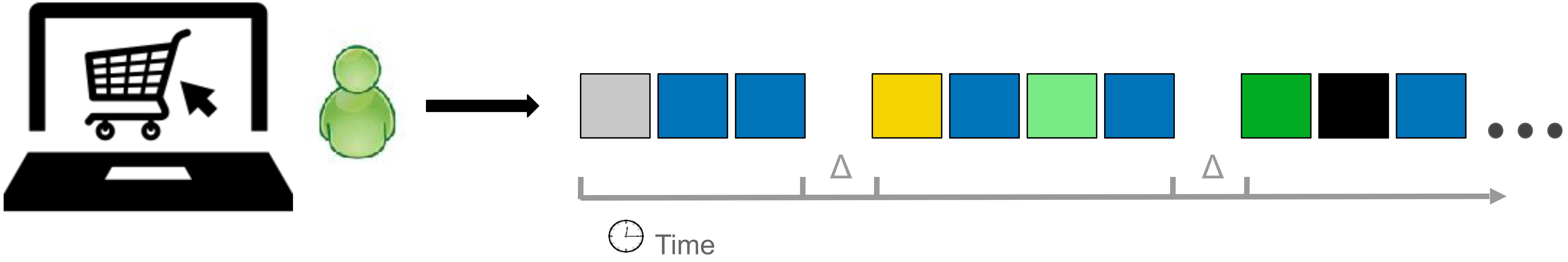


Data: *Client Sequences*



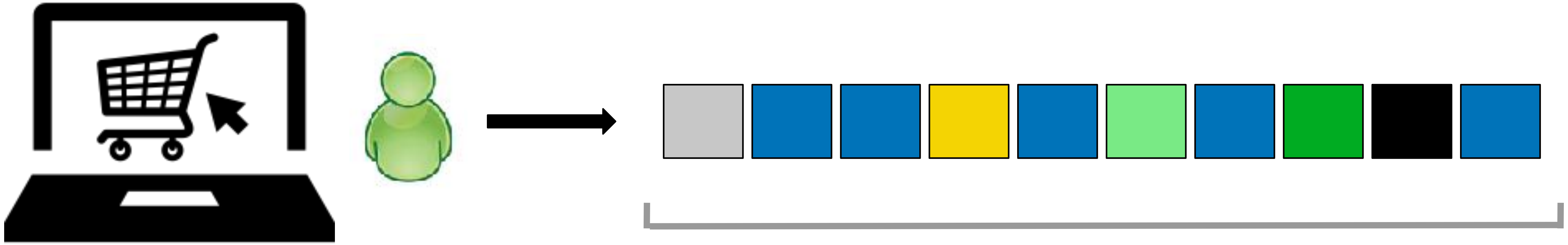
Client Sequences: all actions performed by a single user

Data: *Session Sequences*

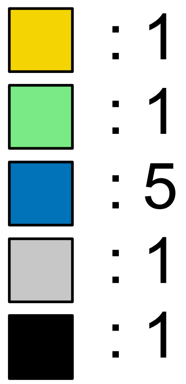


Session Sequences: all actions performed by a single user within a defined amount of time (Δ) from each other.
Δ is usually 30 min.

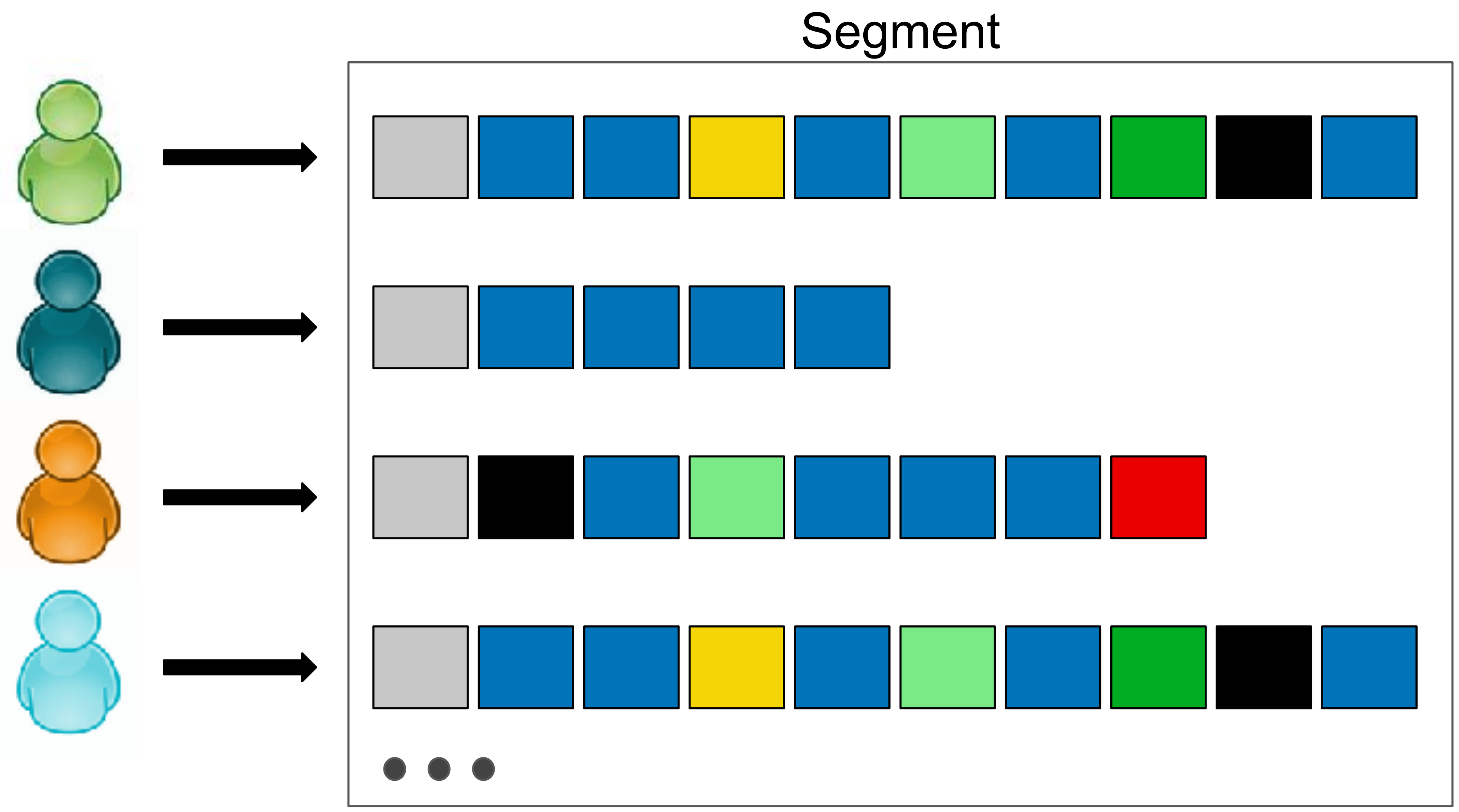
Data: *Sequence Attributes*



Start time | End time | Duration | Action Counts

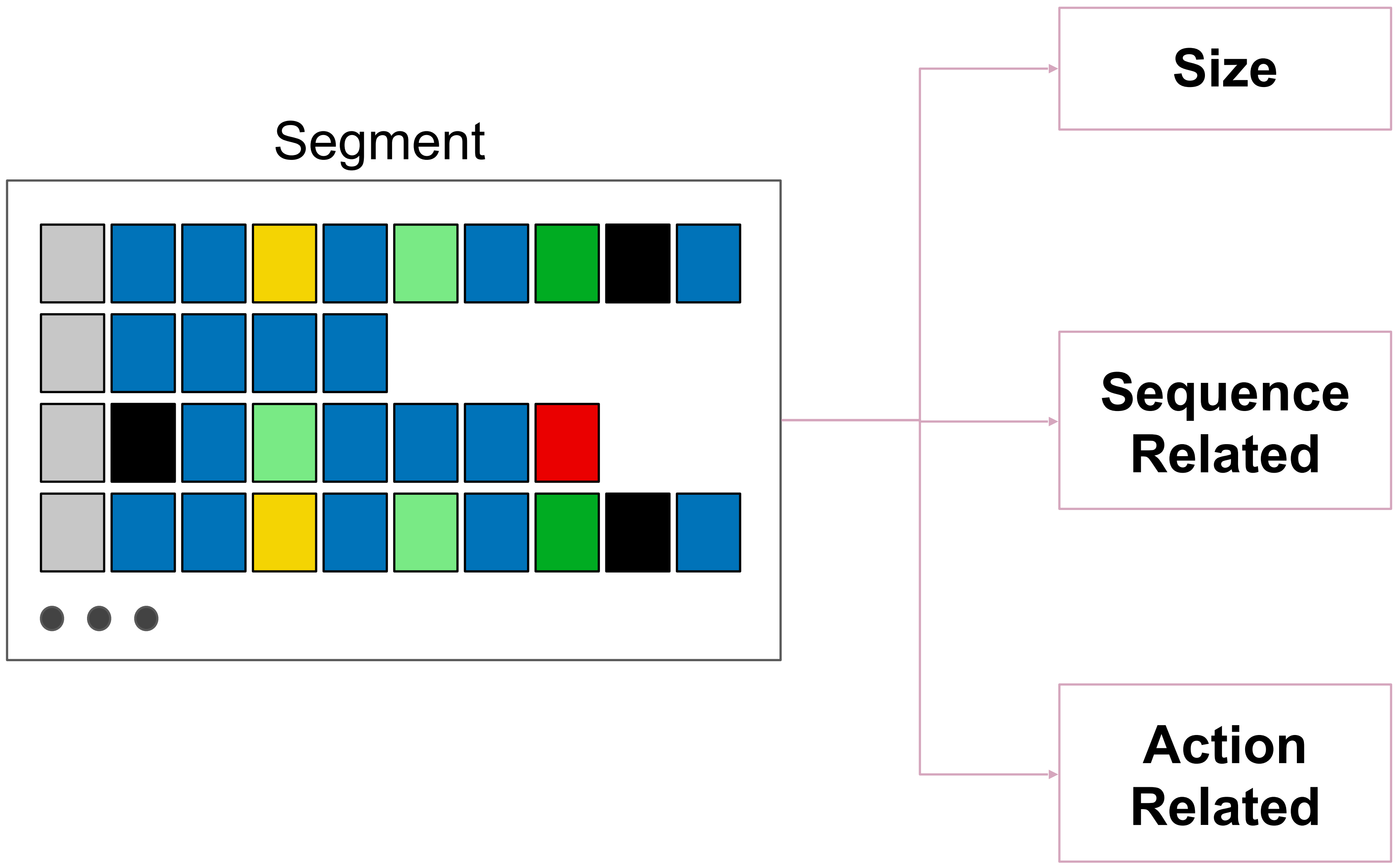


Data: *Segments*



Segment: any set of sequences

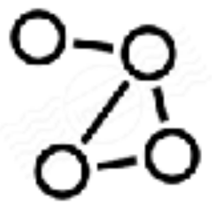
Data: *Segment Attributes*



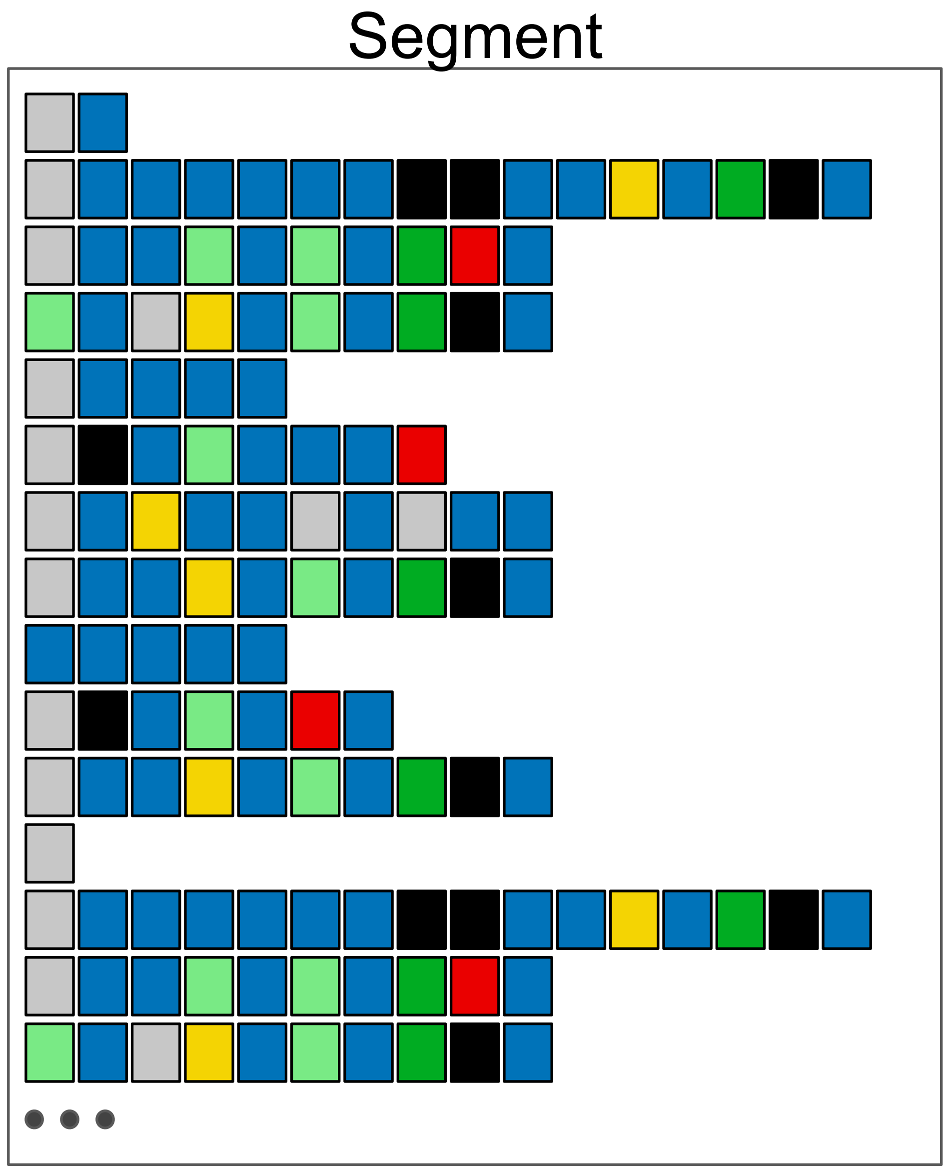
Counts of sequences:
Absolute, Relative

Sequence Distributions:
Start Time, Duration, Action Counts

Action Distributions:
Action Transitions:
action before, action after



Real-world Clickstream Data



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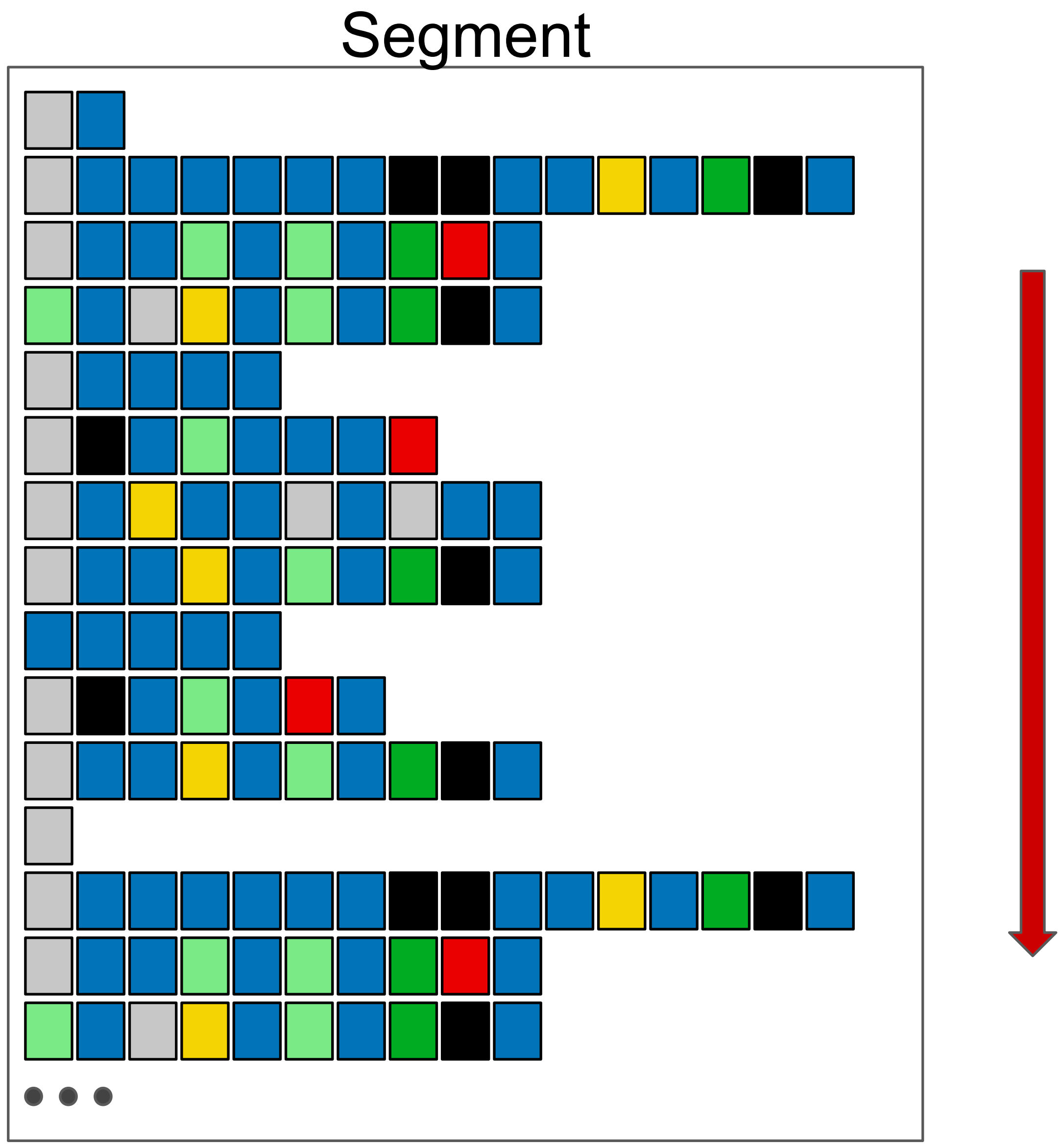

Scale is huge

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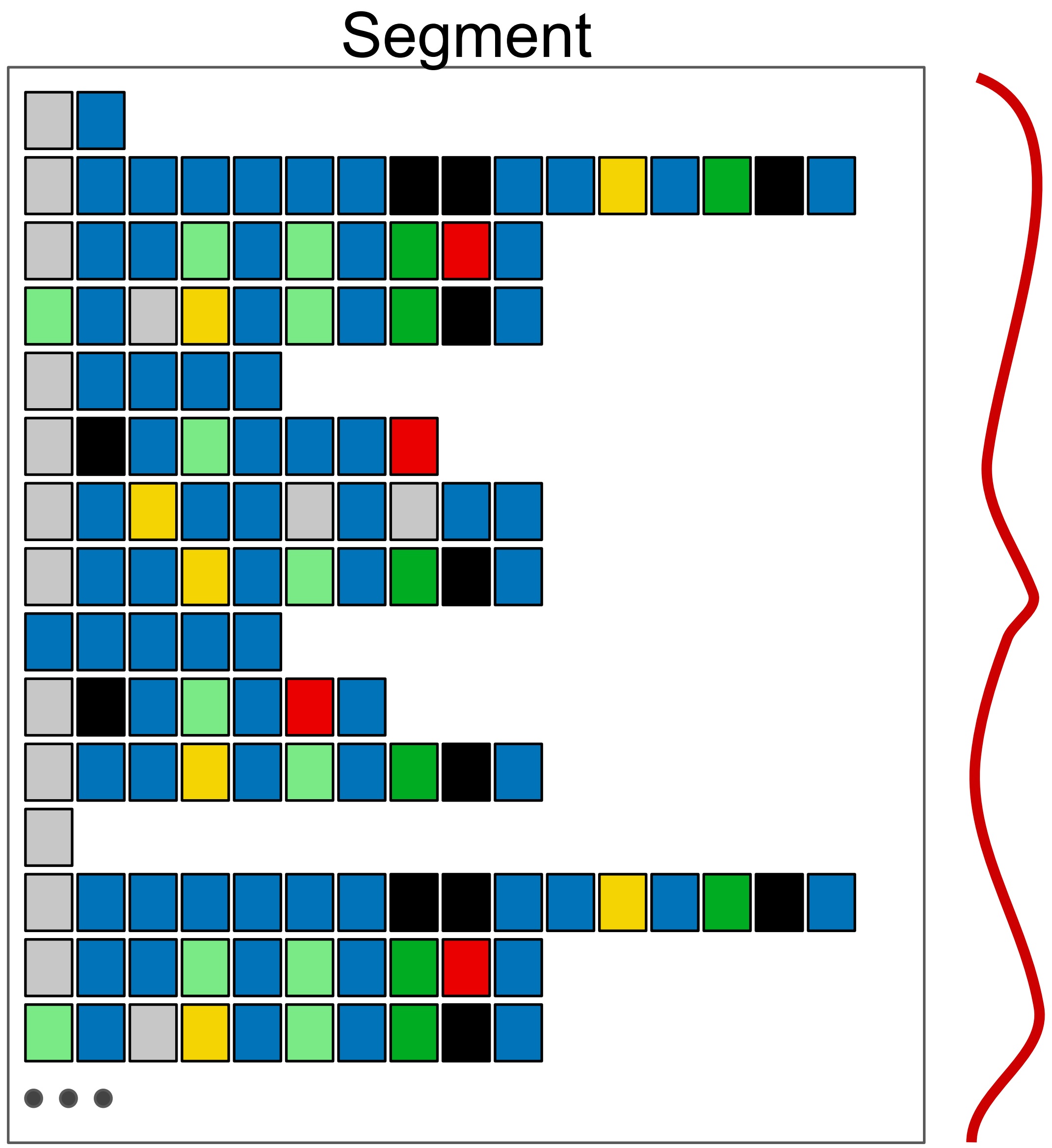

