Problem-Driven Visualization Through Design Studies

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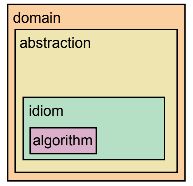
http://www.cs.ubc.ca/~tmm/talks.html#chinavis20

Nested model: Four levels of visualization concerns



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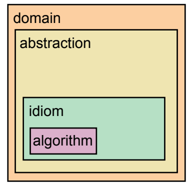
  - **who** are the target users?



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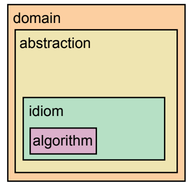

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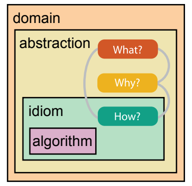

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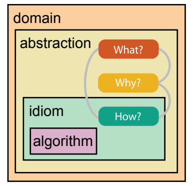

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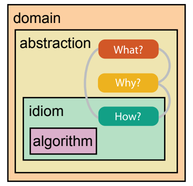

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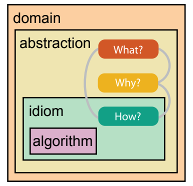

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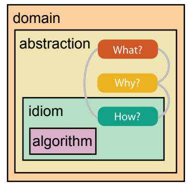

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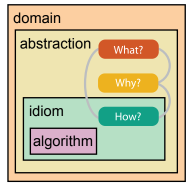

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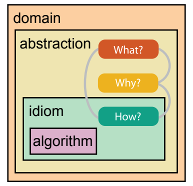
- *algorithm*
  - efficient computation



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Algorithm
Your code is too slow

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Validation solution: use methods from appropriate fields at each level

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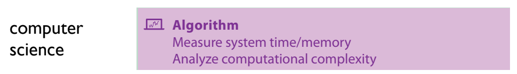

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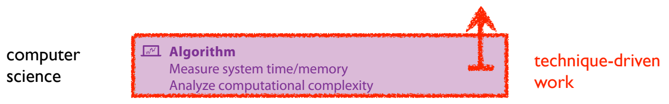

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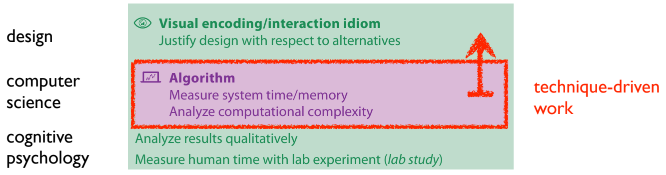

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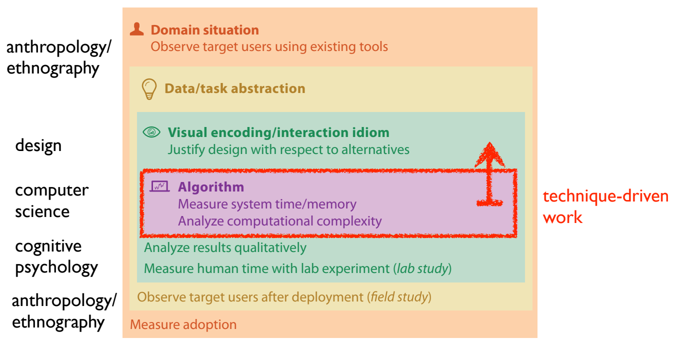

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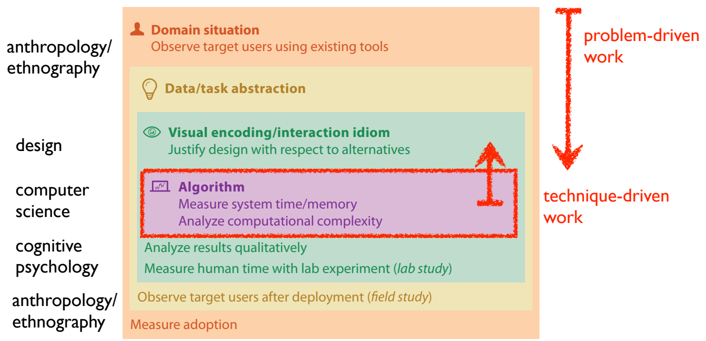