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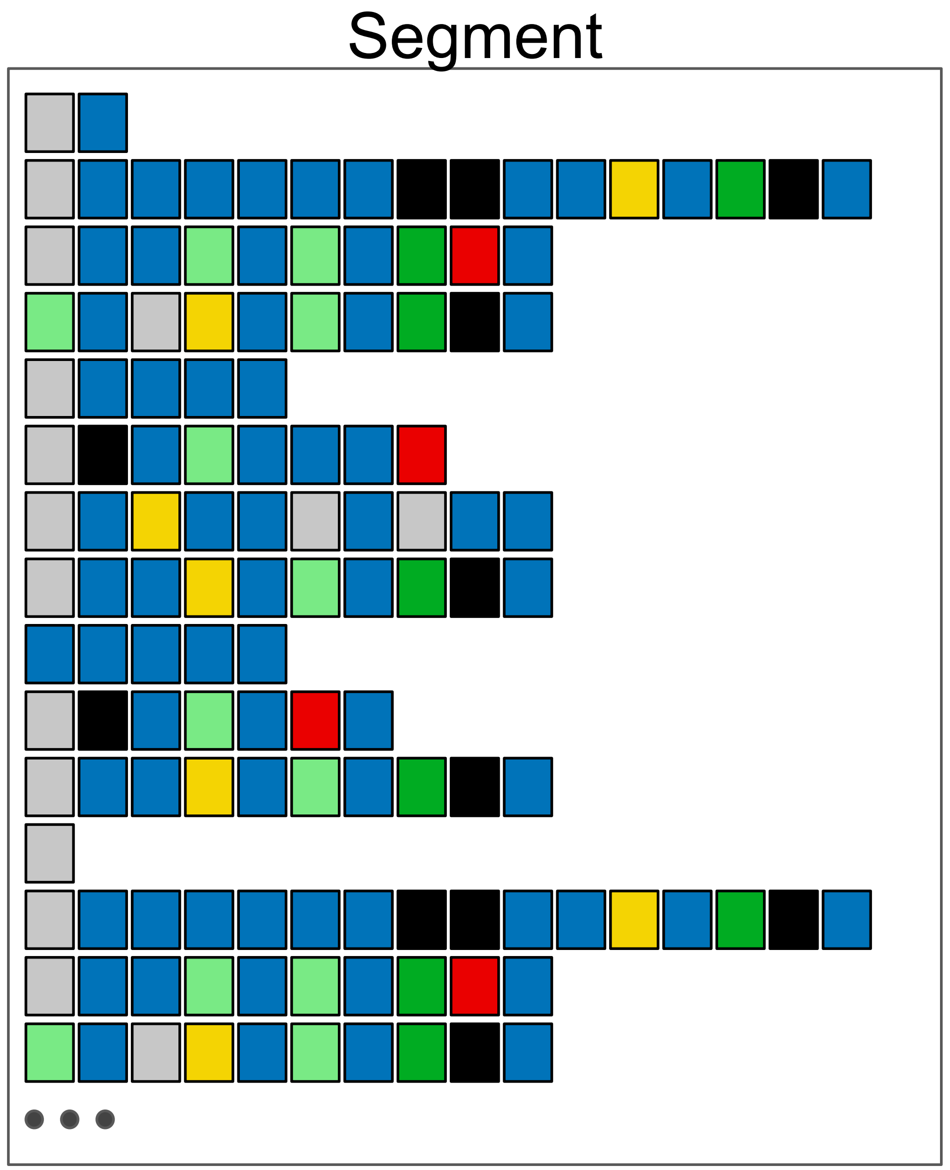


Scale is huge

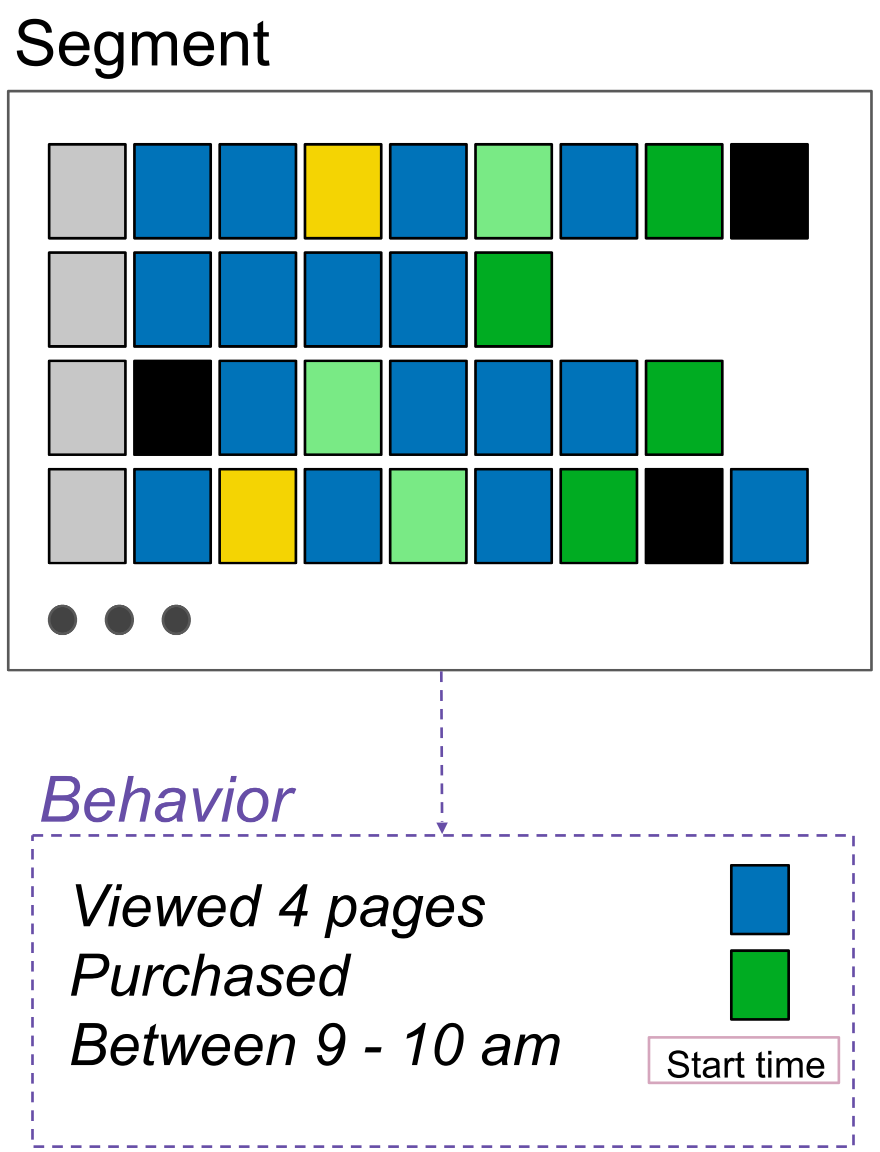
Variability is high

Most work **fails** when applied to real-world data

What are

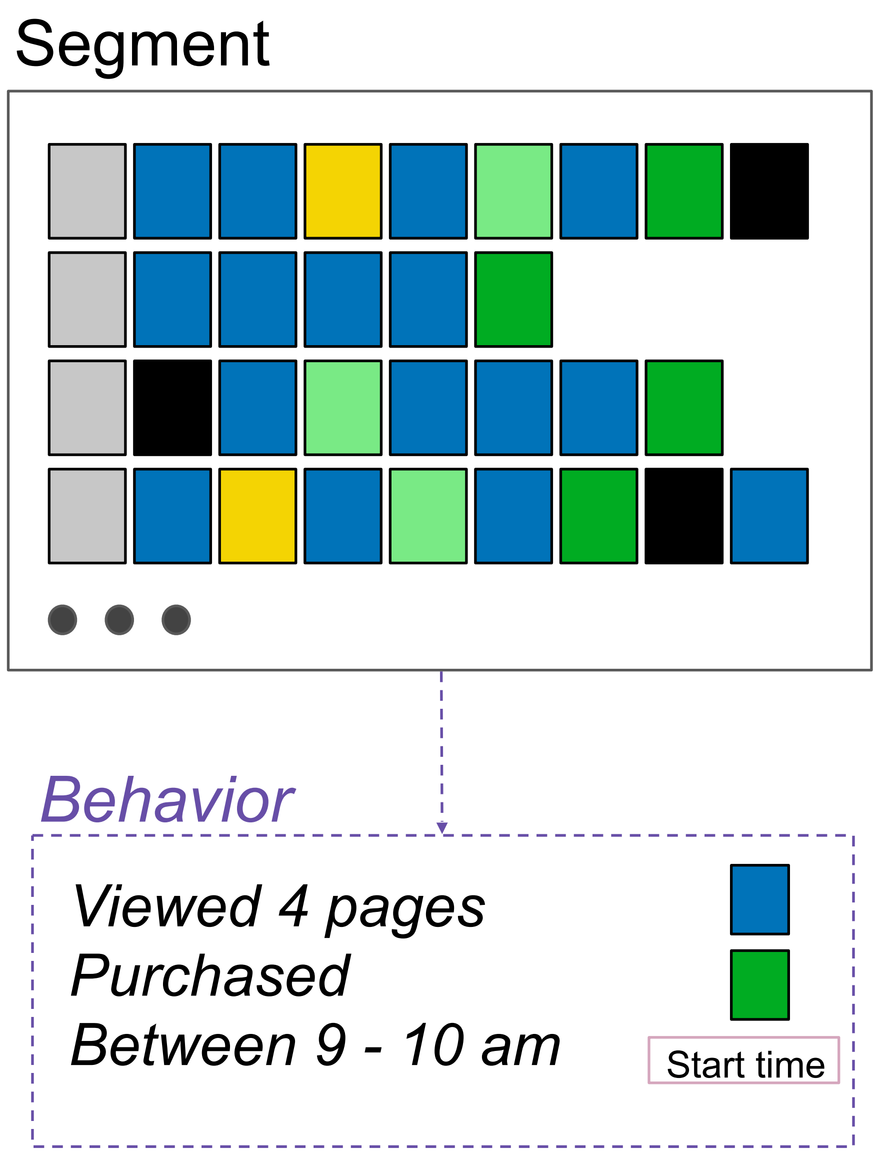
Clickstream Data Analysis Tasks?

Tasks: Segment Behavior



Behavior: set of attribute constraints

Tasks: Segment Behavior

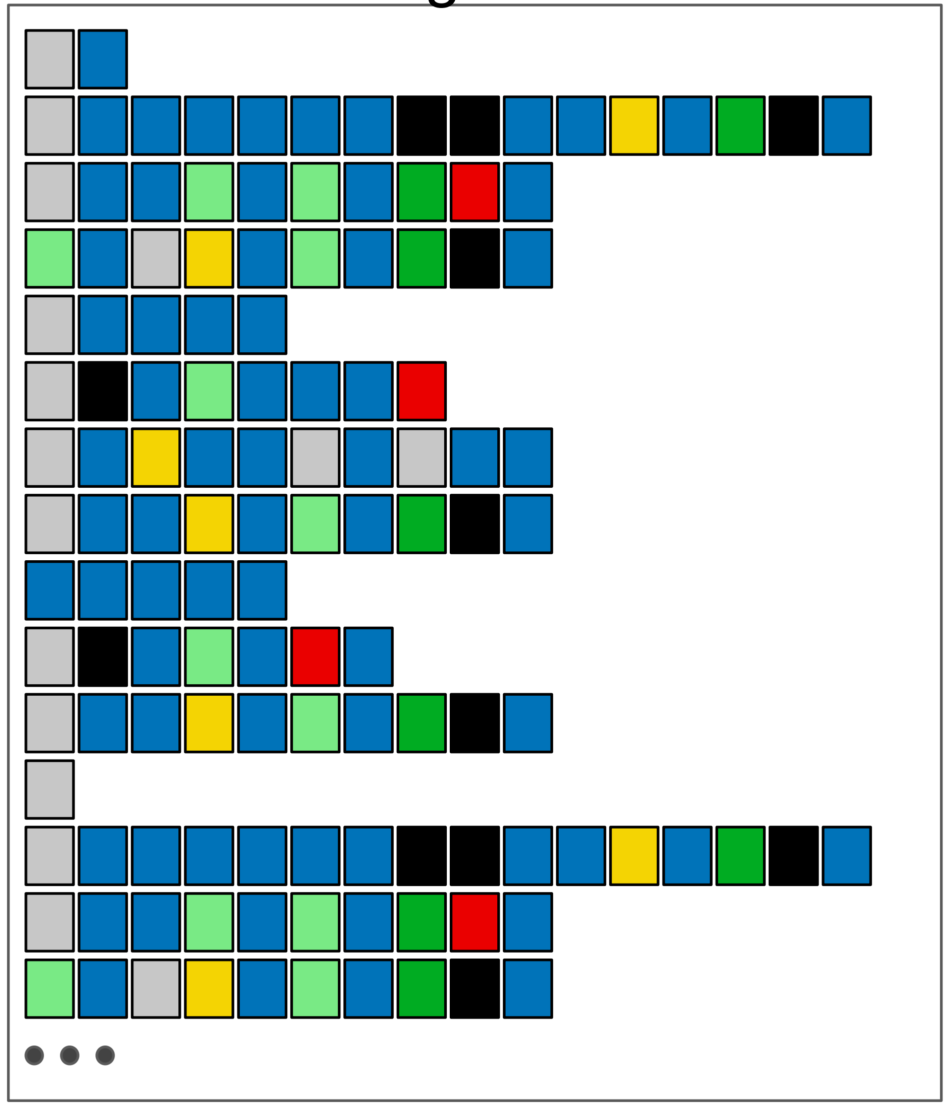


Behavior: set of attribute constraints

- **Expected**
  Users add to cart before purchasing
- **Unexpected**
  No purchases on a certain month
- **Favorable**
  Purchased
- **Unfavorable**
  Bounced

Tasks: Task Abstraction

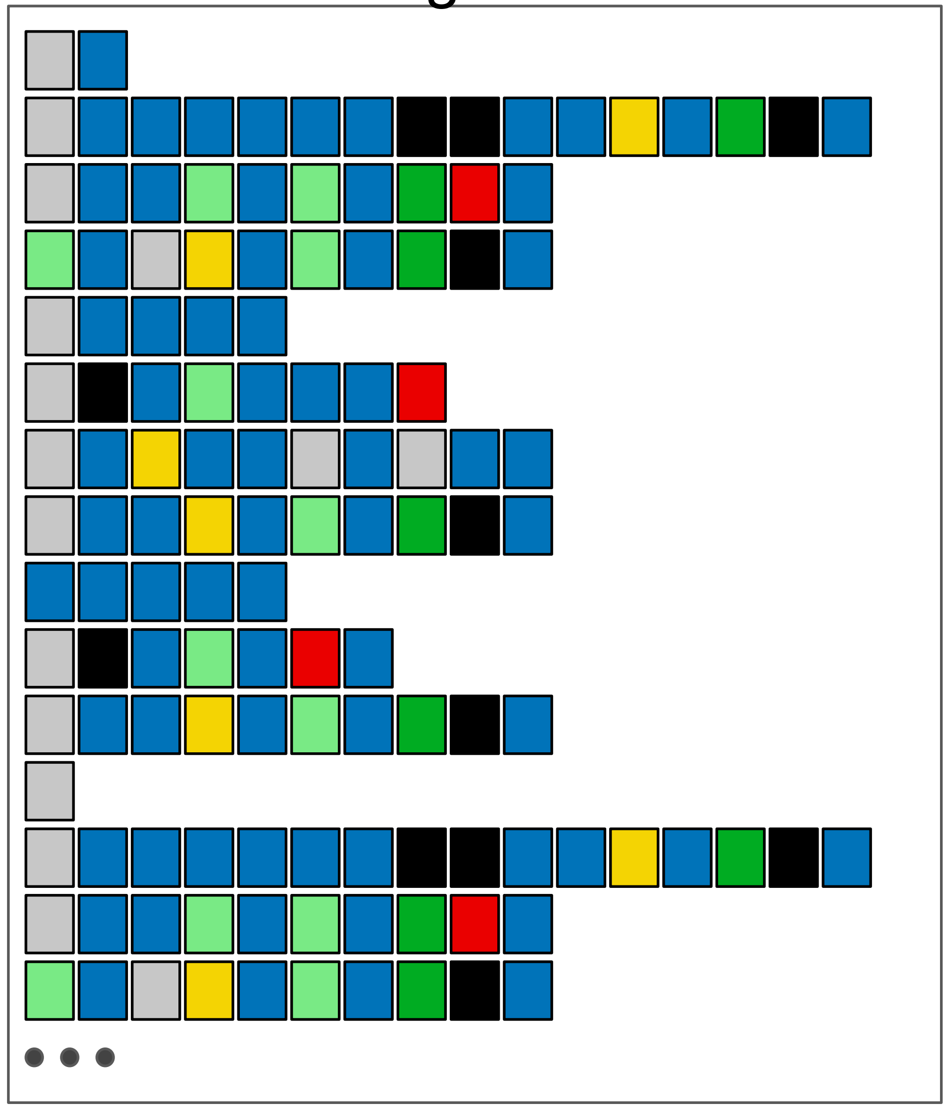
Segment



Identify: Find some set of sequences that constitutes interesting *behavior*

Tasks: Task Abstraction

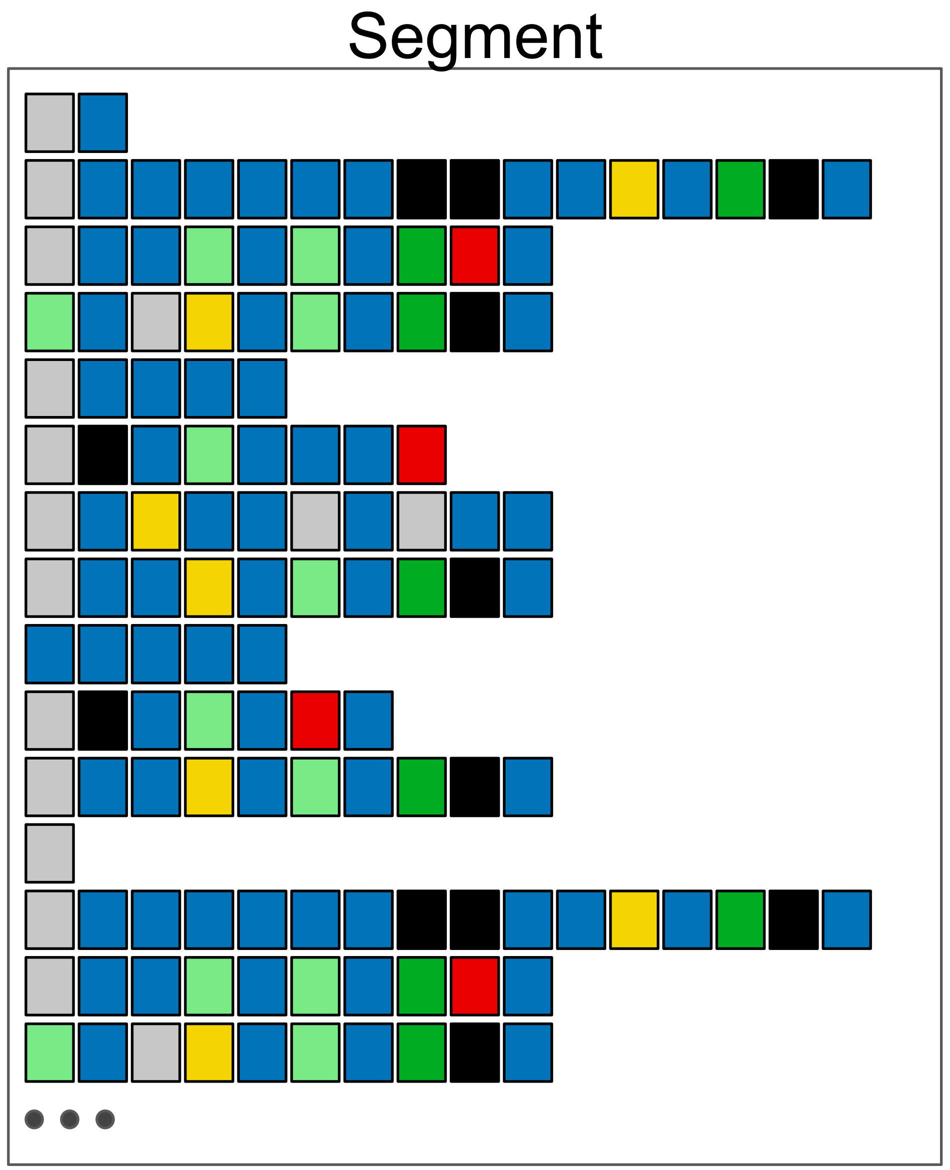
Segment



Identify: Find some set of sequences that constitutes interesting *behavior*

Drilldown: Distinguish more specific *behaviors* to further partition a segment previously defined by looser constraints

Tasks: Task Abstraction



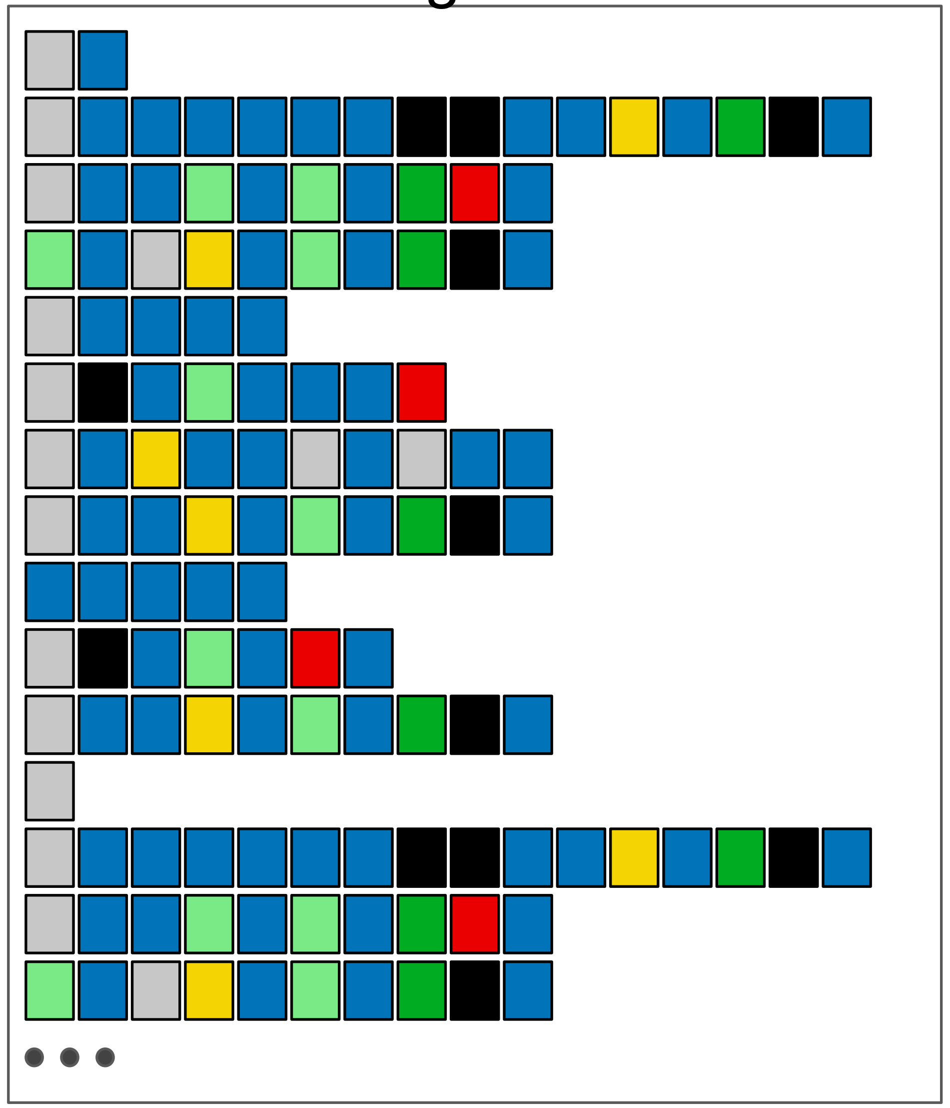
Identify: Find some set of sequences that constitutes interesting *behavior*

Drilldown: Distinguish more specific *behaviors* to further partition a segment previously defined by looser constraints

Frequency: Determine how many sequences are in the segment defined by *behavior*

Tasks: Task Abstraction

Segment



Identify: Find some set of sequences that constitutes interesting *behavior*

Drilldown: Distinguish more specific *behaviors* to further partition a segment previously defined by looser constraints

Frequency: Determine how many sequences are in the segment defined by *behavior*

Ordering within sequence: Match if one action subsequence occurs before (or after) another action subsequence in a sequence

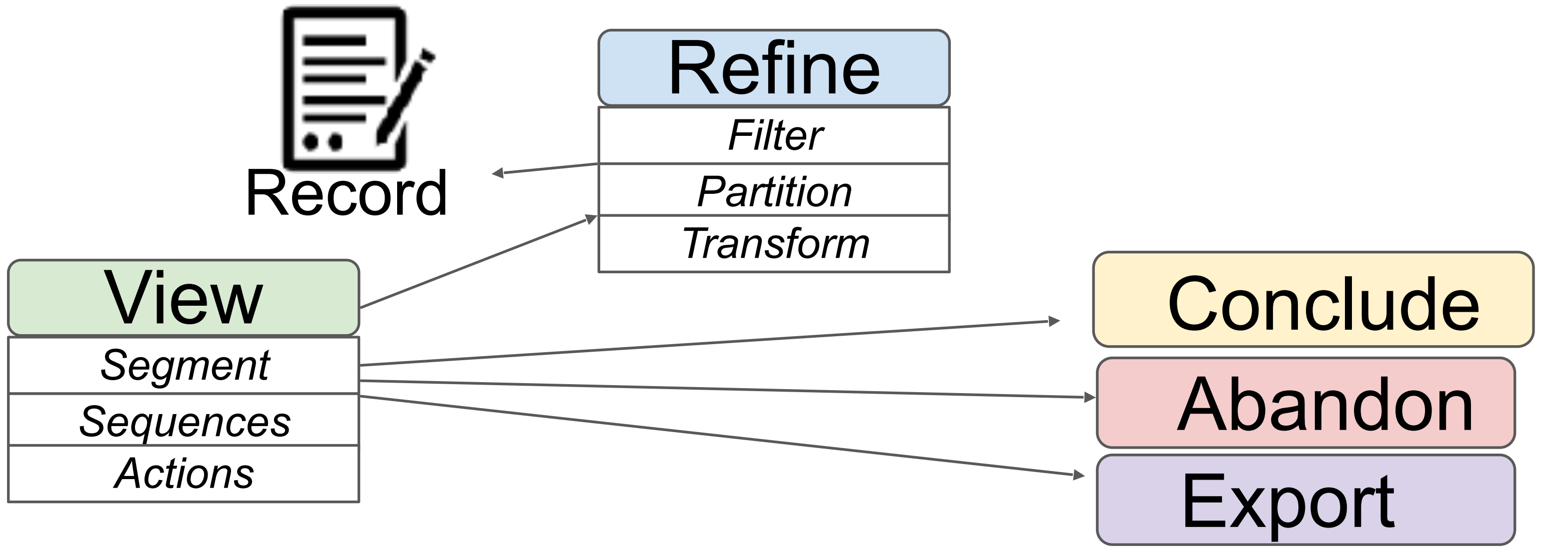
High-Level Segmentifier Analysis Model

High-Level Segmentifier Analysis Model

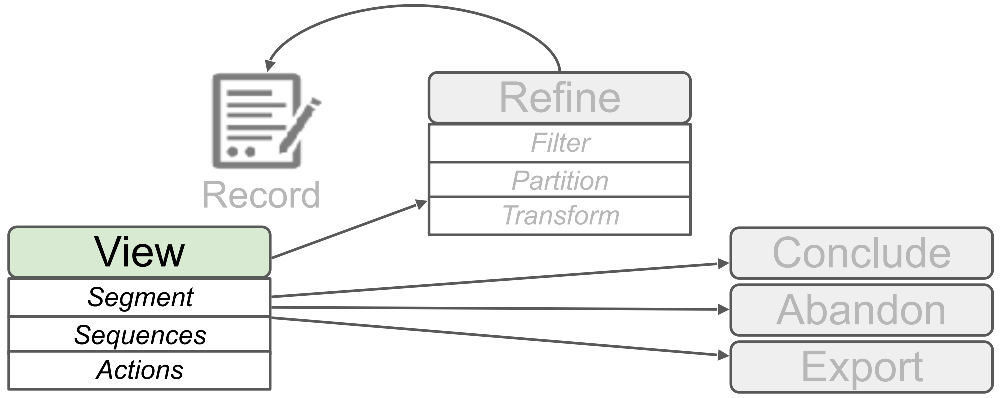
- Abstraction above task/data level to provide design rationale

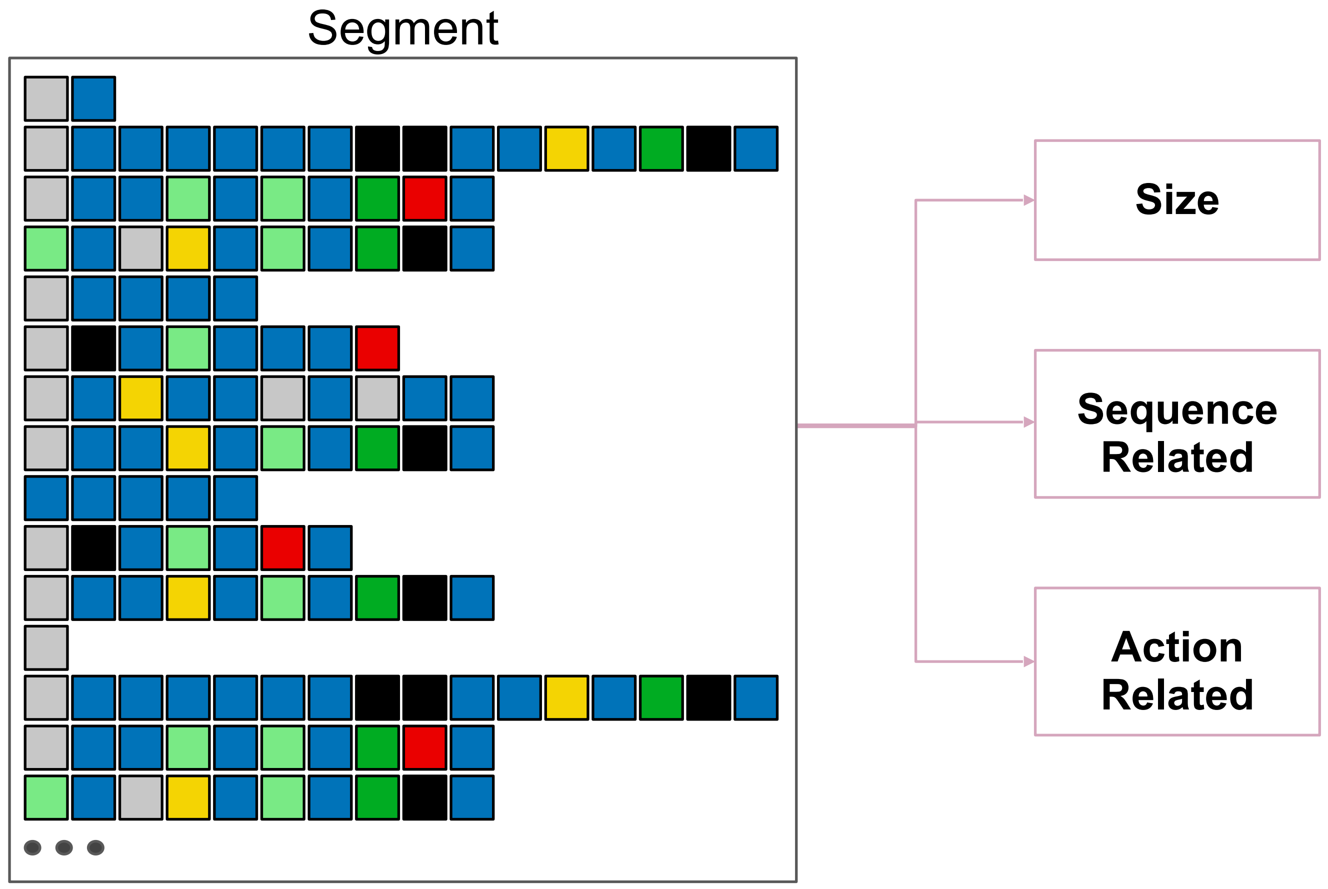
- Take a *giant, noisy dataset* and refine it into *small, clean segments* for
  - actionable insights
  - downstream analysis

- Bridge the gap between *real-world data* and other techniques



High-Level Segmentifier Analysis Model

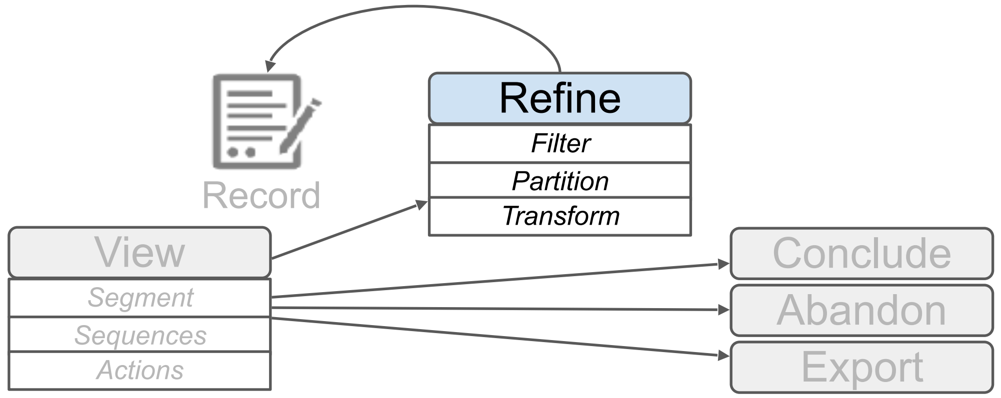


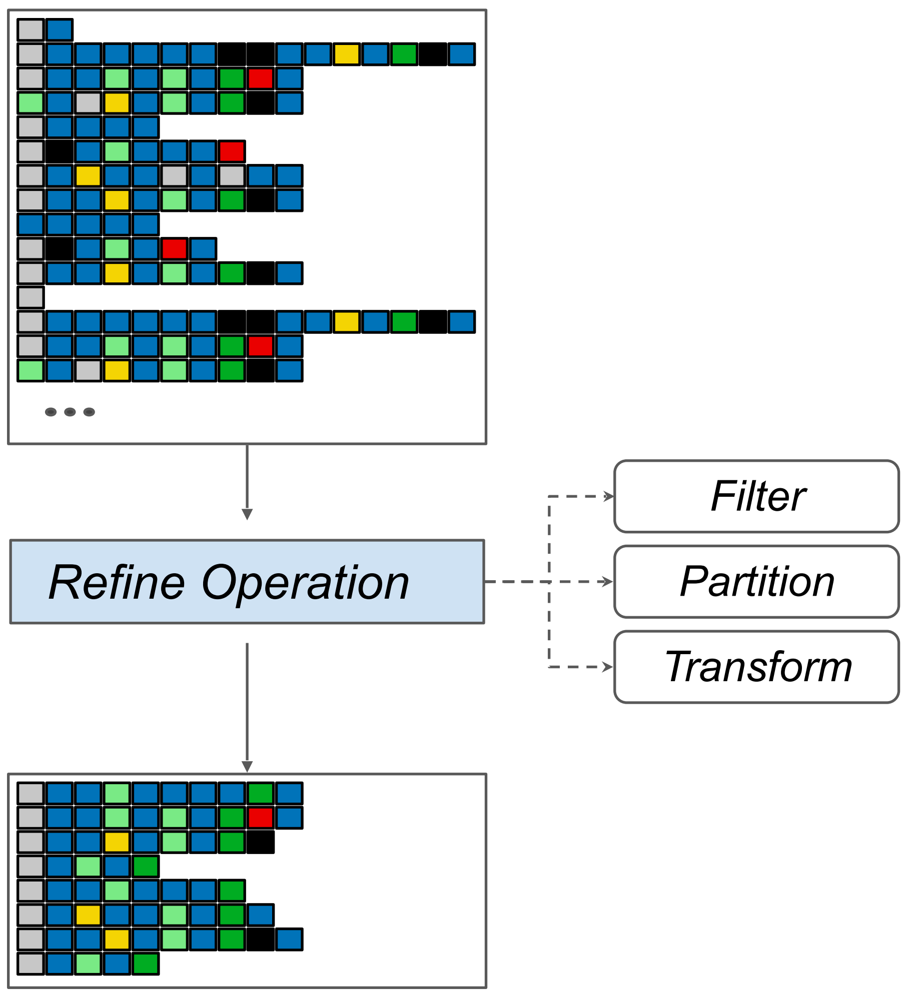


View

- Gives Insight into underlying data of segment
  - Action Attributes
  - Sequence Attributes
  - Segment Attributes
- Leads to:
  - Insights
  - New ways on how to *refine*
  - Whether segment should be *abandoned*
  - Whether segment should be *exported*

High-Level Segmentifier Analysis Model

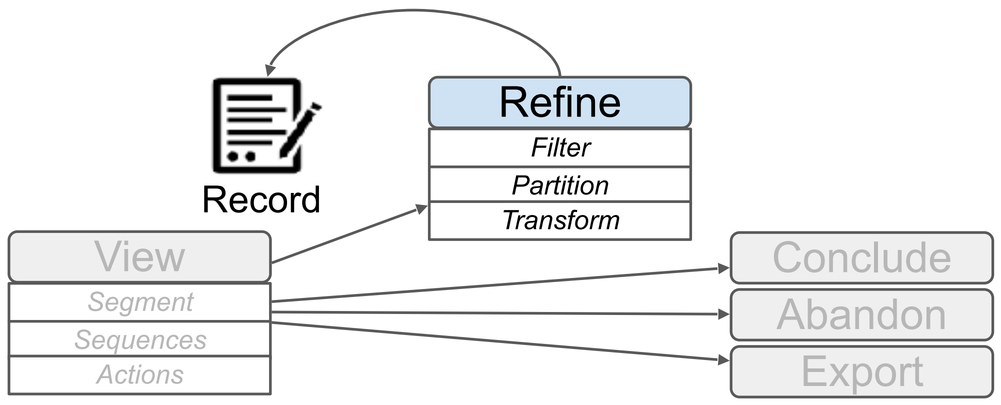


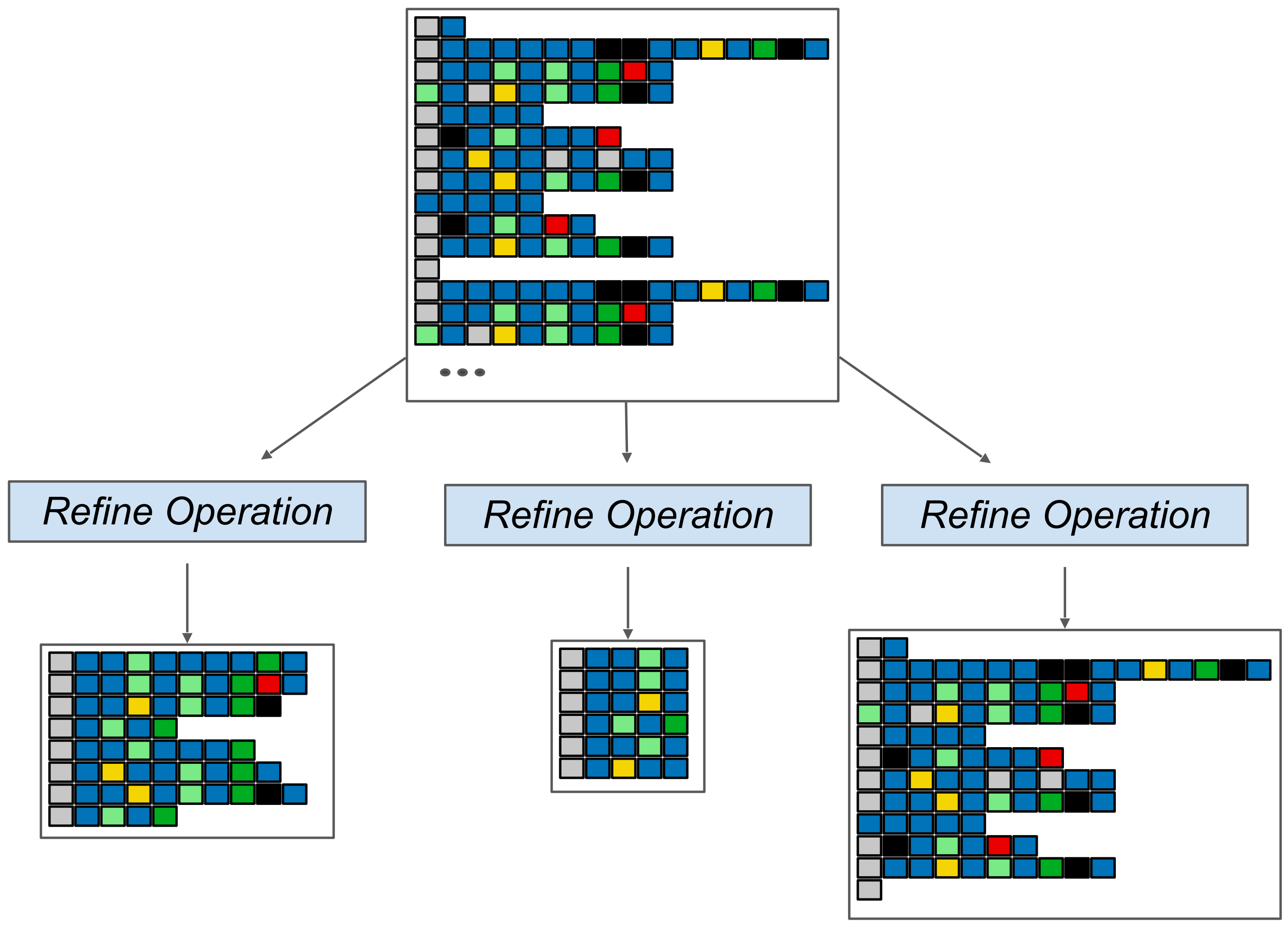


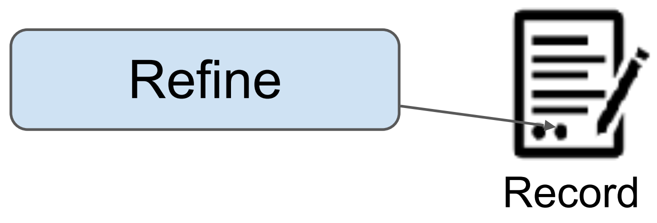
Refine

- Apply operation to create new segments
- Type of Refinements
  - *Filter*
  - *Partition*
  - *Transform*

High-Level Segmentifier Analysis Model

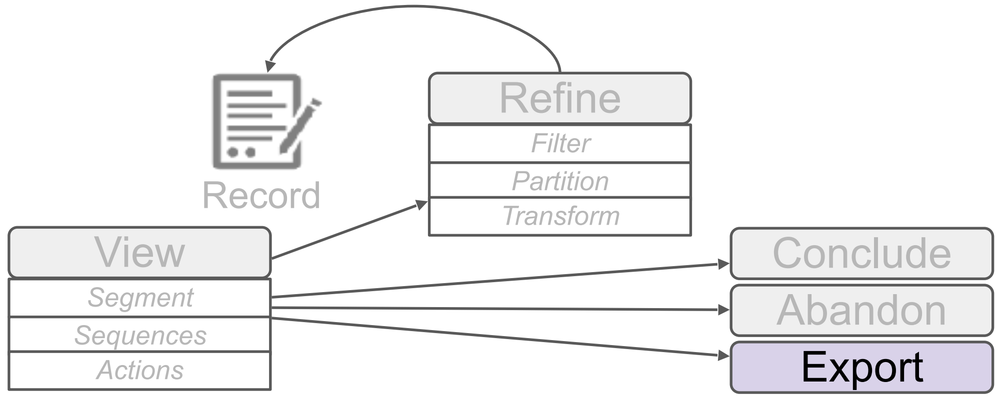


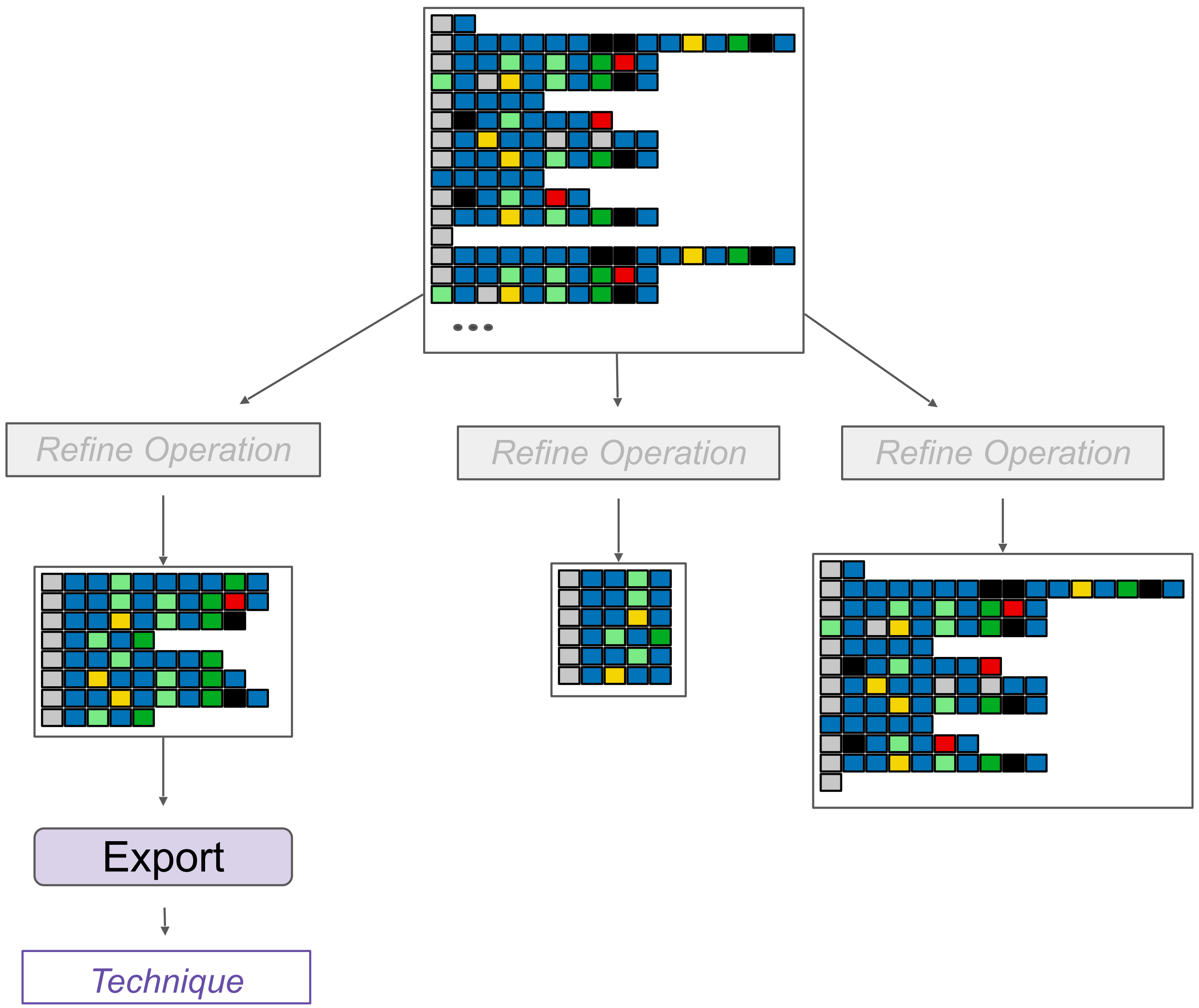




- Record all refinement steps automatically
- Keep track of questions asked and hypotheses tested
- Ability to create and view multiple segments from the same segment