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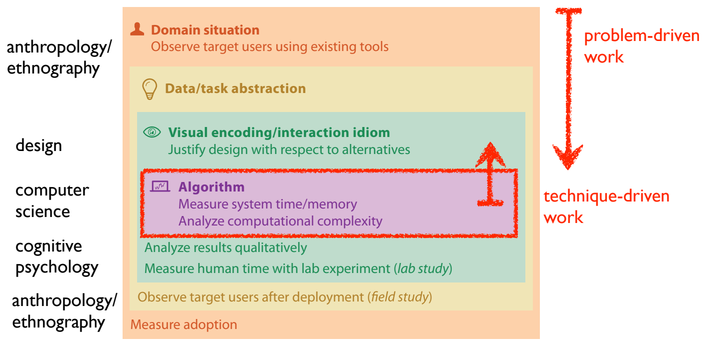
- avoid mismatches between level and validation



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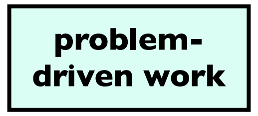

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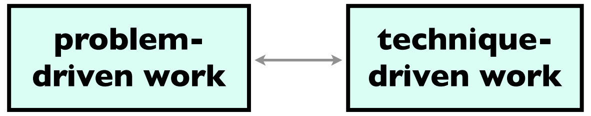

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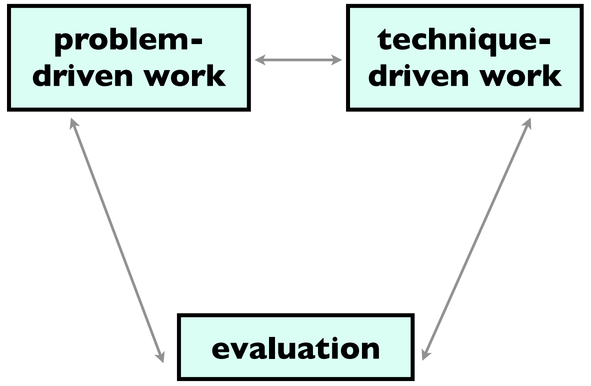

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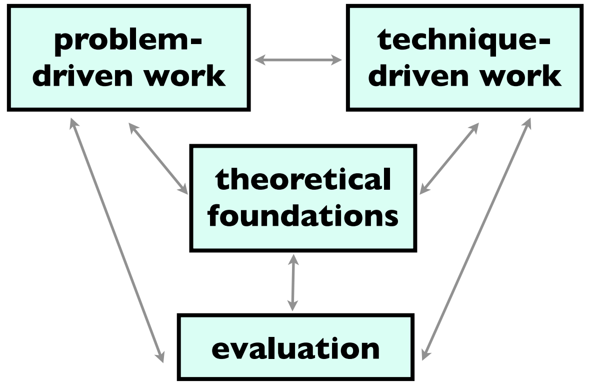

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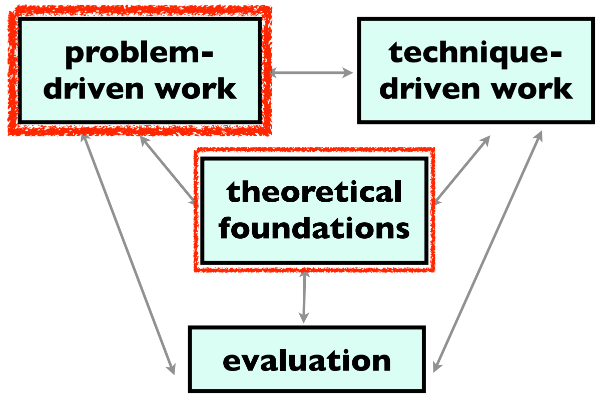

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"A design study is a project in which visualization researchers analyze a specific real-world problem faced by domain experts, design a visualization system that supports solving this problem, validate the design, and reflect about lessons learned in order to refine visualization design guidelines."

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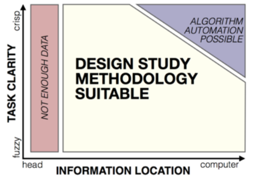