High-Level Segmentifier Analysis Model

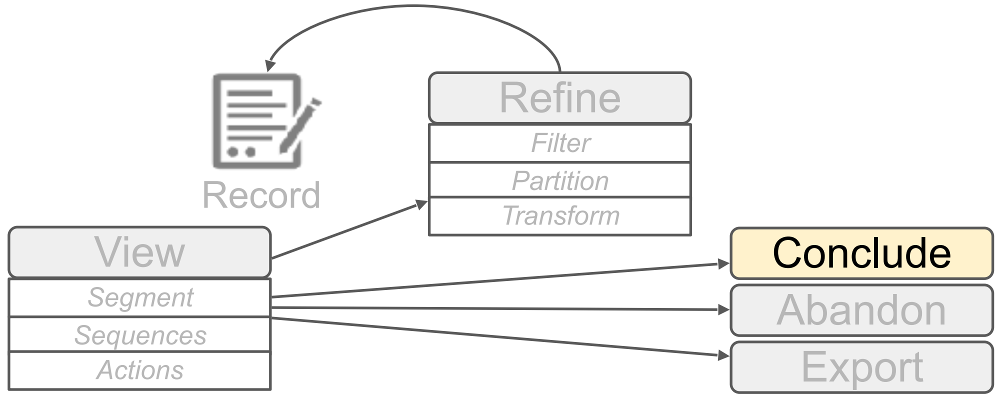


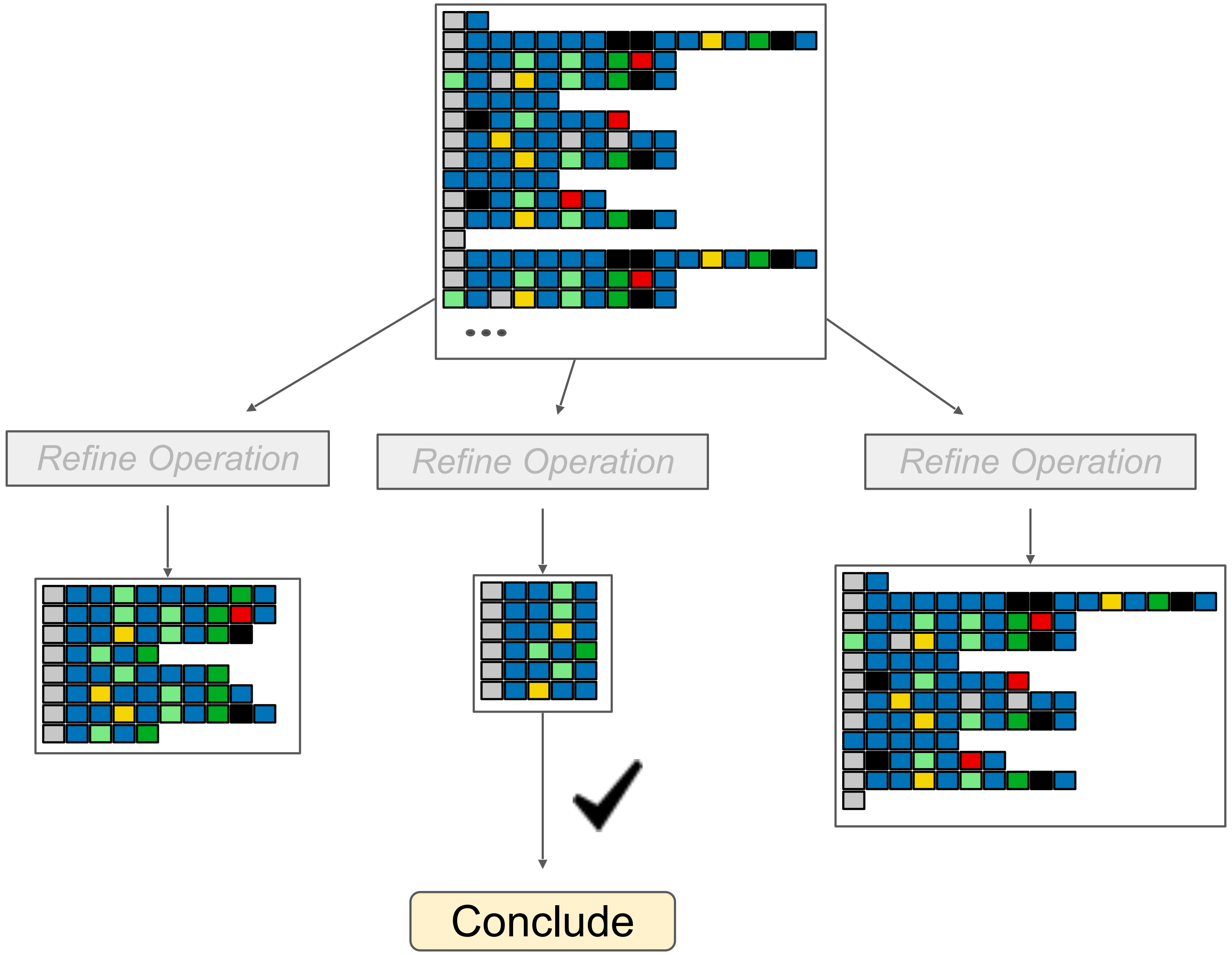


Export

- Export refined segments for further downstream analysis, to more specific tools:
  - Pattern mining
  - Clustering

High-Level Segmentifier Analysis Model

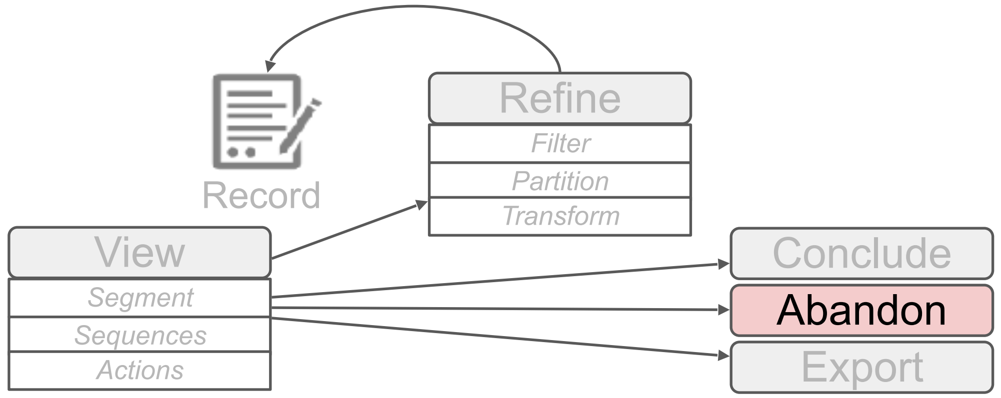


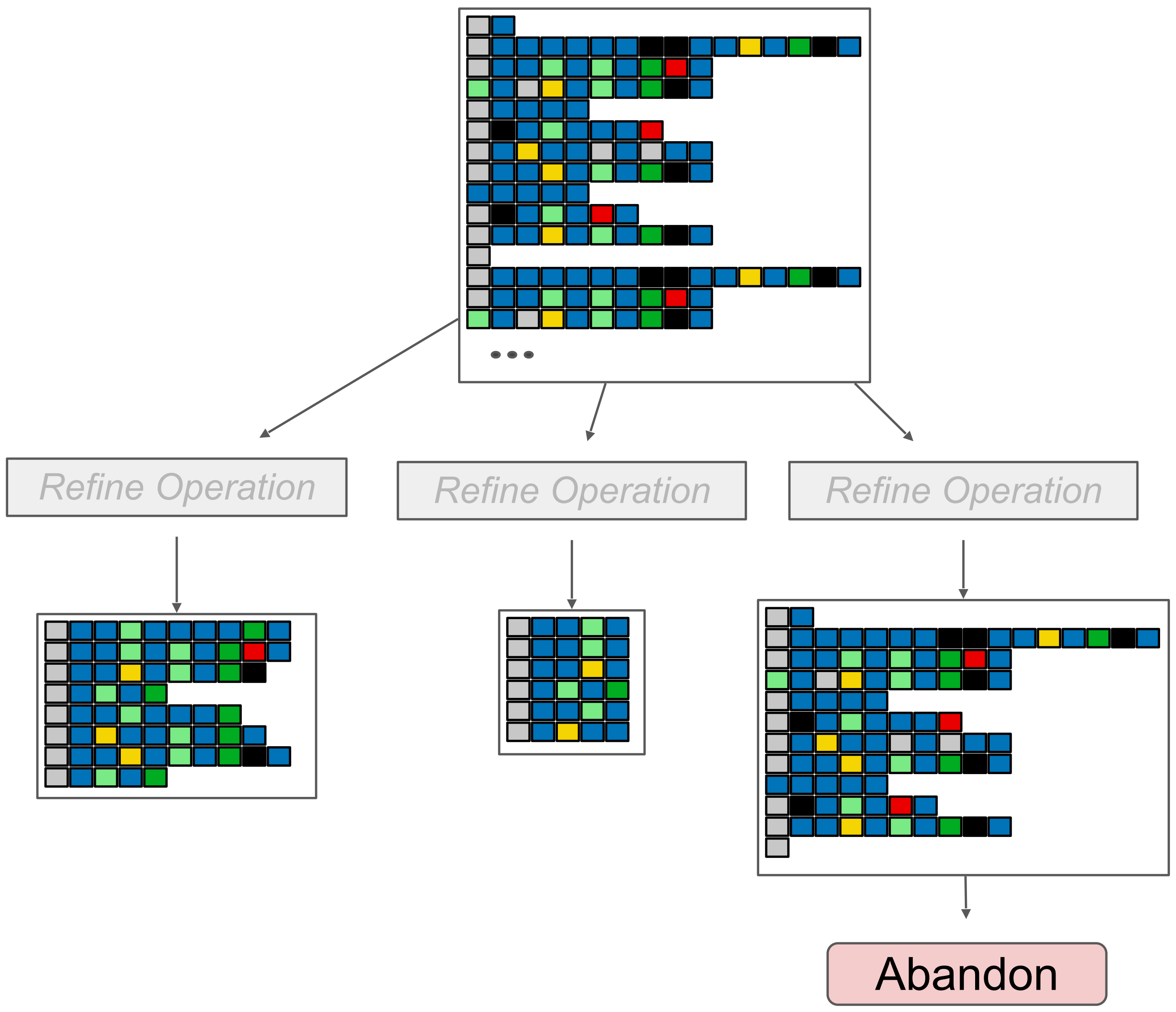


Conclude

- Discover actionable insight by *viewing* segment

High-Level Segmentifier Analysis Model

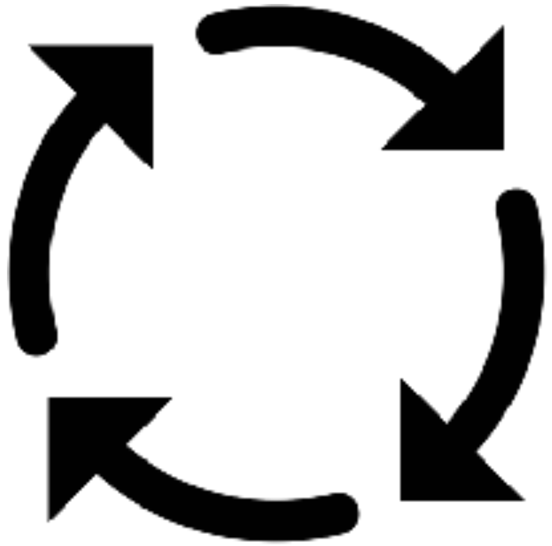




Abandon

- By *viewing* the segment, analyst *abandons* if:
  - No actionable insights
  - No further ways to *refine*
  - Not suitable for *export*

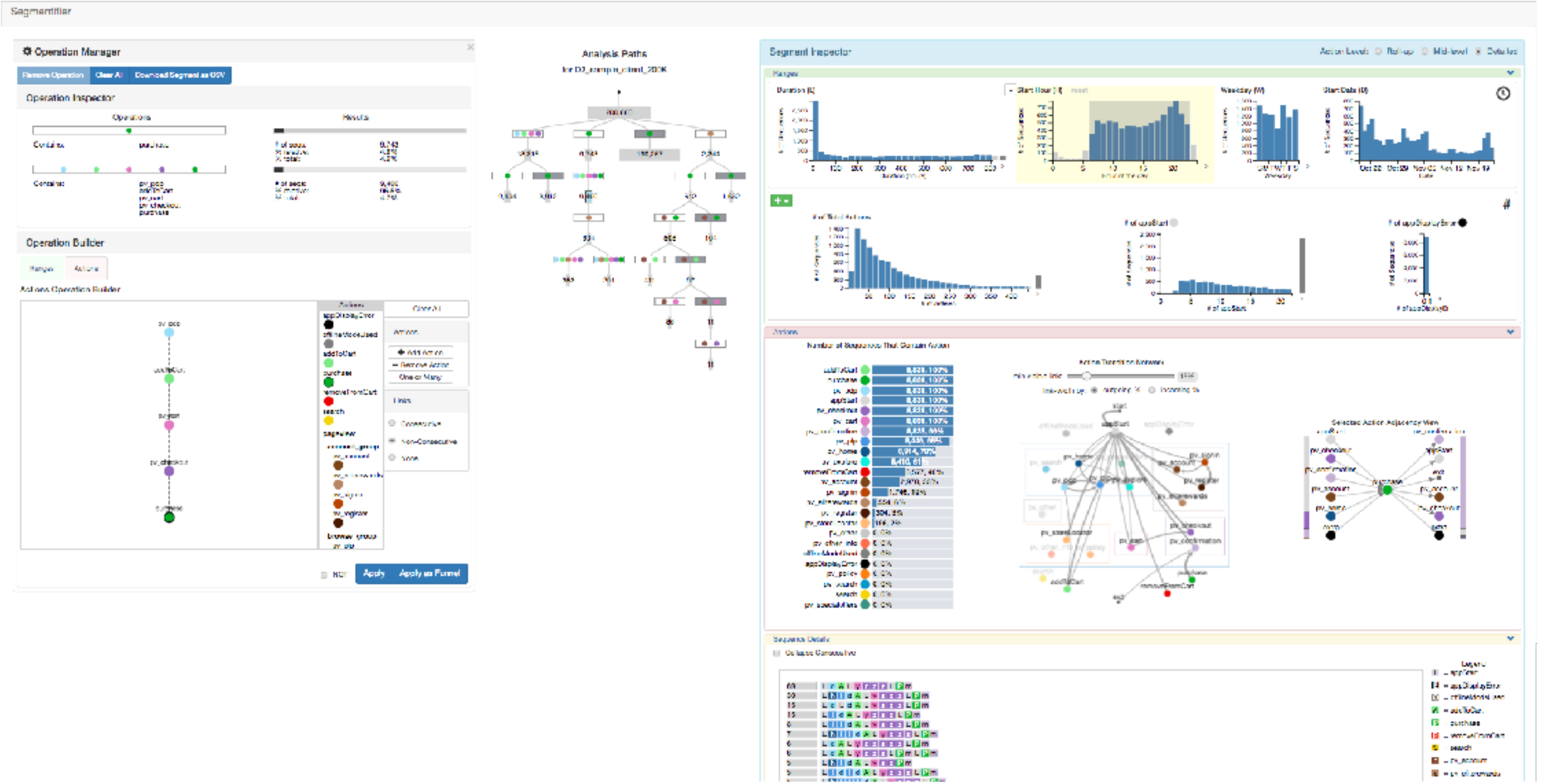
Why Visual Analytics?



- Automation would be nice...
  - Put data in, actionable results appear
- … but it is not realistic
  - Many possible questions, data-driven interplay between finding answers and generating new questions
- Human-in-the-loop visual data analysis
  - Integrate computing power of machine with intuition of domain experts

Solution

The Segmentifier Interface

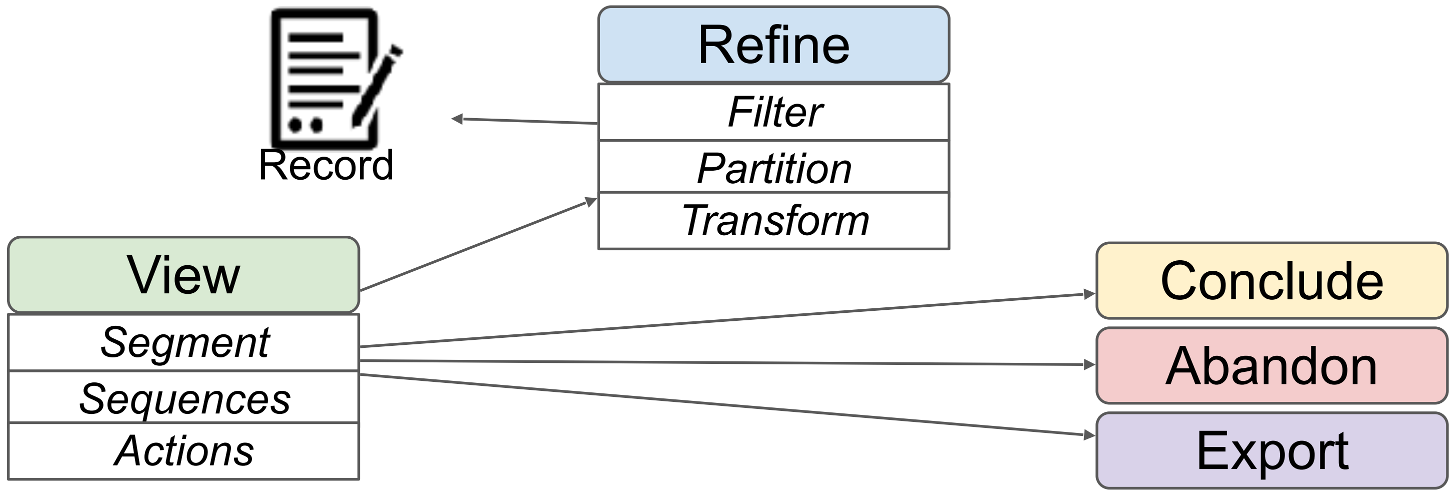


Video

https://www.youtube.com/watch?v=TobYDFelSOg

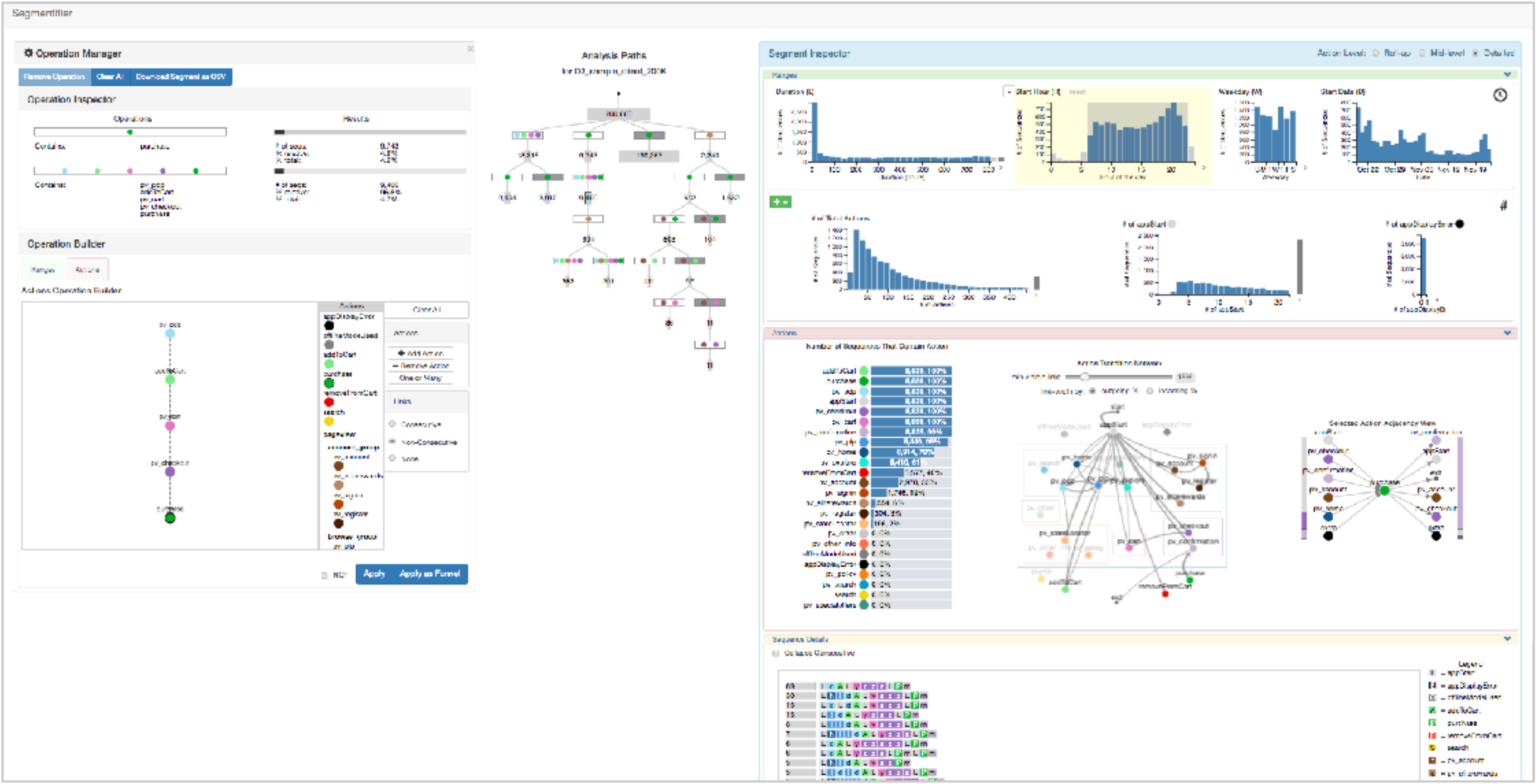
Segmentifier Contributions

➢ Thorough **characterization of task and data abstraction** for clickstream data analysis



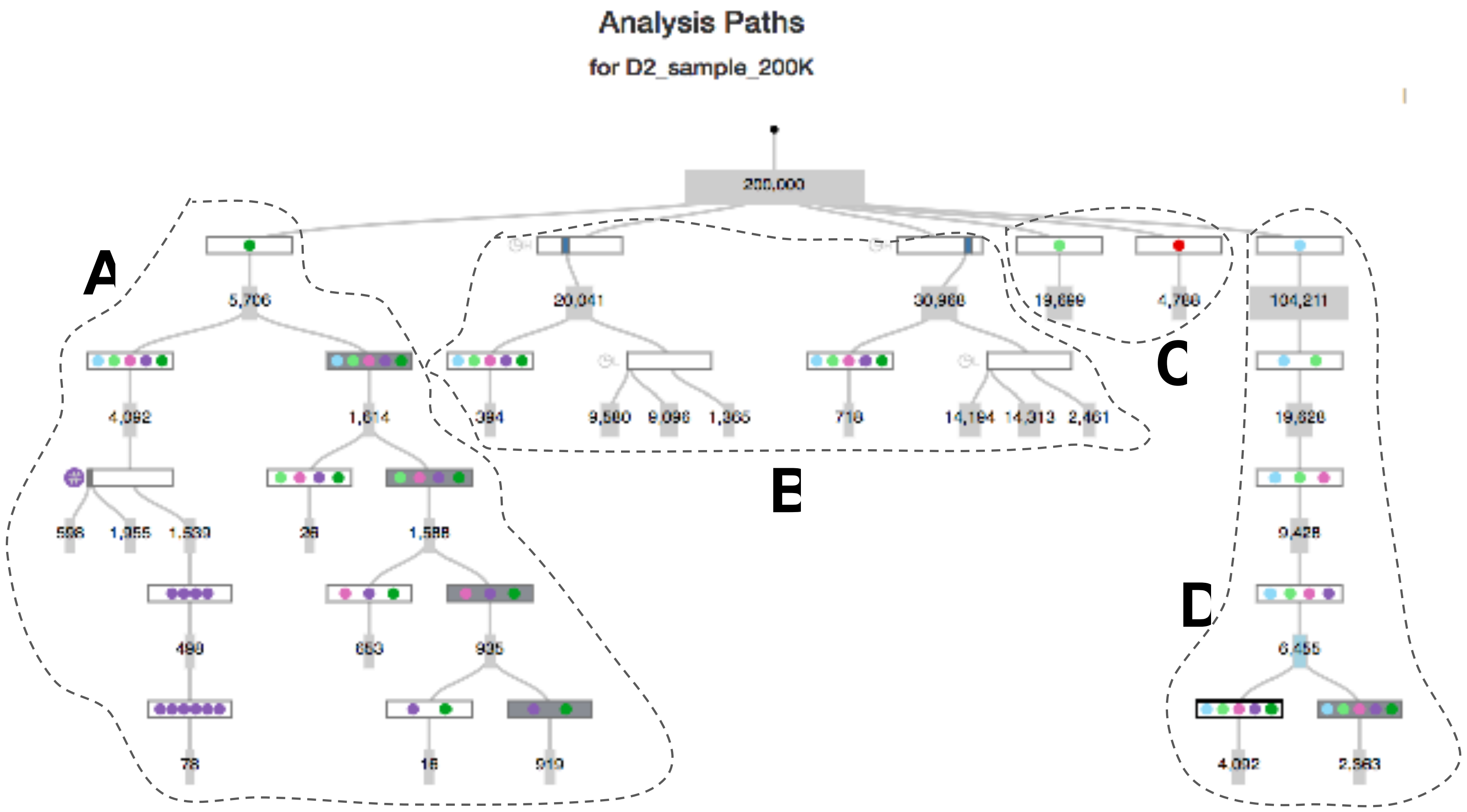
Segmentifier Contributions

- ➢ Thorough **characterization of task and data abstraction** for clickstream data analysis
- ➢ **Segmentifier: novel analytics interface** for refining data segments and viewing characteristics before downstream fine-grained analysis



Segmentifier Contributions

- Thorough **characterization of task and data abstraction** for clickstream data analysis
- **Segmentifier: novel analytics interface** for refining data segments and viewing characteristics before downstream fine-grained analysis
- Preliminary **evidence of utility**



Three case studies of problem-driven work

- e-commerce

- facilities management

- biology

e commerce by shashank singh from the Noun Project   Biology by tezar tantular from the Noun Project   Business by Colourcreatype from the Noun Project

Michael Oppermann

Ocupado

Visualizing Location-Based Counts Over Time Across Buildings

http://www.cs.ubc.ca/labs/imager/tr/2020/ocupado/

Ocupado: Visualizing Location-Based Counts Over Time Across Buildings.

Oppermann and Munzner. Computer Graphics Forum (Proc. EuroVis 2020) 39(3):127-138 2020.

Video

https://www.youtube.com/watch?v=KcwjVK8eUdw

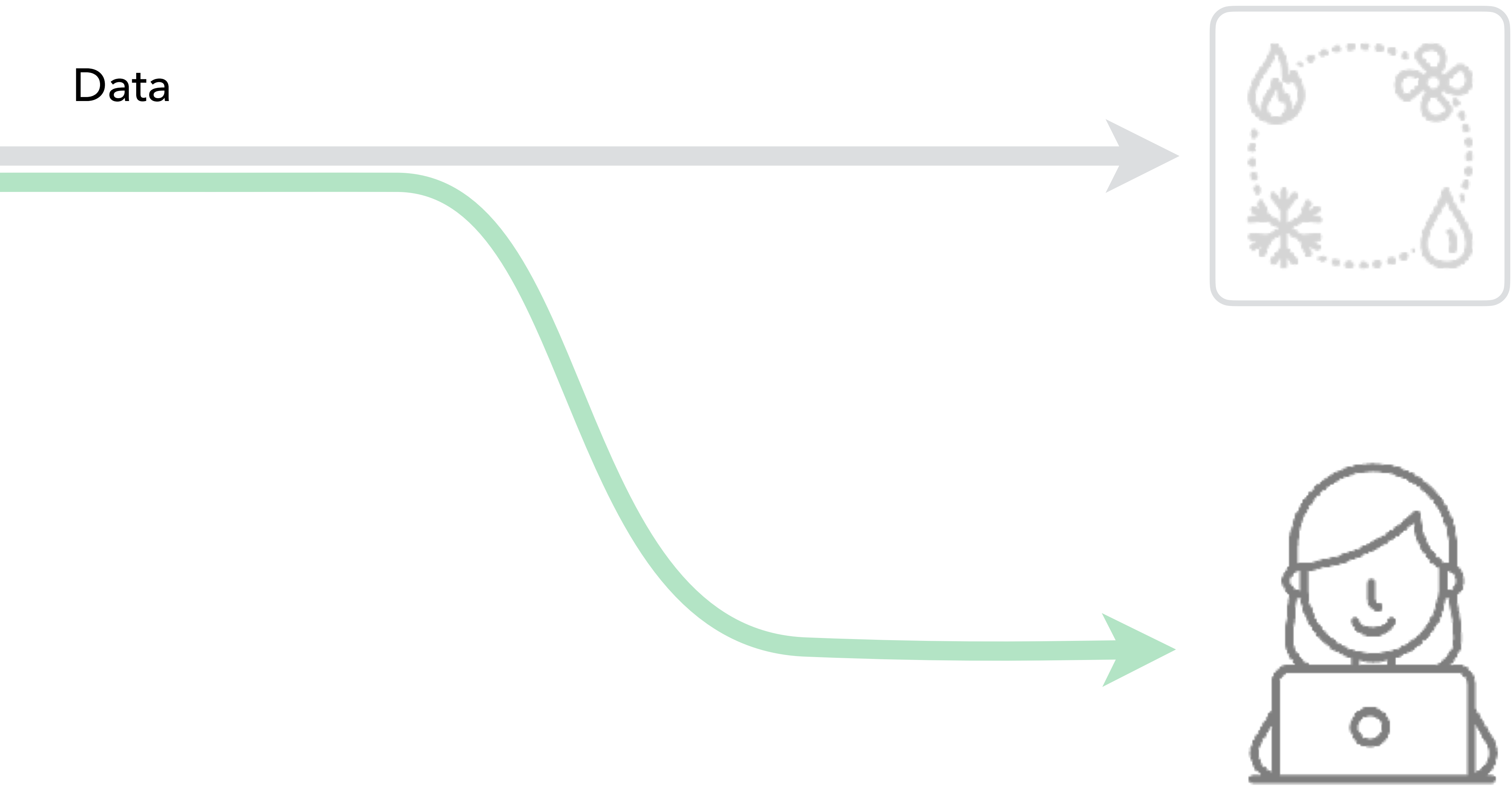
Location-Based Counts

- Regular intervals (e.g., every 5 minutes)
- Spatial hierarchy (Zone → Floor → Building → Campus)
- No trajectories or device identifiers are recorded
- Intrinsic privacy advantages

Data

Automated HVAC control

Data

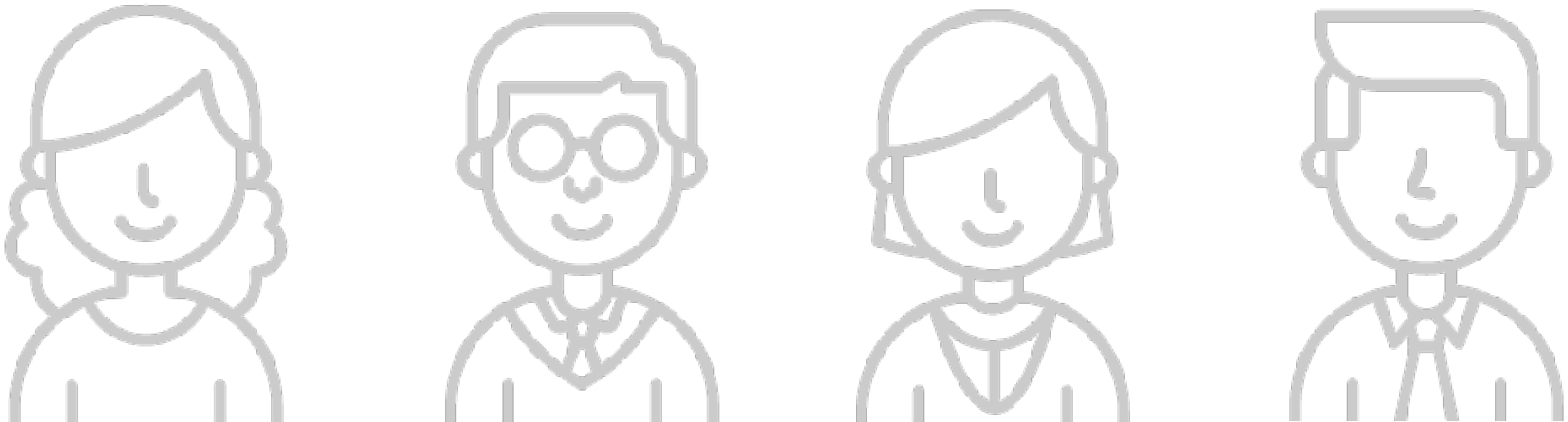


Decision making

WiFi connections as a proxy for occupancy

WiFi connections as a proxy for occupancy

Interviews with potential stakeholders



Focus Domains

- Space planning
- Building management
- Custodial services
- Classroom management
- Data quality control

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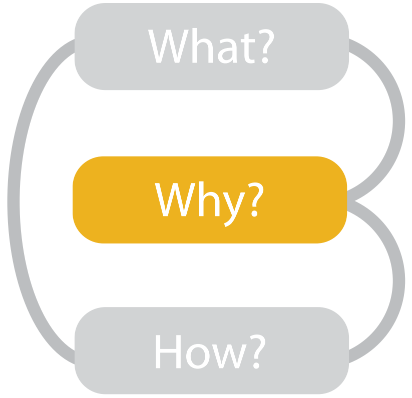
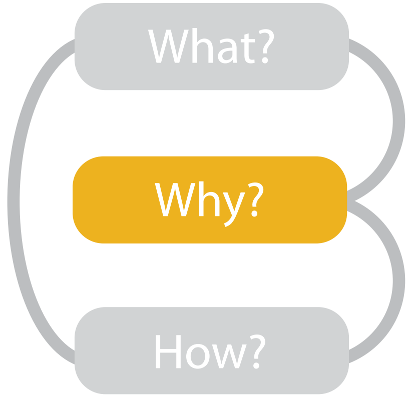
Semi-structured discussions and live demos



Tasks

Confirm assumptions or previous observations.

Do students occupy room x in evenings or on weekends?



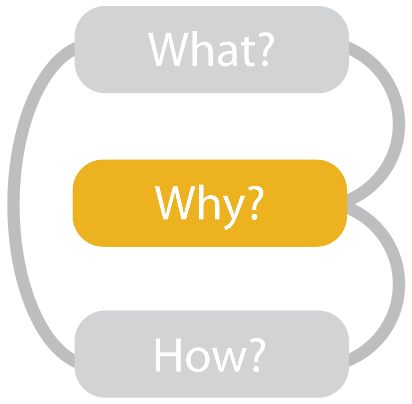
Tasks

- **Confirm** assumptions or previous observations.
- **Monitor** the current/recent utilization rate.
  Which rooms are empty/busy?

Tasks

- **Confirm** assumptions or previous observations.
- **Monitor** the current/recent utilization rate.
- **Communicate** space usage and justify decisions.

  Space usage improved after renovation.



Tasks

- **Confirm** assumptions or previous observations.
- **Monitor** the current/recent utilization rate.
- **Communicate** space usage and justify decisions.
- **Validate** the data (quality control).
  Check minimum size of a room that can be captured.

Spatial and Temporal Data Granularities

Visualization Prototypes

Sandbox

Data sketches,
static data export

Time

Visualization Prototypes

Sandbox

Data sketches,
static data export

- original plan: different interface for each stakeholder
- realization: task & data abstractions match multiple stakeholders
  - if slice by space & time granularity

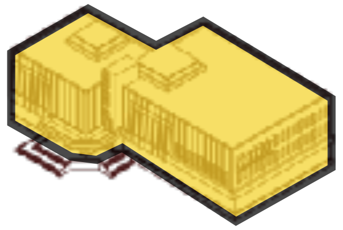
Spatial and Temporal Data Granularities

Regions of interest

Zone

Floor

Building



Spatial and Temporal Data Granularities

Regions of interest

Zone

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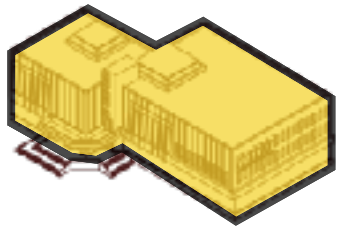


Periods of interest

Mondays

Weekdays

last 12 hours

Summer term

Fr 8-10am

Weekends

Visualization Prototypes

Sandbox

Data sketches,
static data export

Campus Explorer

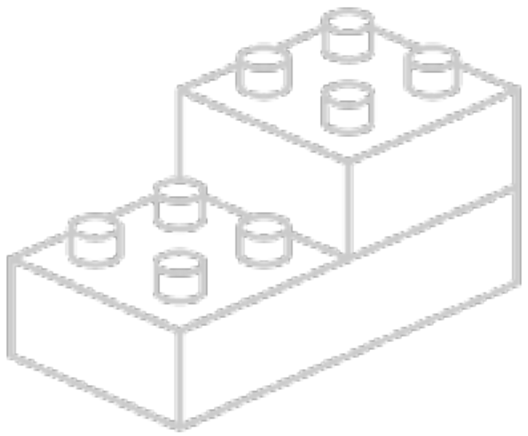
Live-data stream,
cross-building analysis

Building Recent

Building Long-term

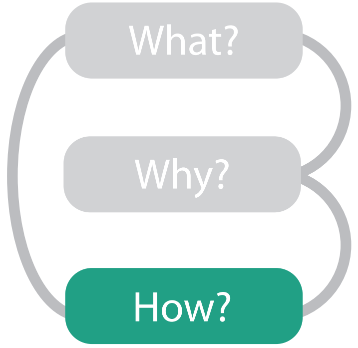
Region Compare

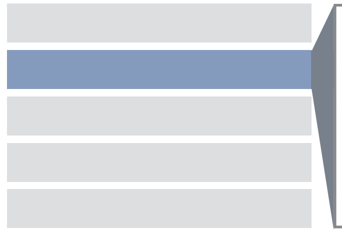
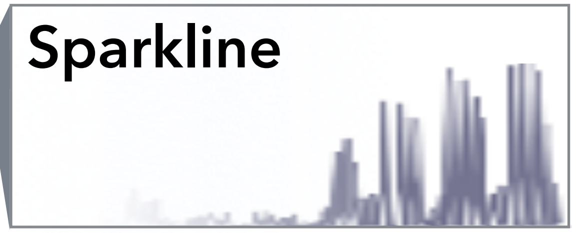
Time



Reusable Visualization Components

Reusable Visualization Components



Layout	Visual Encoding	Facet	Comparisons
	**Sparkline** 	Juxtaposition	Repeating patterns, trends, outliers (contiguous)

Reusable Visualization Components

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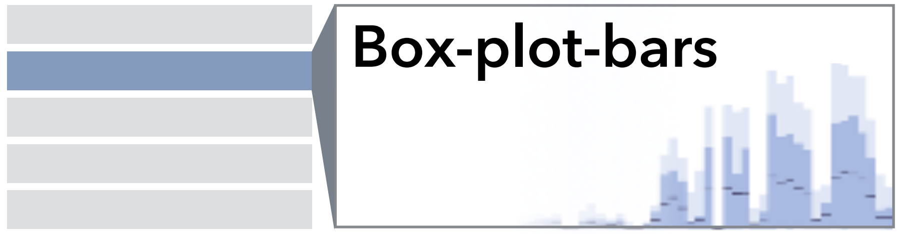
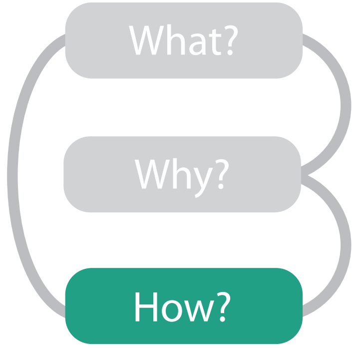
	**Sparkline**	Juxtaposition	Repeating patterns, trends, outliers (contiguous)
	**Box-plot-bars**	Juxtaposition	Repeating patterns, trends, outliers *(non-contiguous)*



Reusable Visualization Components

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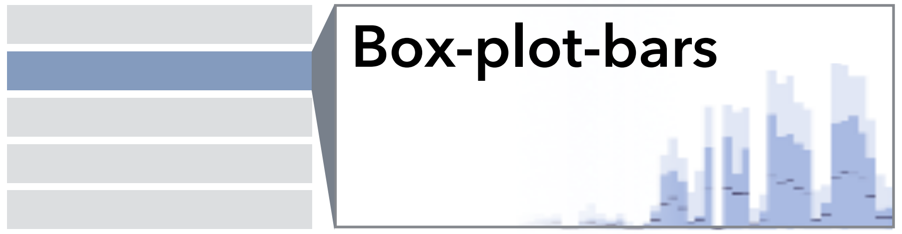
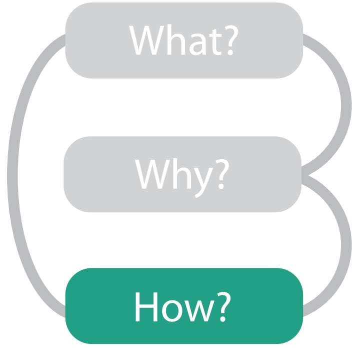
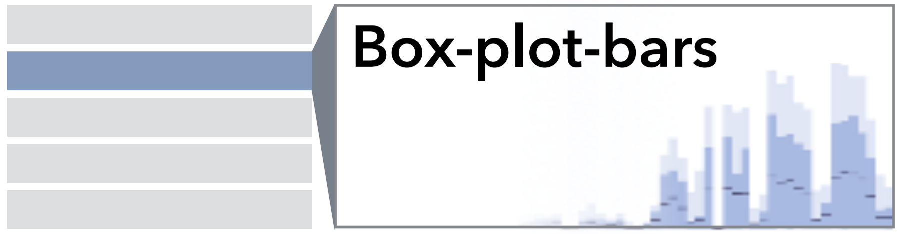
	**Box-plot-bars**	Juxtaposition	Repeating patterns, trends, outliers *(non-contiguous)*
	**Confidence band line chart**	Aggregation	Typical utilization profiles



Reusable Visualization Components

Layout / Visual Encoding	Facet	Comparisons
 Sparkline	Juxtaposition	Repeating patterns, trends, outliers (contiguous)
 Box-plot-bars	Juxtaposition	Repeating patterns, trends, outliers *(non-contiguous)*
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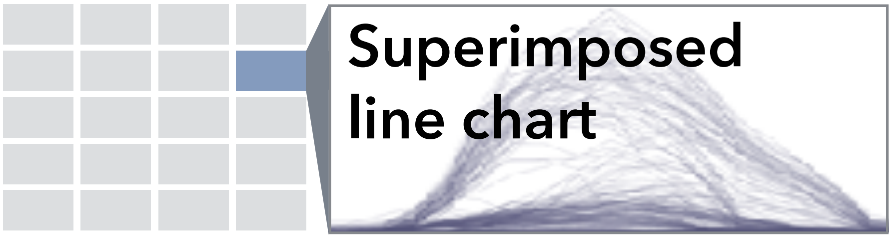
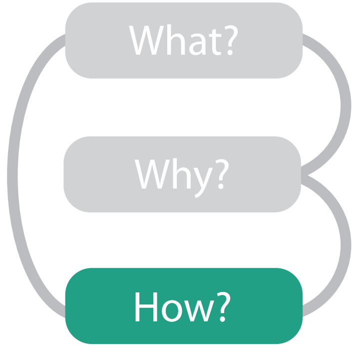
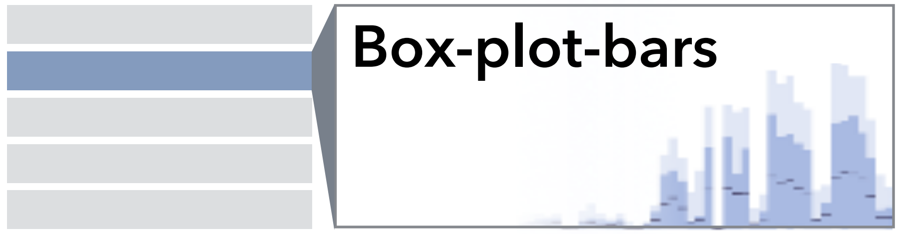
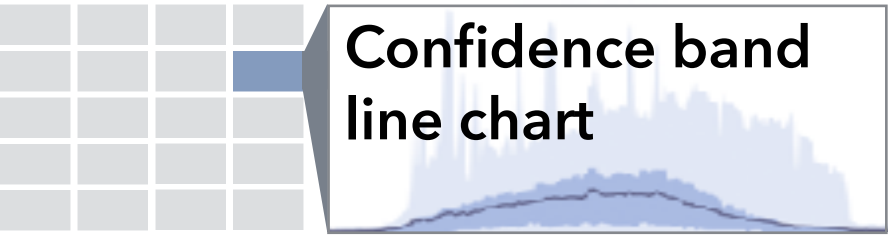
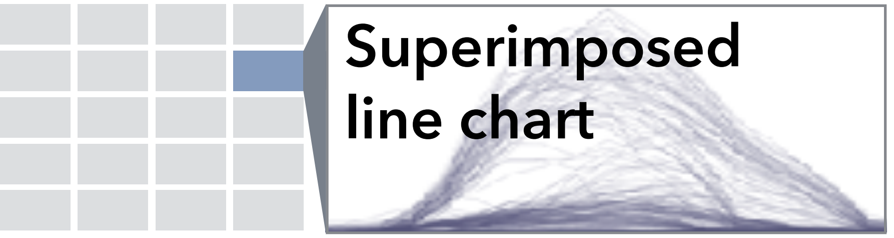
 Superimposed line chart	Superposition	Within-session patterns, outliers

Reusable Visualization Components



	Layout	Visual Encoding	Facet	Comparisons
Temporal		Sparkline	Juxtaposition	Repeating patterns, trends, outliers (contiguous)
		Box-plot-bars	Juxtaposition	Repeating patterns, trends, outliers *(non-contiguous)*
		Confidence band line chart	Aggregation	Typical utilization profiles
		Superimposed line chart	Superposition	Within-session patterns, outliers

What?
Why?
How?