Michael Sedlmair

Miriah Meyer

Design Study Methodology

Reflections from the Trenches and from the Stacks

http://www.cs.ubc.ca/labs/imager/tr/2012/dsm/

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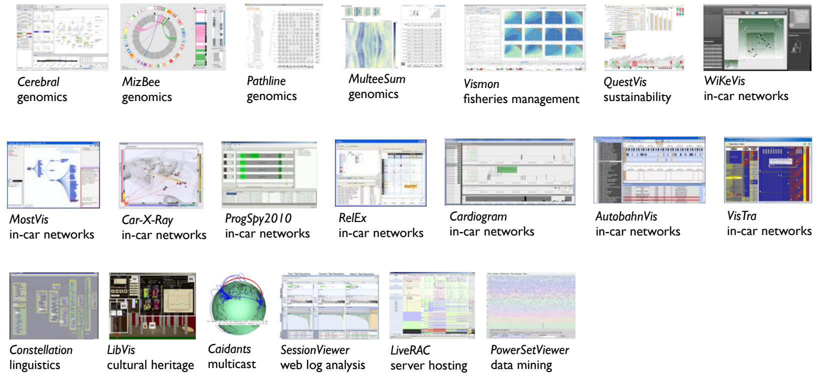
Lessons learned from the trenches: 20+ between us



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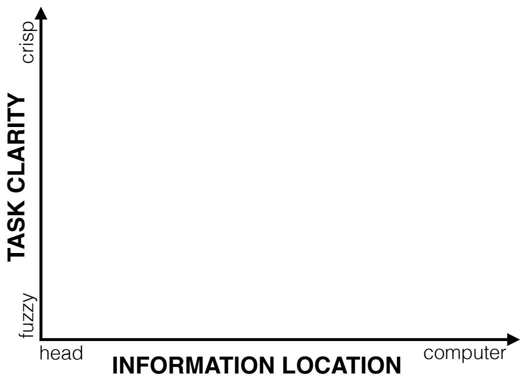

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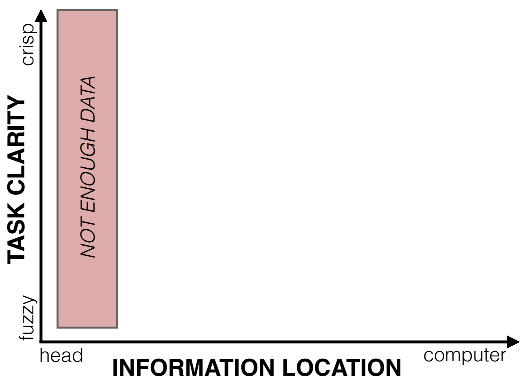

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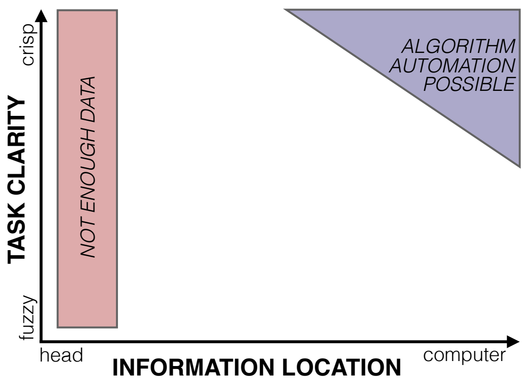

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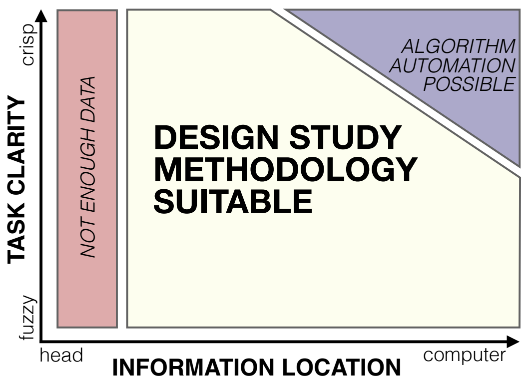

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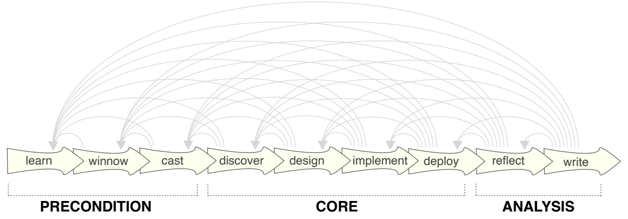
9-stage framework