Reusable Visualization Components

	Layout	Visual Encoding	Facet	Comparisons
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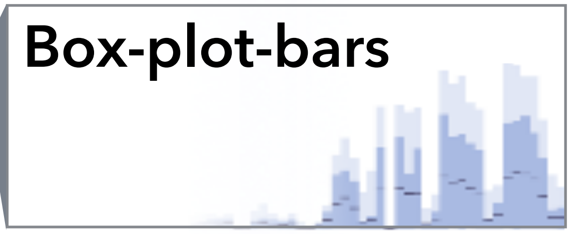
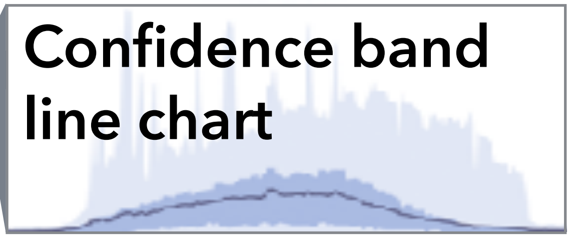
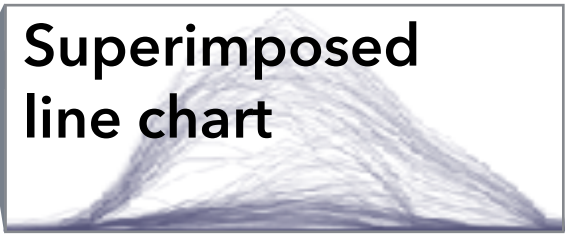
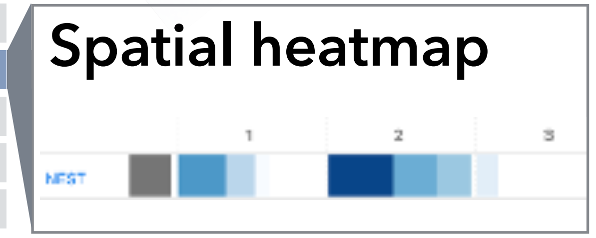
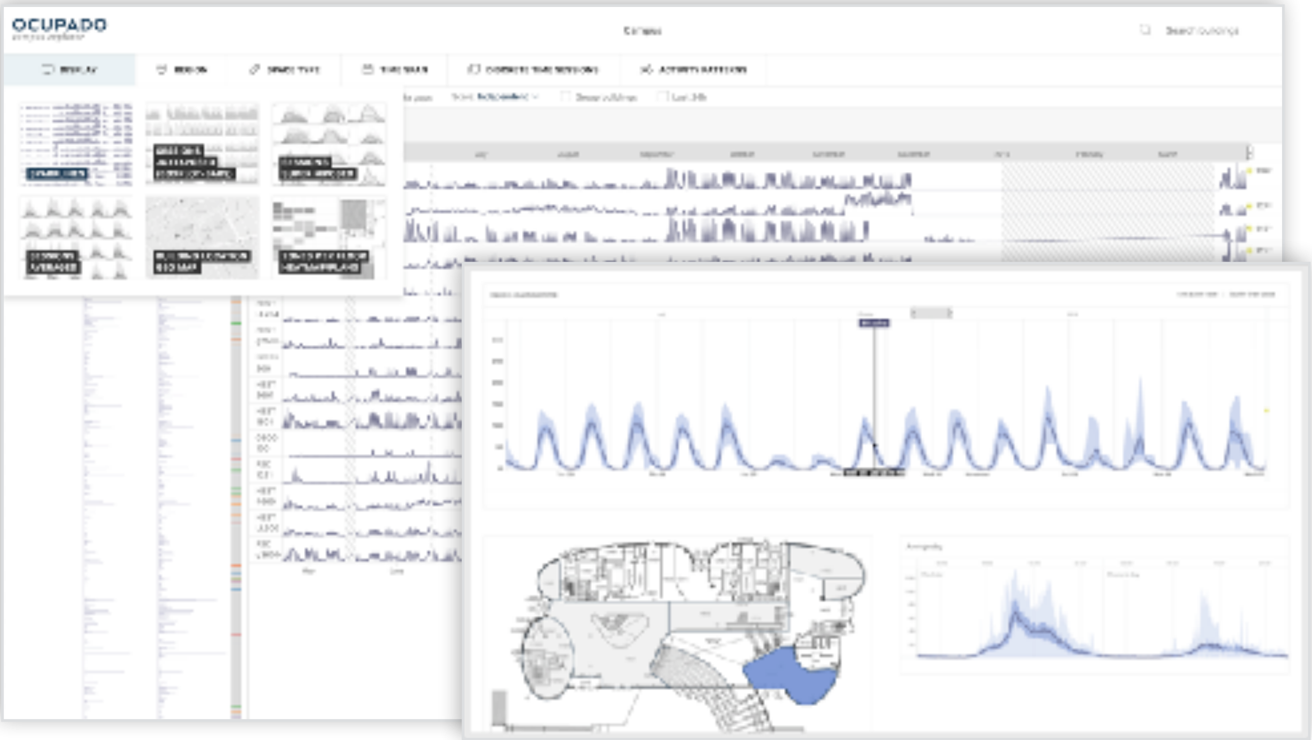
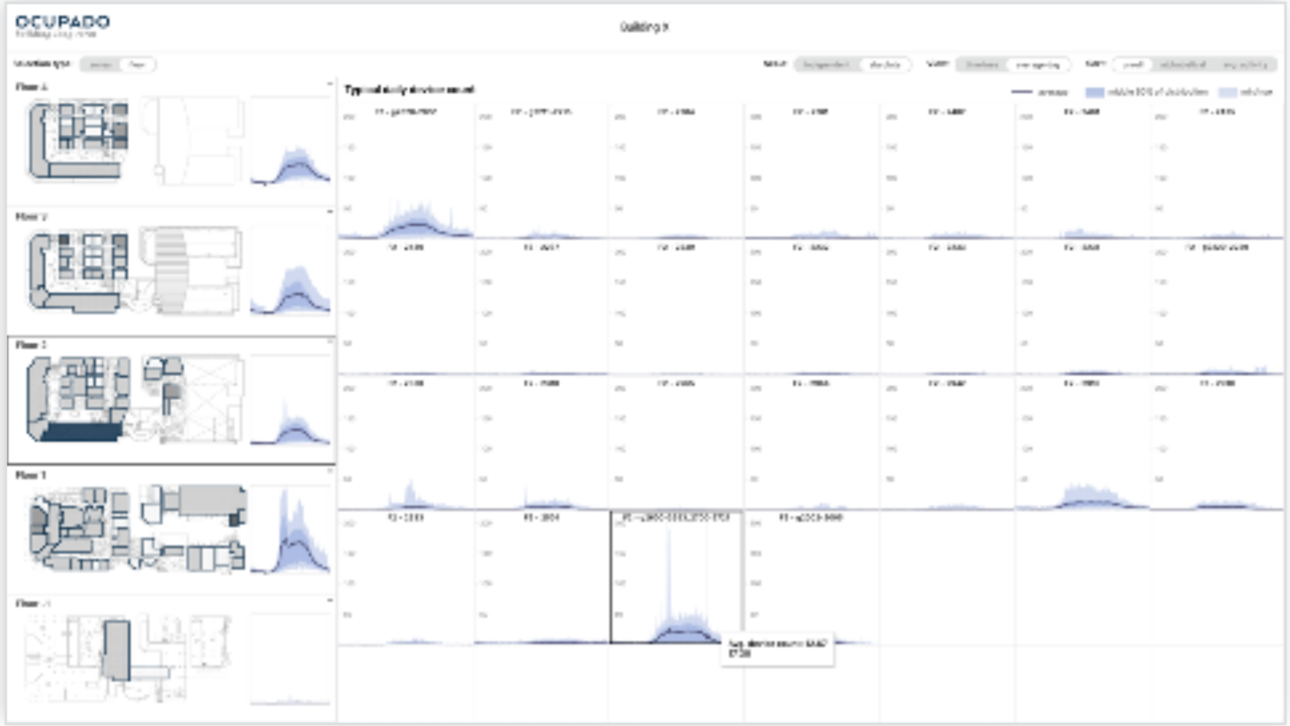
		Box-plot-bars 	Juxtaposition	Repeating patterns, trends, outliers *(non-contiguous)*
		Confidence band line chart 	Aggregation	Typical utilization profiles
		Superimposed line chart 	Superposition	Within-session patterns, outliers
Spatial		**Floor plan with symbols** 	Superposition	Within local spatial neighborhood
		Spatial heatmap 	Containment (nested)	Across distributed regions

Ocupado Interfaces



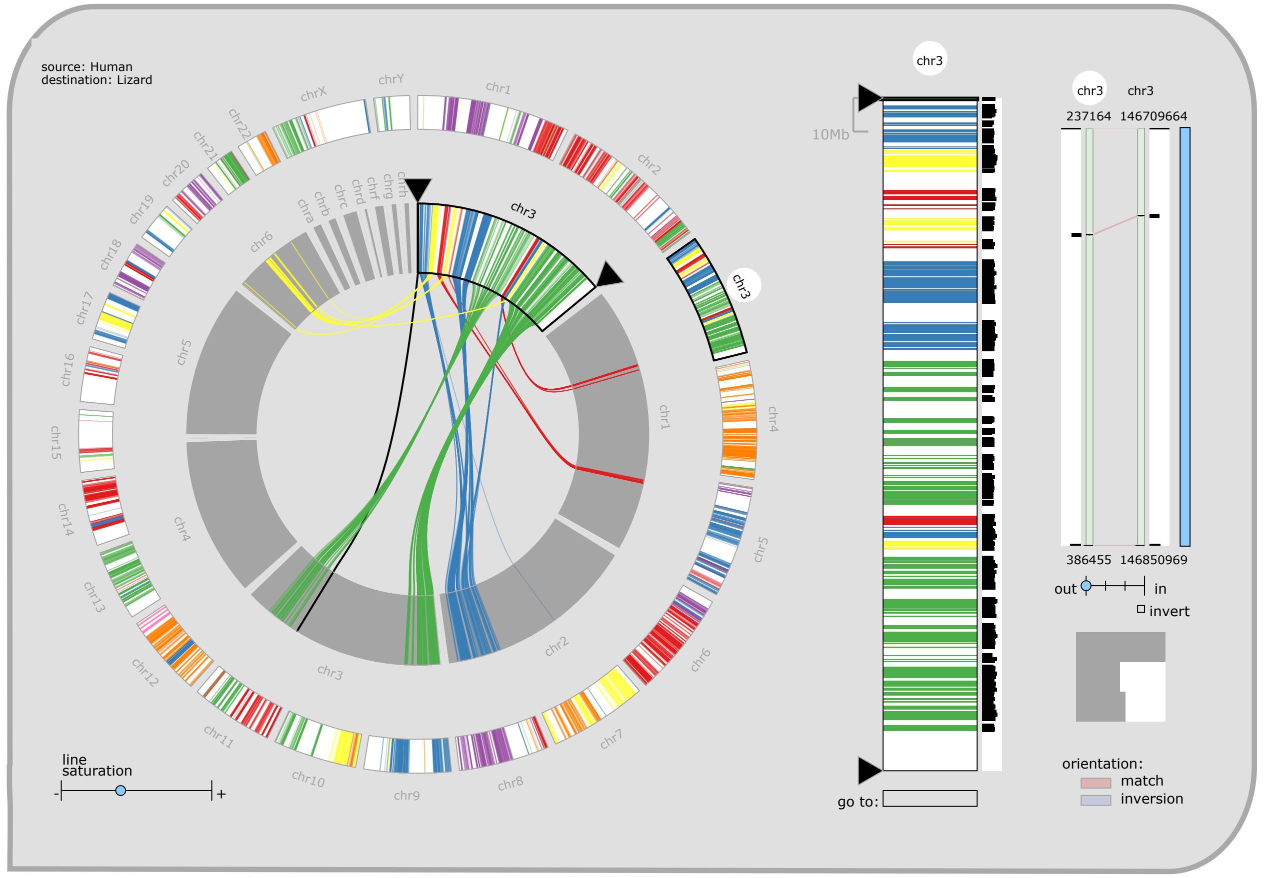


Ocupado Contributions

- Analysis and abstraction of data and tasks for studying space utilization
- Ocupado, a set of visual decision support tools
- Generalizable design choices for visualizing non-trajectory spatiotemporal data relating to large-scale indoor environments

MizBee

A Multiscale Synteny Browser



joint work with:

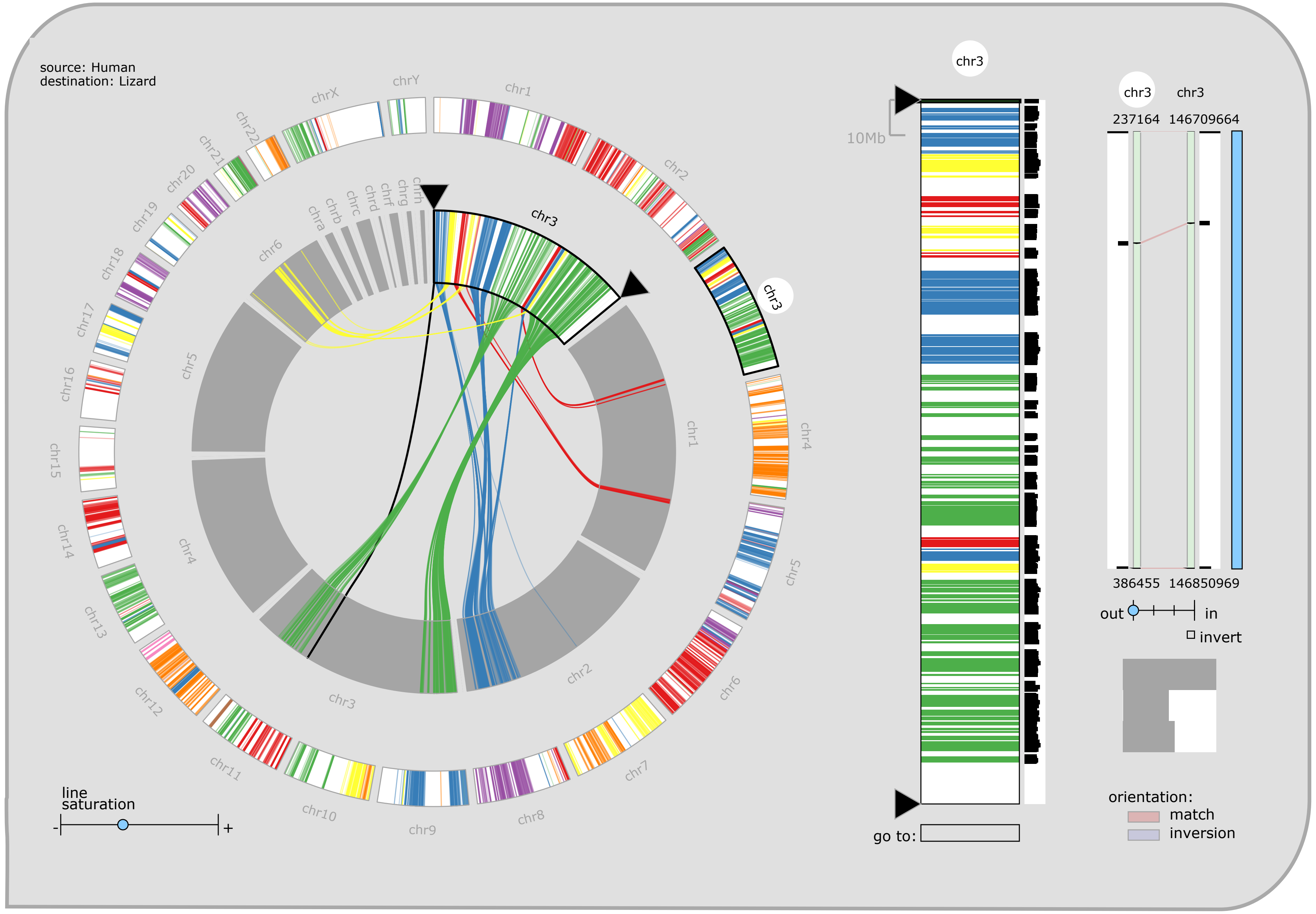
Miriah Meyer, Hanspeter Pfister

http://www.cs.utah.edu/~miriah/mizbee

MizBee: A Multiscale Synteny Browser.

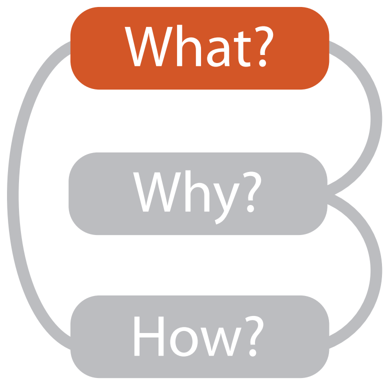
Meyer, Munzner, Pfister. IEEE Trans. Visualization and Computer Graphics 15(6):897-904, 2009 (Proc. InfoVis 2009).

Video

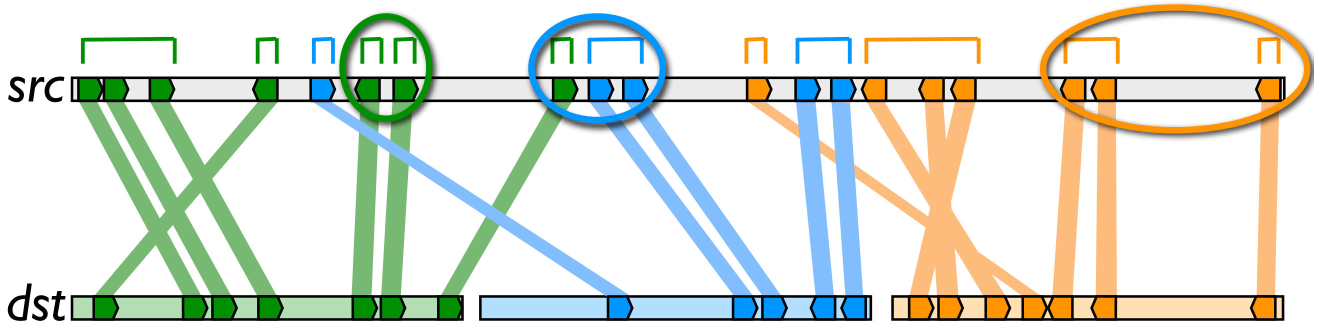


https://www.youtube.com/watch?v=86p7brwuz2g

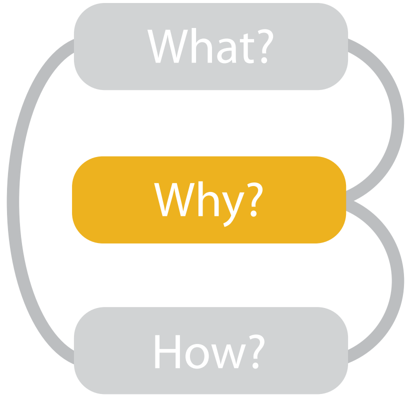
What: Data abstraction



- data: multiscale lists
  - features: hundreds of thousands
    - ordered attribute: position in chromosome sequence coordinates
    - categorical attributes: orientation, chromosome of matching feature
    - quantitative attributes: length, similarity score
  - syntenic blocks: thousands
    - contiguous sets of features on same chromosome
    - combine thresholded features if
      - destination chromosome and orientation match
      - close together
  - chromosomes: dozens
  - genomes: two

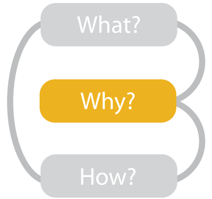


Why: Tasks in domain language



- analyze conservation (similarity) relationships between genomic features
  - high-level biology questions
    - evolution
      - how long ago did two species share common ancestor?
    - function
      - which segment of the genome is responsible for specific function in the cell?
    - ...
  - low-level data-centric questions
    - algorithm refinement
      - are paired features within a block contiguous?
      - which chromosomes share conserved blocks?
      - are similarity scores alike within block?
      - ...