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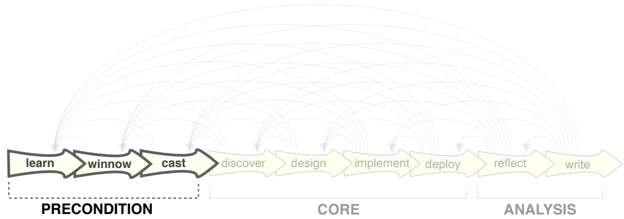
9-stage framework

learn
winnow
cast



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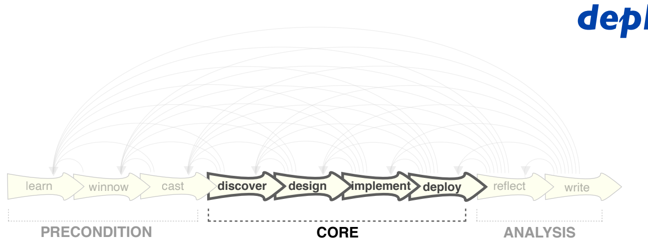
9-stage framework

discover
design
implement
deploy



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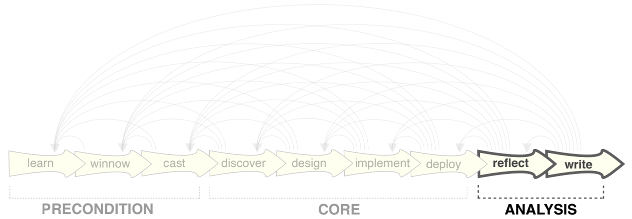
9-stage framework

reflect
write

- guidelines: confirm, refine, reject, propose



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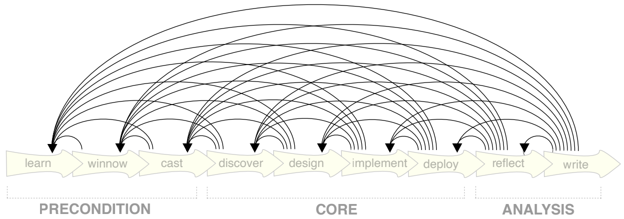

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32 pitfalls & how to avoid them

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32 pitfalls & how to avoid them

PF-1	premature advance: jumping forward over stages	general
PF-2	premature start: insufficient knowledge of vis literature	learn
PF-3	premature commitment: collaboration with wrong people	winnow
PF-4	no real data available (yet)	winnow
PF-5	insufficient time available from potential collaborators	winnow
PF-6	no need for visualization: problem can be automated	winnow
PF-7	researcher expertise does not match domain problem	winnow
PF-8	no need for research: engineering vs. research project	winnow
PF-9	no need for change: existing tools are good enough	winnow
PF-10	no real/important/recurring task	winnow
PF-11	no rapport with collaborators	winnow
PF-12	not identifying front line analyst and gatekeeper before start	cast
PF-13	assuming every project will have the same role distribution	cast
PF-14	mistaking fellow tool builders for real end users	cast

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PF-14	mistaking fellow tool builders for real end users	cast
PF-15	ignoring practices that currently work well	discover
PF-16	expecting *just talking* or *fly on wall* to work	discover
PF-17	experts focusing on visualization design vs. domain problem	discover
PF-18	learning their problems/language: too little / too much	discover
PF-19	abstraction: too little	design
PF-20	premature design commitment: consideration space too small	design

PF-21	mistaking technique-driven for problem-driven work	design
PF-22	nonrapid prototyping	implement
PF-23	usability: too little / too much	implement
PF-24	premature end: insufficient deploy time built into schedule	deploy
PF-25	usage study not case study: non-real task/data/user	deploy
PF-26	*liking* necessary but not sufficient for validation	deploy

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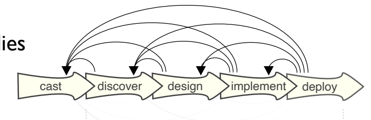
PF-26	*liking* necessary but not sufficient for validation	deploy
PF-27	failing to improve guidelines: confirm, refine, reject, propose	reflect
PF-28	insufficient writing time built into schedule	write
PF-29	no technique contribution ≠ good design study	write
PF-30	too much domain background in paper	write
PF-31	story told chronologically vs. focus on final results	write
PF-32	premature end: win race vs. practice music for debut	write

[Design Study Methodology: Reflections from the Trenches and the Stacks. Sedlmair, Meyer & Munzner. IEEE TVCG 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).]

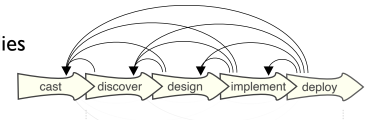
Design studies & user-centered design

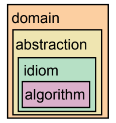
- user-centered design: well-known HCI methodology
  - iterative refinement & deployment
  - evaluation through case studies & field studies



Design studies & user-centered design

- user-centered design: well-known HCI methodology
  - iterative refinement & deployment
  - evaluation through case studies & field studies
- what's specific to visualization?
  - discovering task and data **abstractions**
  - designing visual encoding & interaction **idioms** that map to abstractions





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

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Kim Dextras-Romagnino

Segmentifier

Interactive Refinement of Clickstream Data

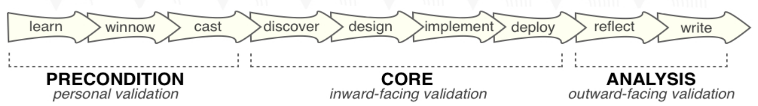
http://www.cs.ubc.ca/labs/imager/tr/2019/segmentifier

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

Process: Design Study Methodology

- **Precondition Phase** (5 months) : interviews with 12 employees
- **Core Phase** (11 months): Iterative design and implementation
- **Analysis Phase** (3 months): Reflect and write



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

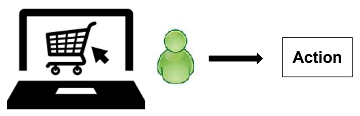
Clickstream Data

Clickstream Analysis Tasks

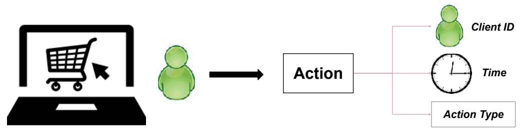
Segmentifier Analysis Model

What is ***Clickstream Data***?

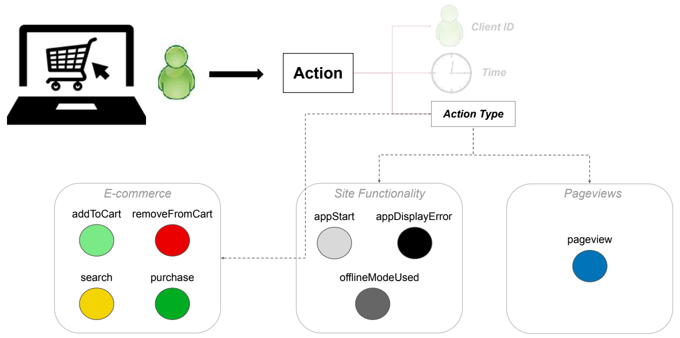
Data: *Actions*



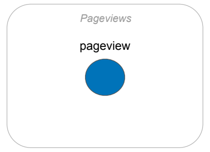
Data: *Action Attributes*



Data: *Action Types*



Action Hierarchy



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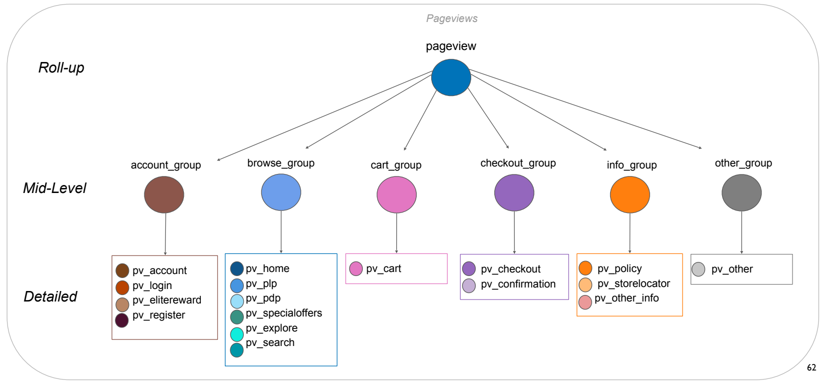
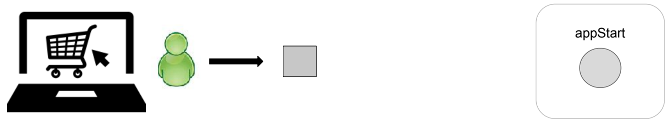


Data: *Sequences*



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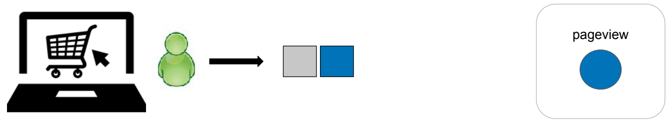
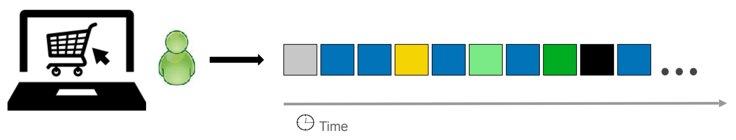
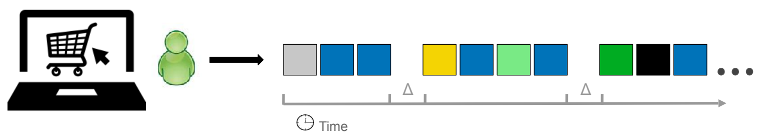