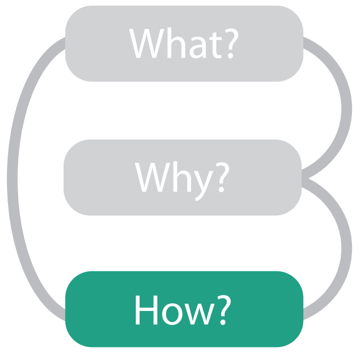
Why: Tasks abstraction



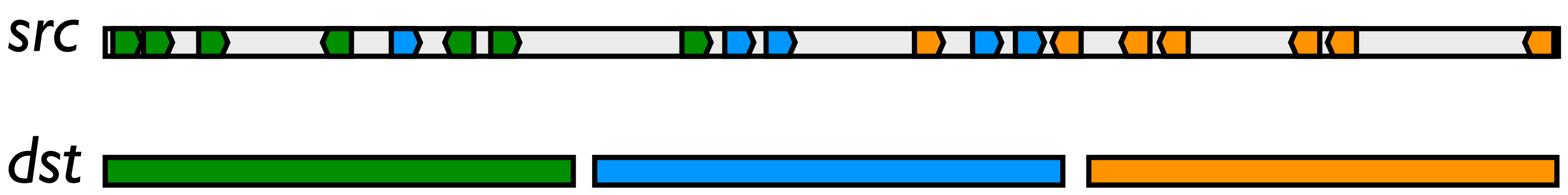
- relationship types: proximity, size, orientation, similarity
- data scales: genome, chromosome, block, feature
- topics: algorithm in/out, block reliability, high-level science

	relationship				scale			
	genome	chromosome	block	feature	proximity / location	size	orientation	similarity
Which chromosomes share conserved blocks?	x				x			
For one chromosome, how many other chromosomes does it share blocks with?	x	x			x			
What is the density of coverage and where are the gaps on: chromosomes? blocks?	x	x	x		x			
Where are the blocks: on chromosomes? around a specific location on a chromosome?	x	x			x			
What are the sizes and locations of other genomic features near a block?		x			x	x		
How large are the blocks?		x				x		
Do neighboring blocks go to the same: chromosomes? relative location on a chromosome?	x	x			x			
Are the orientations matched or inverted for: block pairs? feature pairs?		x	x				x	
Do the orientations match for pairs of: neighboring blocks? features within a block?		x	x				x	
Are similarity scores alike: with respect to neighboring blocks? within a block?		x	x					x
Are the paired features within a block contiguous?			x		x			
How large is a feature relative to other genes within a block?			x			x		
What are the sizes, locations, and names of features within a block?			x		x	x		
What are the differences between individual nucleotides of feature pairs?				x				x

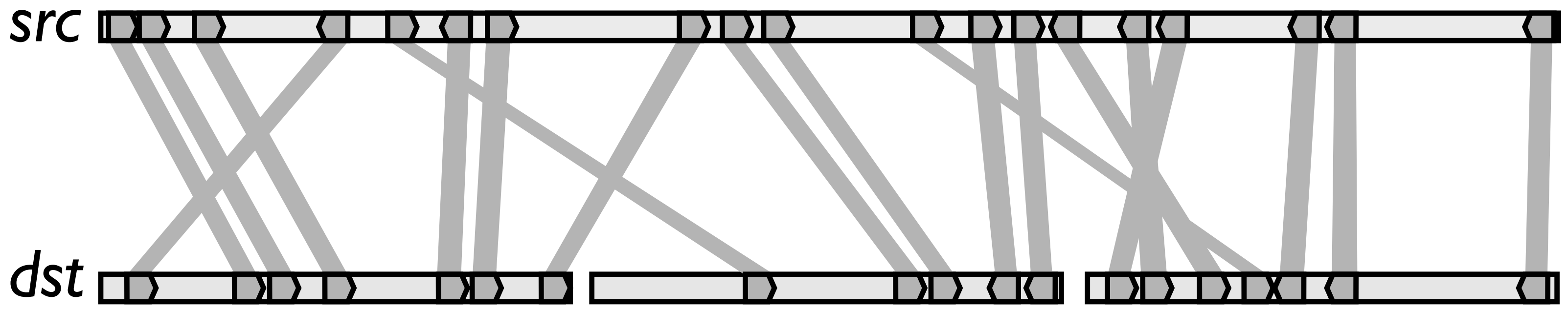
How: Idiom design choices

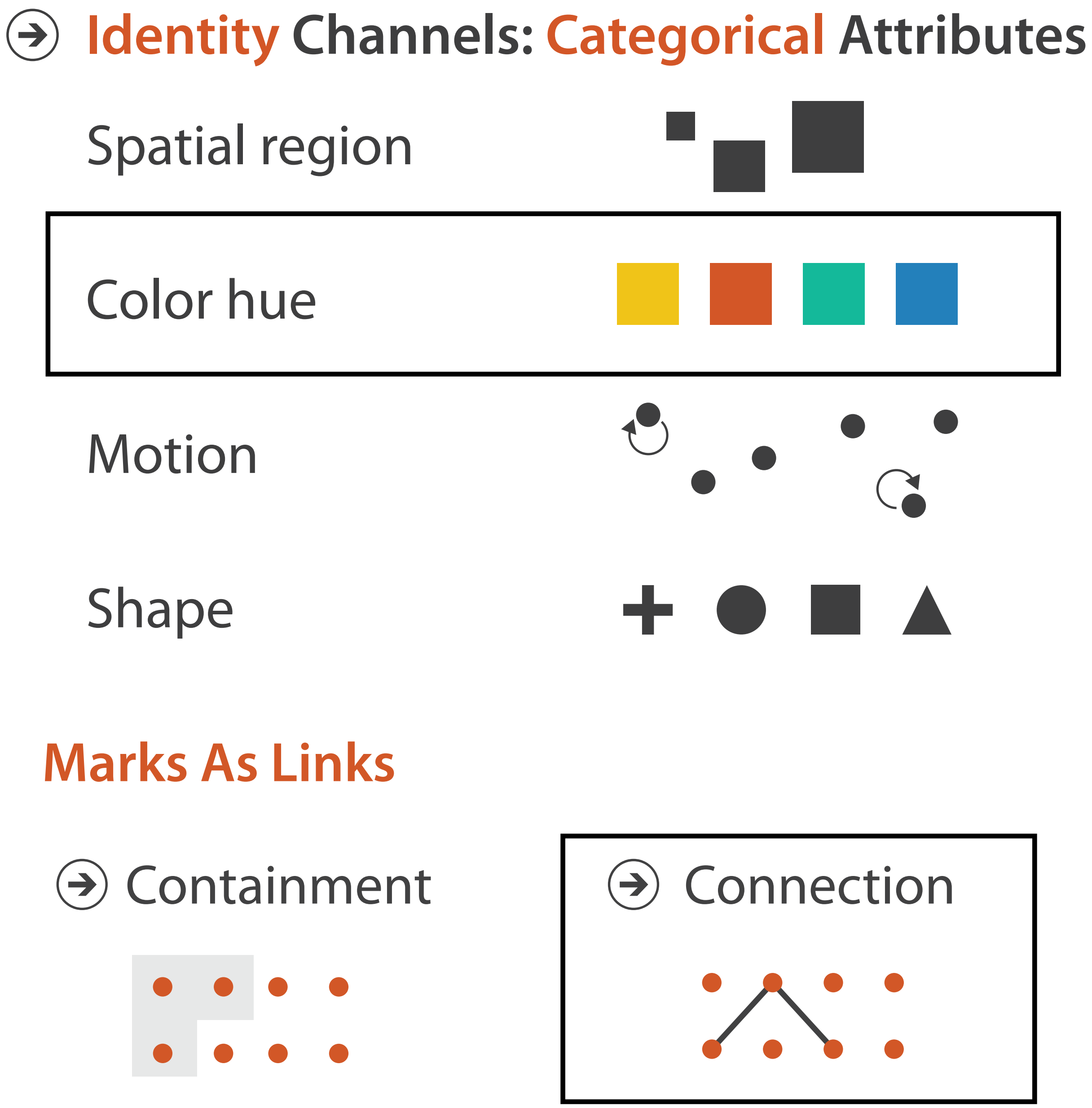


- encode match relationships between chromosome segments with both
  - color



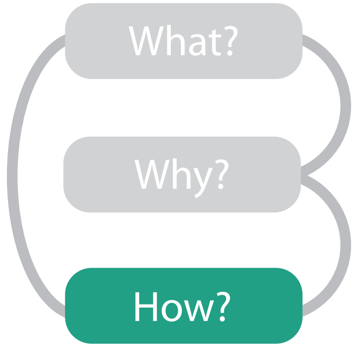
  - connection marks

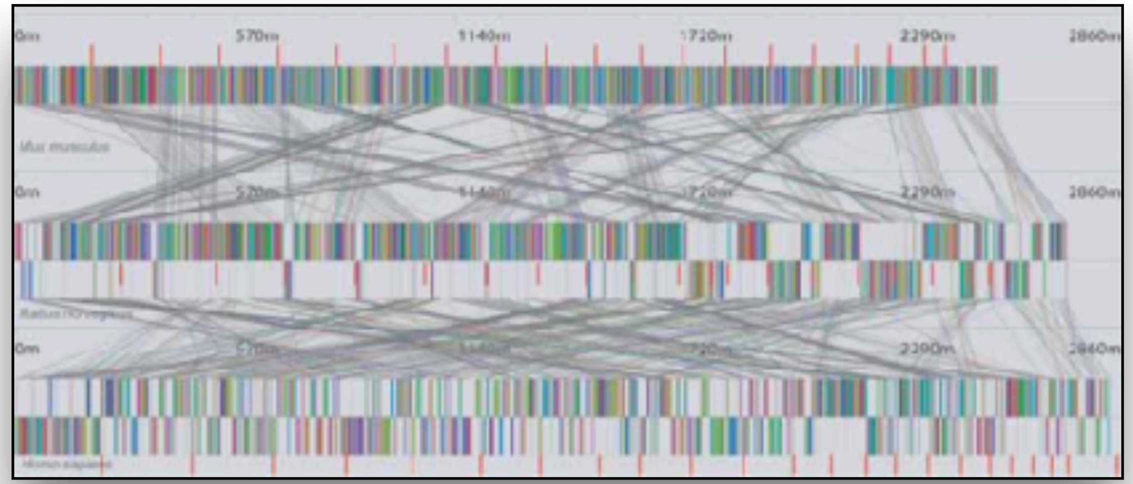




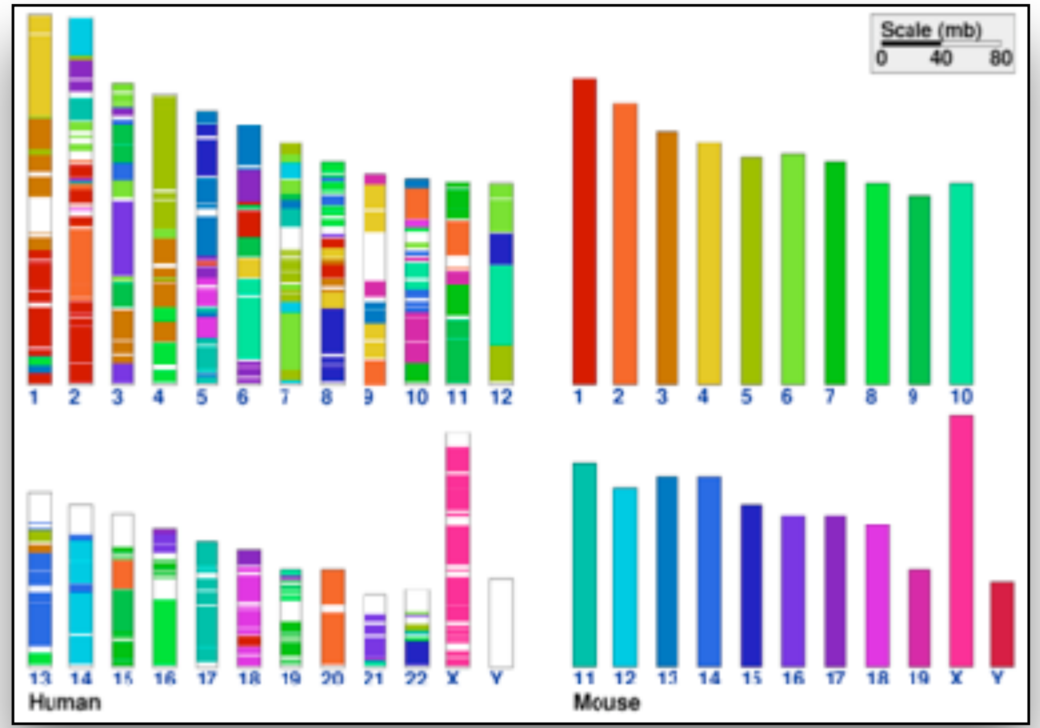
How: Arrange space

- design space of arrangements

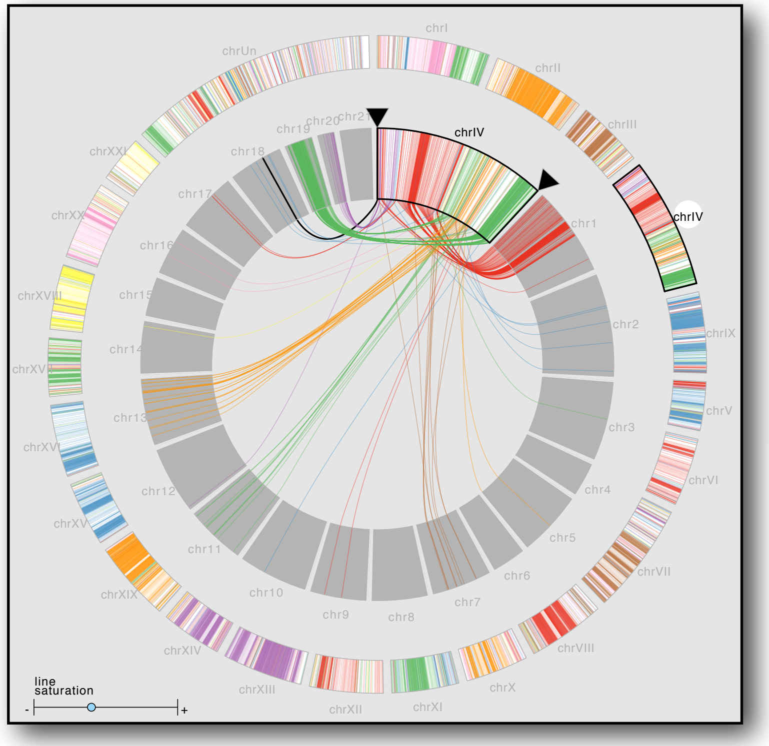




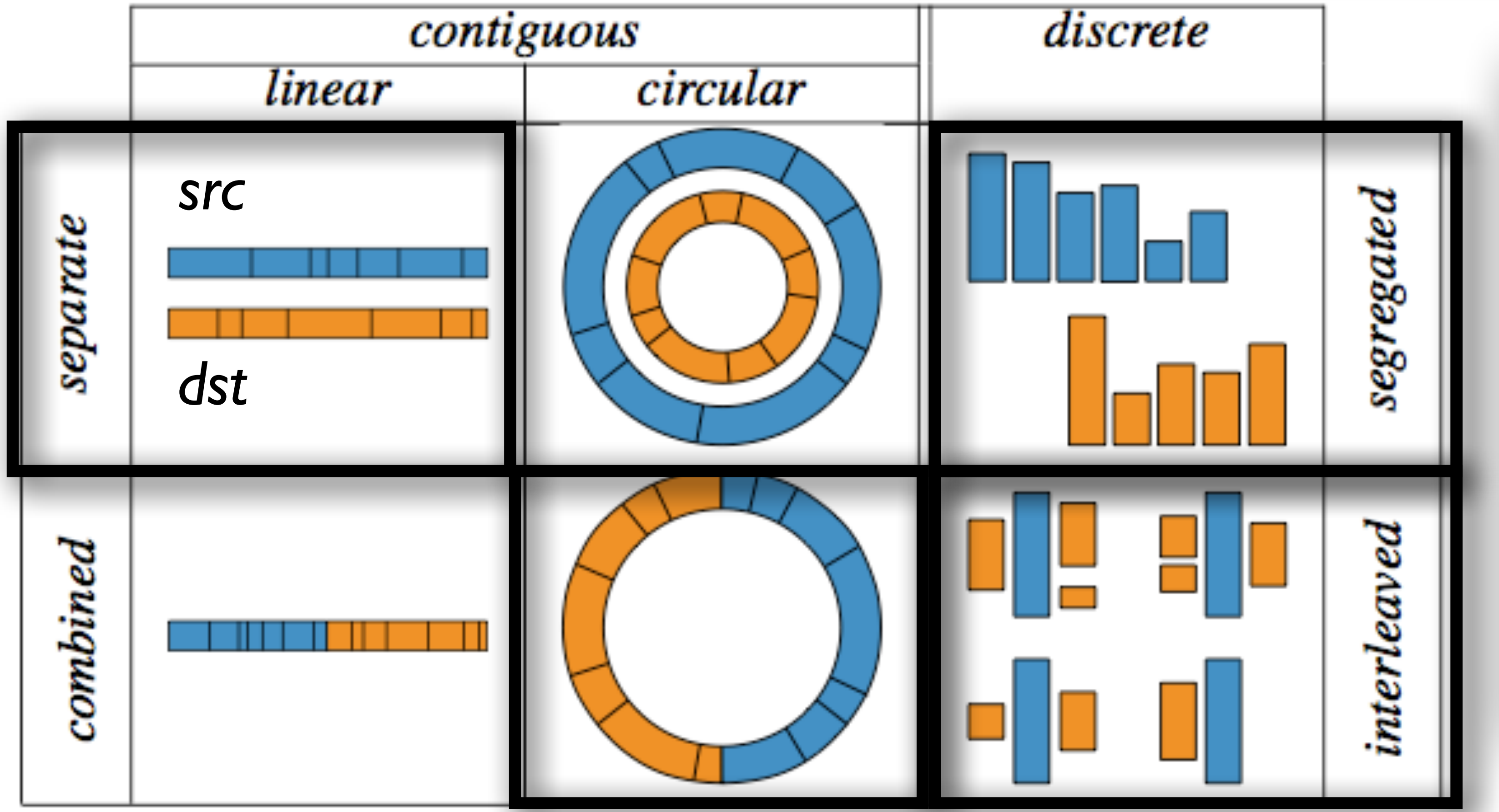
Mauve [Darling04]

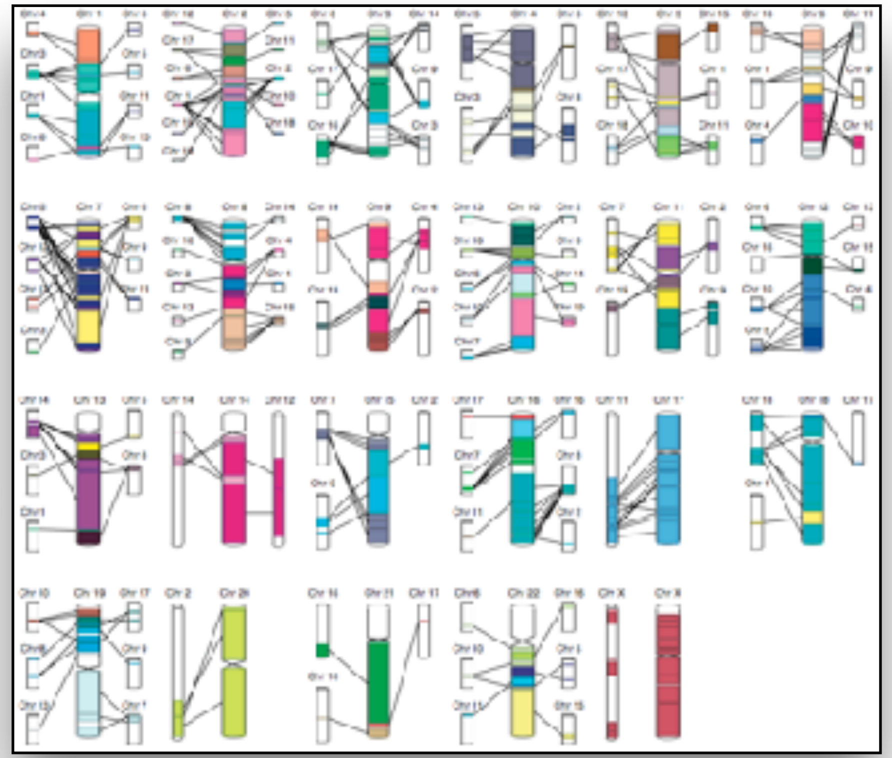


Cinteny



MizBee

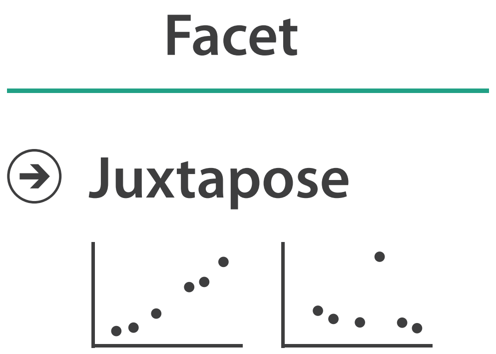


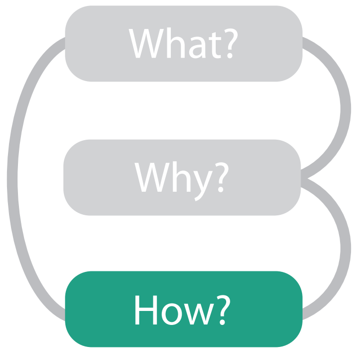


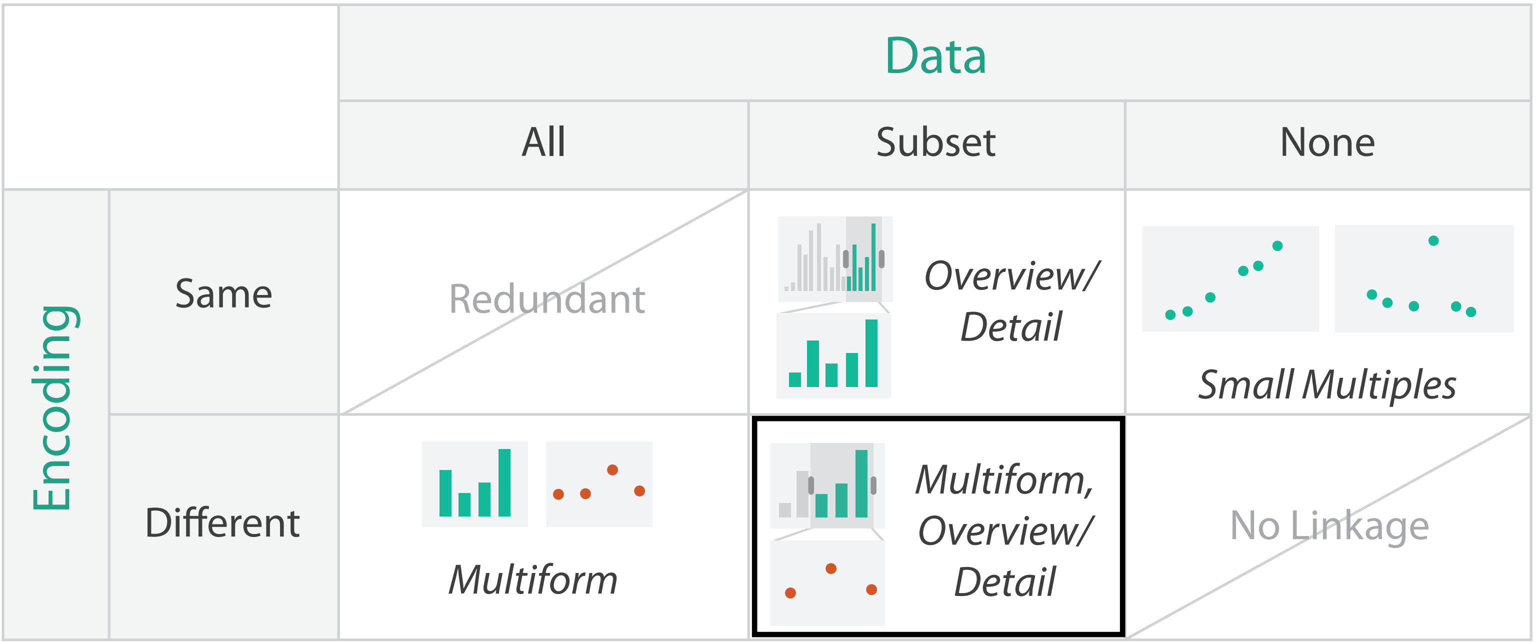
Apollo [Lewis02]

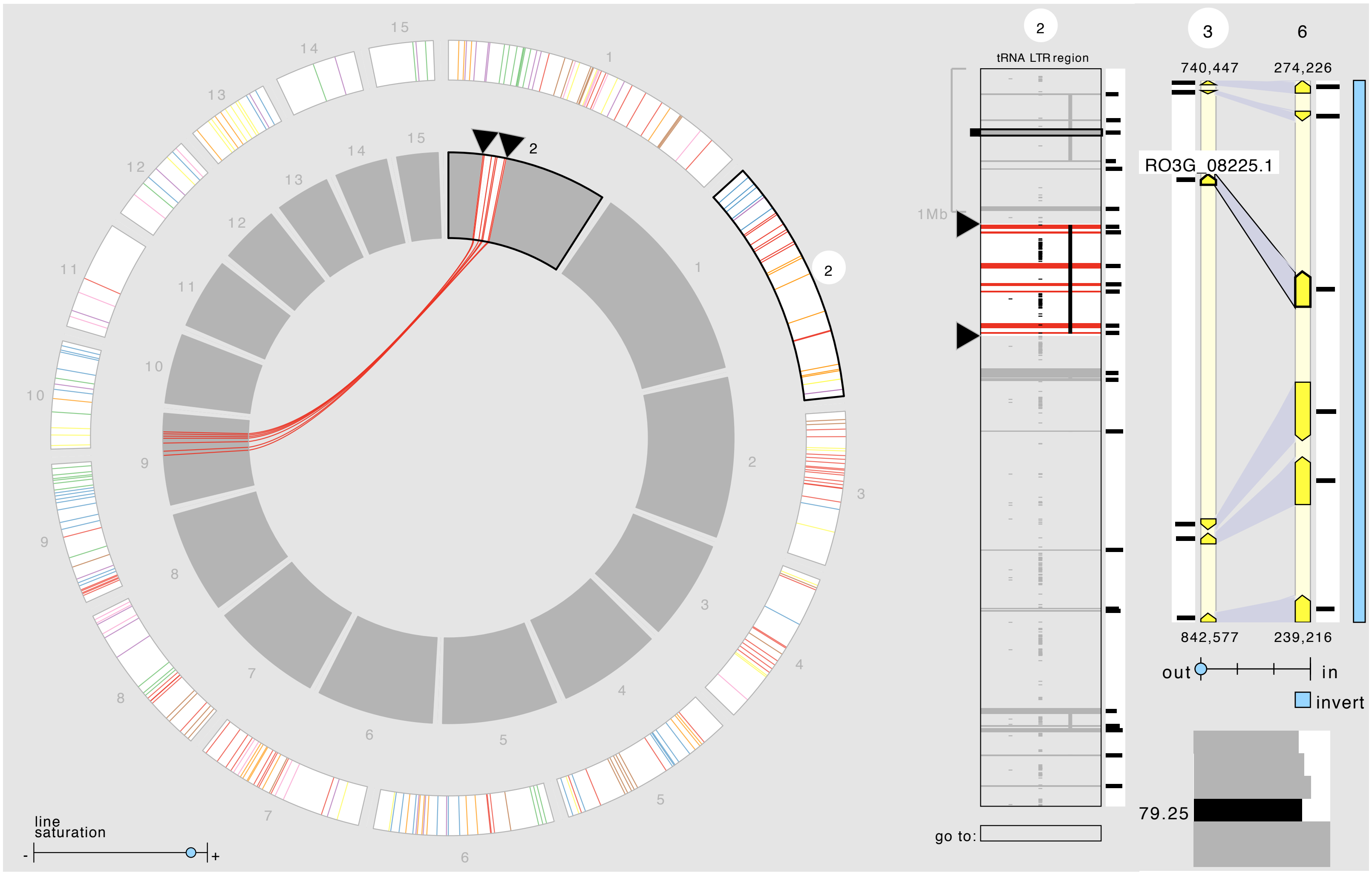
How: Idiom design choices

- juxtapose linked views
  - *multiform overview-detail*
    - three views: genome, chromosome, block
    - different visual encoding in each