Data: *Client Sequences*



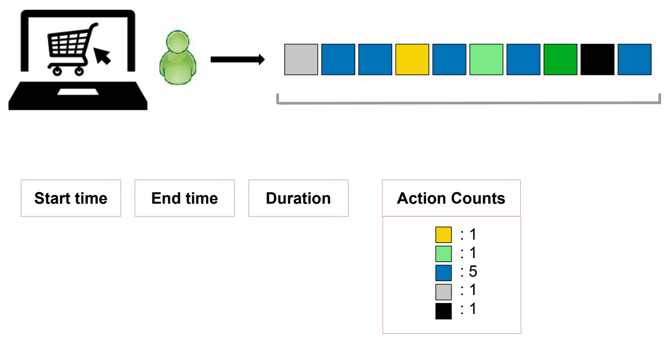
Client Sequences: all actions performed by a single user

Data: *Session Sequences*

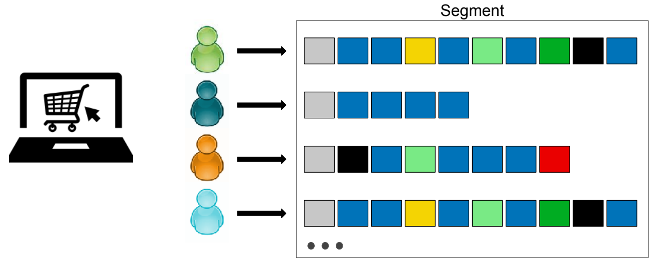


Session Sequences: all actions performed by a single user within a defined amount of time (Δ) from each other.
Δ is usually 30 min.

Data: *Sequence Attributes*

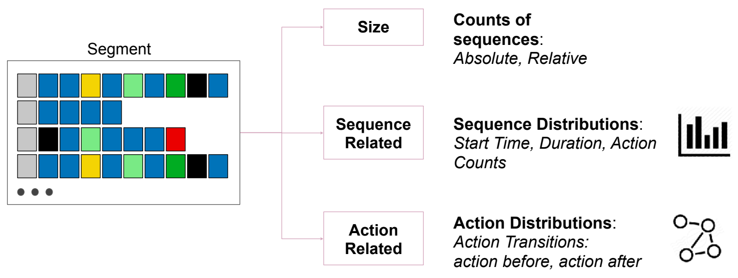


Data: *Segments*

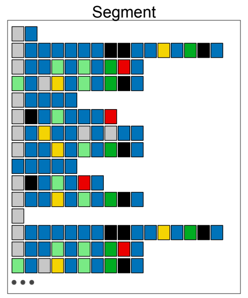


Segment: any set of sequences

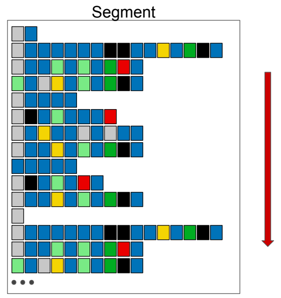
Data: *Segment Attributes*



Real-world Clickstream Data

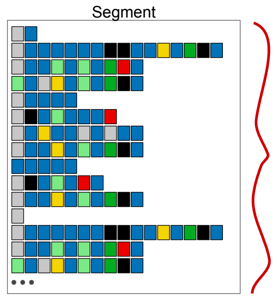


Real-world Clickstream Data



Scale is huge

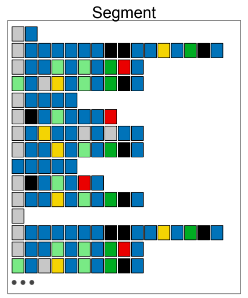
Real-world Clickstream Data



Scale is huge

Variability is high

Real-world Clickstream Data



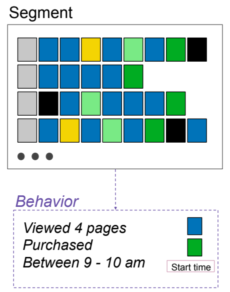
Scale is huge

Variability is high

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

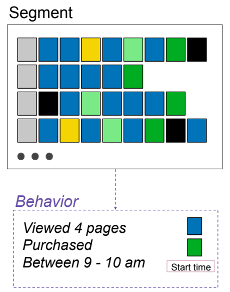
What are
Clickstream Data Analysis Tasks?