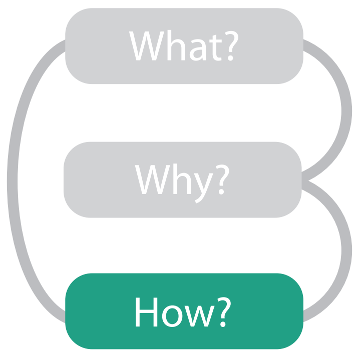




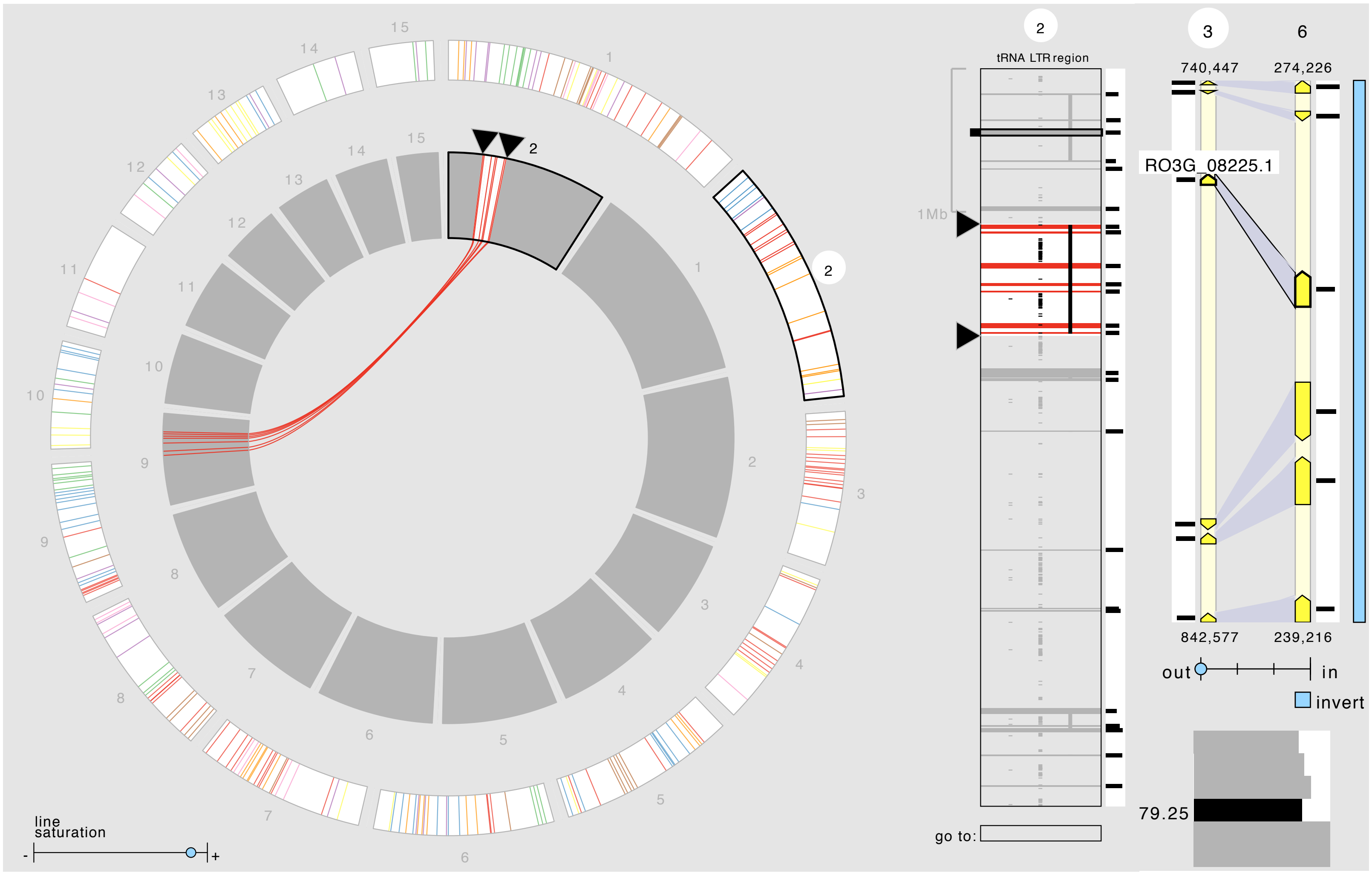


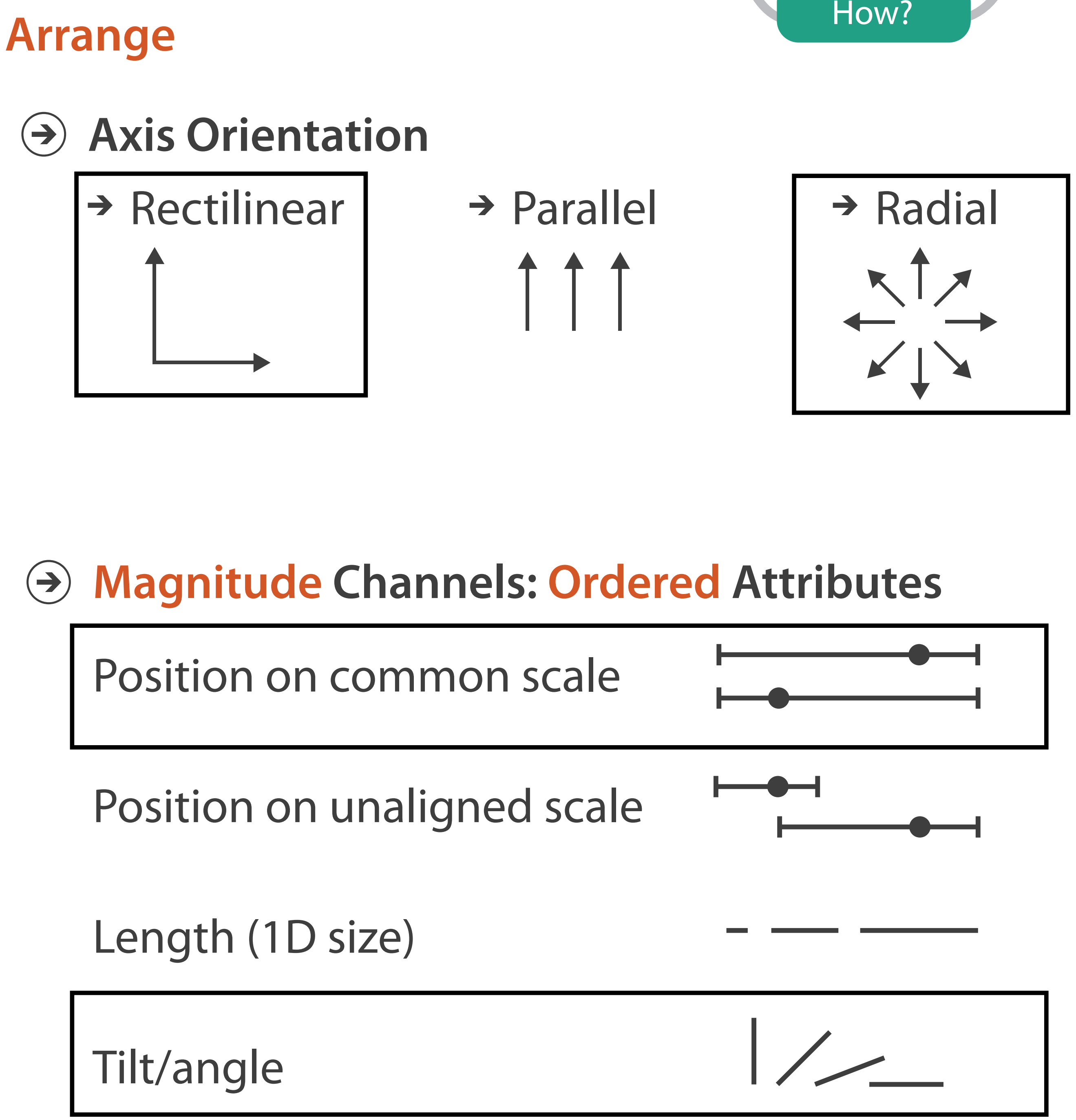


How: Idiom design choices



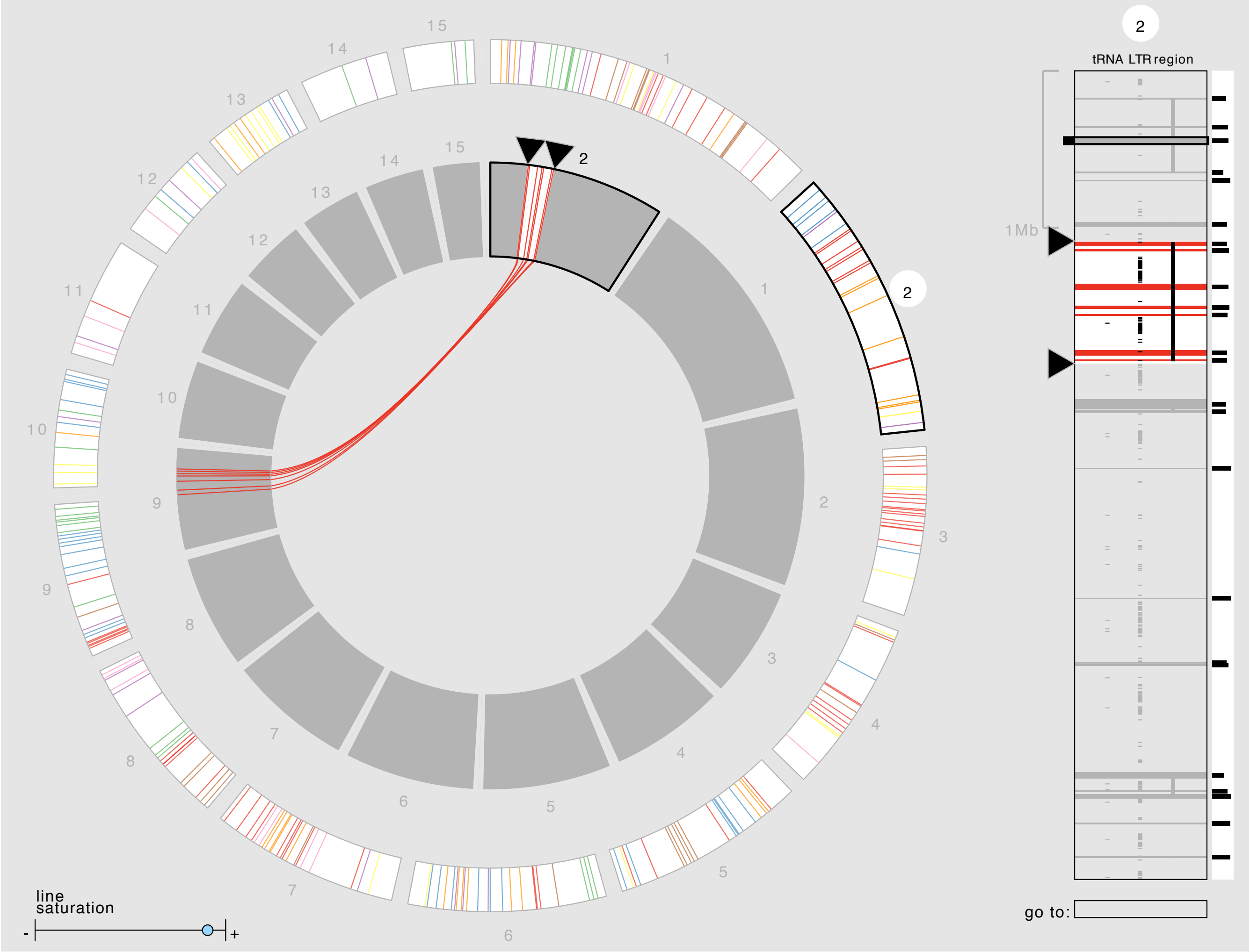
- axis orientation
  - radial: genome
  - rectilinear: chromosome, block
    - aligned position more accurate than angle

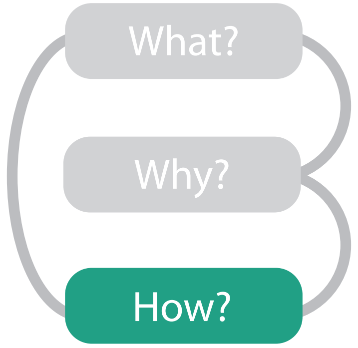




How: Idiom design choices

- filter

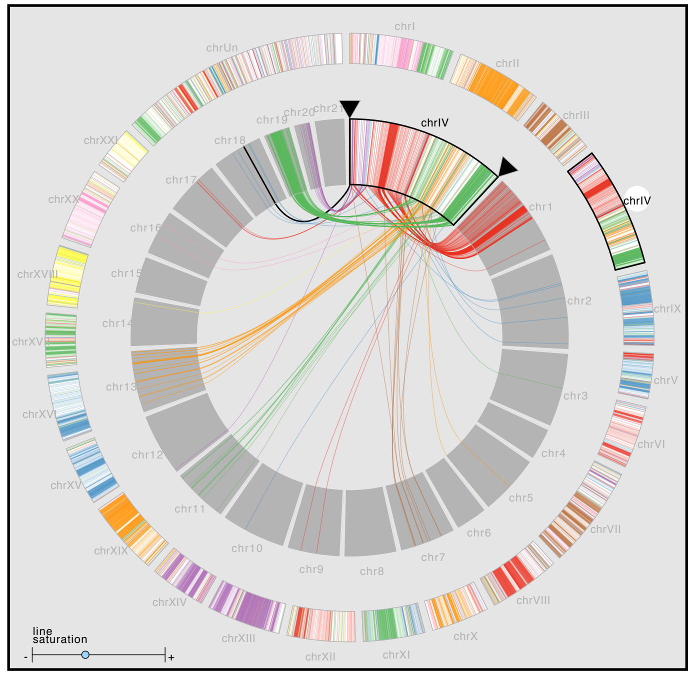


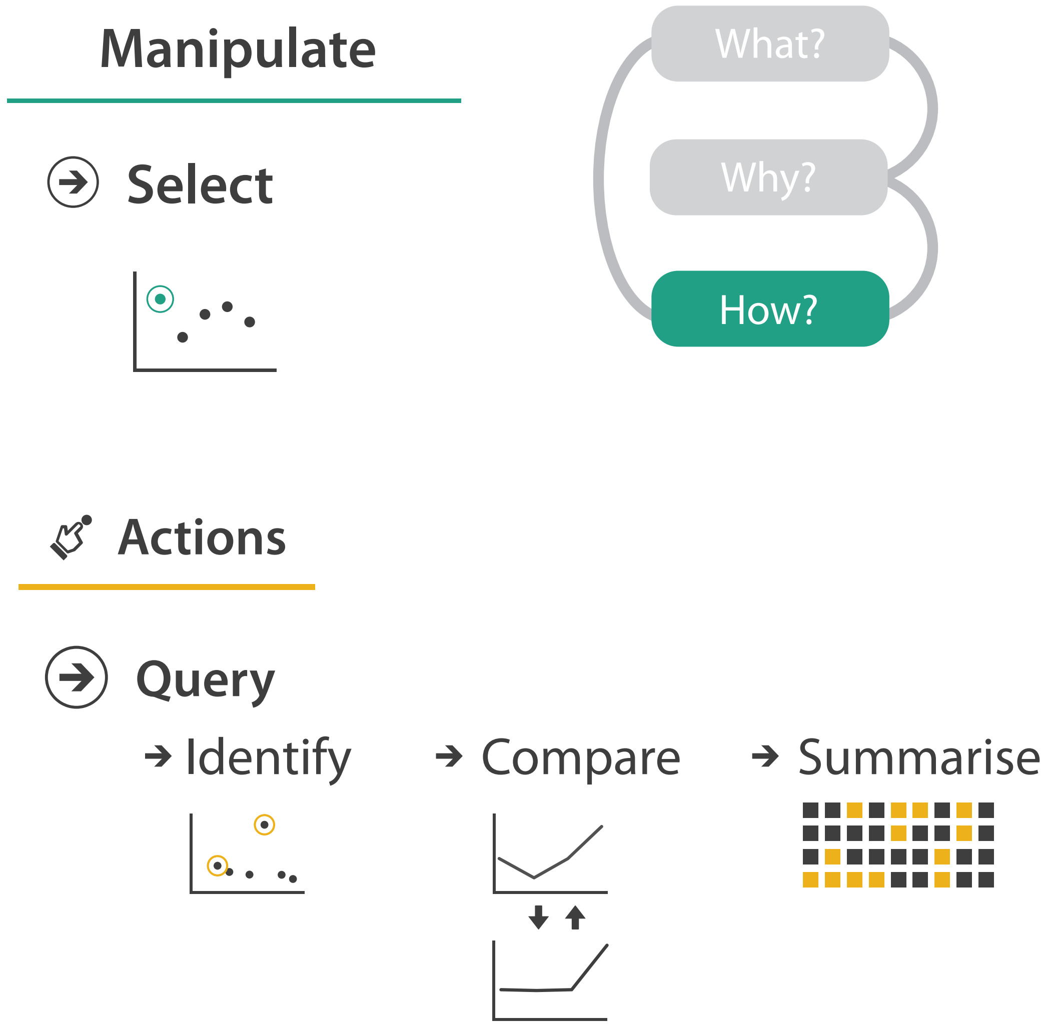


Reduce

How: Idiom design choices

- outer ring: summarize relationships with color
  - select one chromosome from set of source chromosomes
- inner ring:
  - destination chromosomes around copy of selected source chromosome
  - show relationship details with connection marks as well as color





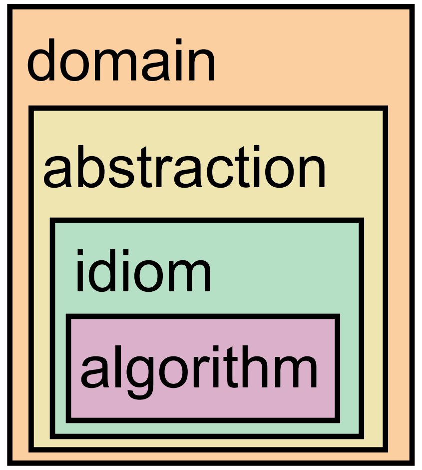
MizBee contributions

- first synteny browser with side-by-side linked views
  - across the range of scales
  - encoding all four conservation relationship types
    - proximity, size, orientation, similarity

- open source
  http://www.cs.utah.edu/~miriah/mizbee

Visualization: Abstractions & idioms

- levels of design
  - identify abstractions
    - crucial & difficult, iterative process
  - select appropriate idioms
    - or create new ones if necessary

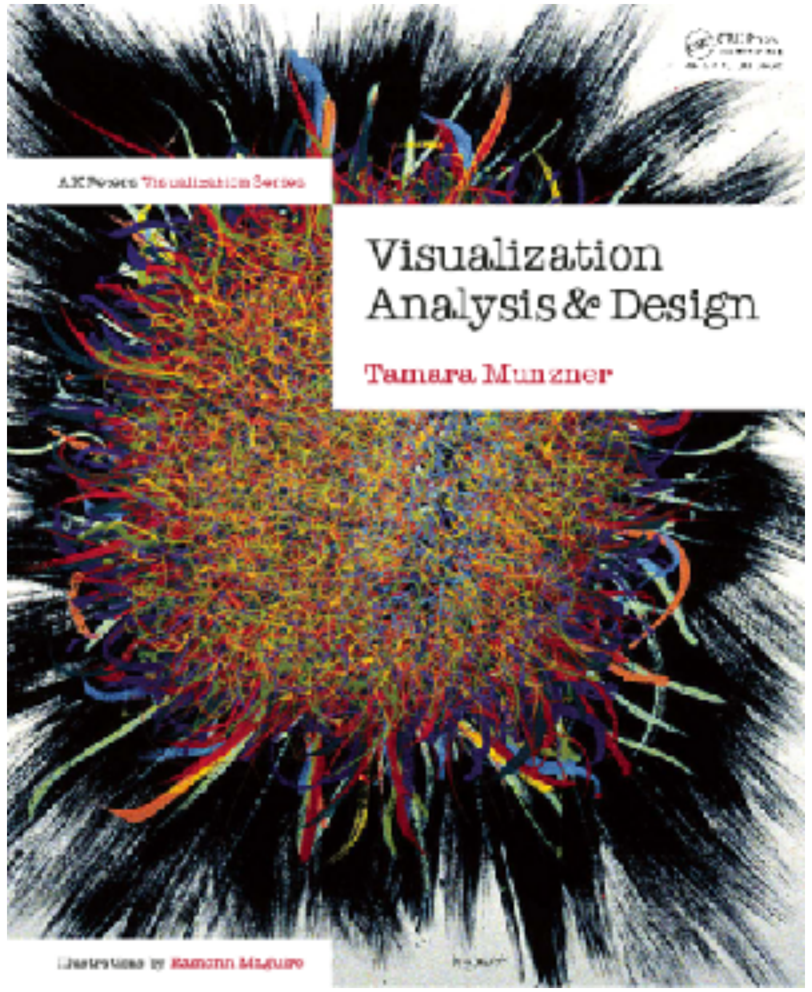


- three examples
  - different domains
  - different abstractions
  - different idioms



More information

- theoretical foundations: book
  (+ tutorial/course lecture slides)
  http://www.cs.ubc.ca/~tmm/vadbook



Visualization Analysis and Design.
Munzner.
AK Peters Visualization Series.
CRC Press, 2014.

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