Tasks: Segment Behavior



Behavior: set of attribute constraints

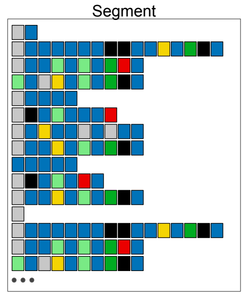
Tasks: Segment Behavior



Behavior: set of attribute constraints

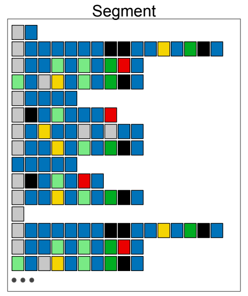
- **Expected**
  Users add to cart before purchasing
- **Unexpected**
  No purchases on a certain month
- **Favorable**
  Purchased
- **Unfavorable**
  Bounced

Tasks: Task Abstraction



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

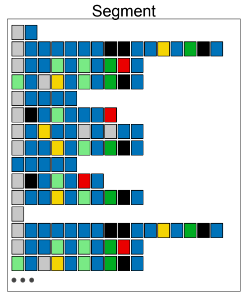
Tasks: Task Abstraction



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

Tasks: Task Abstraction



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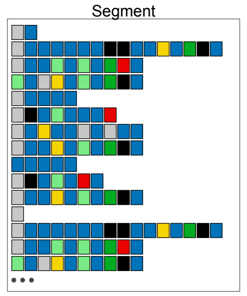
Drilldown: Distinguish more specific *behaviors* to further partition a segment previously defined by looser constraints

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

Tasks: Task Abstraction



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

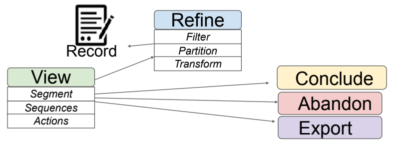
Frequency: Determine how many sequences are in the segment defined by *behavior*

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



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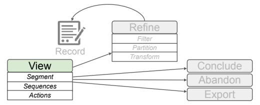
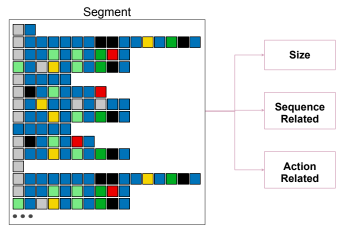
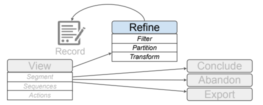


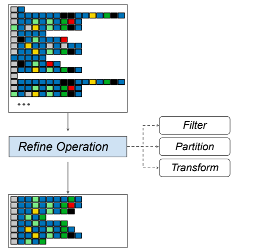


View

- 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

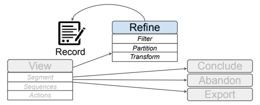


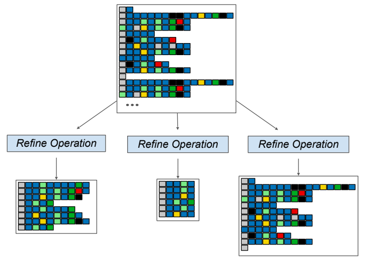


Refine

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

High-Level Segmentifier Analysis Model

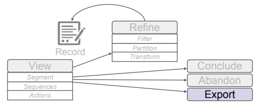


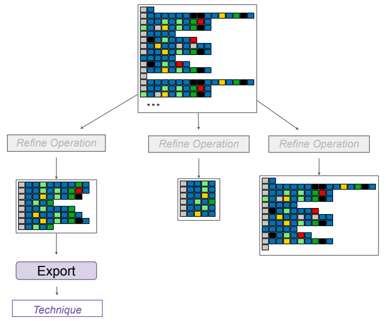


Refine

- 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

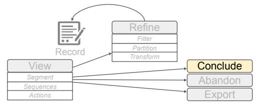


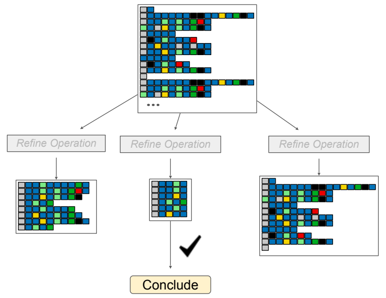


Export

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

High-Level Segmentifier Analysis Model

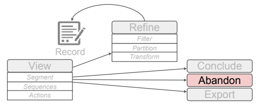


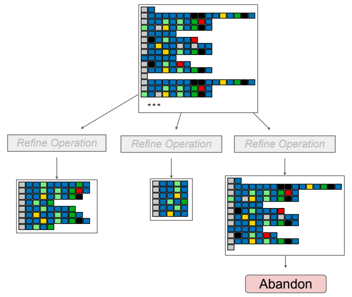


Conclude

- Discover actionable insight by *viewing* segment

High-Level Segmentifier Analysis Model

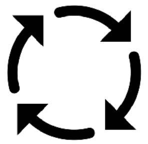




Abandon

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

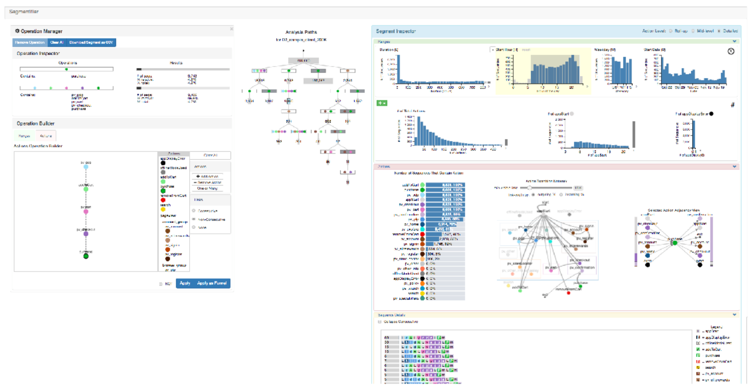
Why Visual Analytics?



- 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

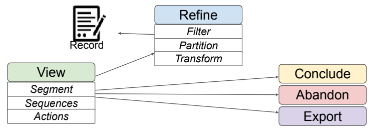


Video

https://www.youtube.com/watch?v=TobYDFelSOg&t=20s

Segmentifier Contributions

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



Segmentifier Contributions

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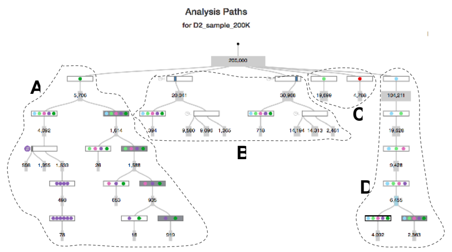
Segmentifier Contributions

- ➢ 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**



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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.

Location-Based Counts

Previous measurement required physical counting or installation of additional hardware.

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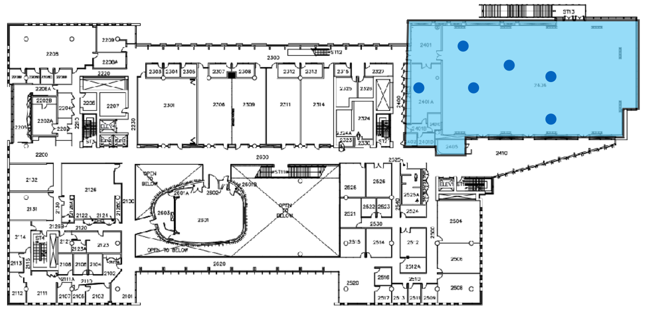
Previous visualization attempts were limited in space and time.

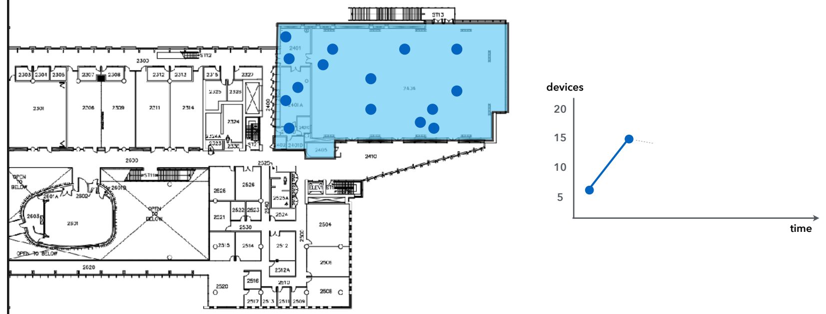
Design Study

WiFi Connections: Location-Based Counts

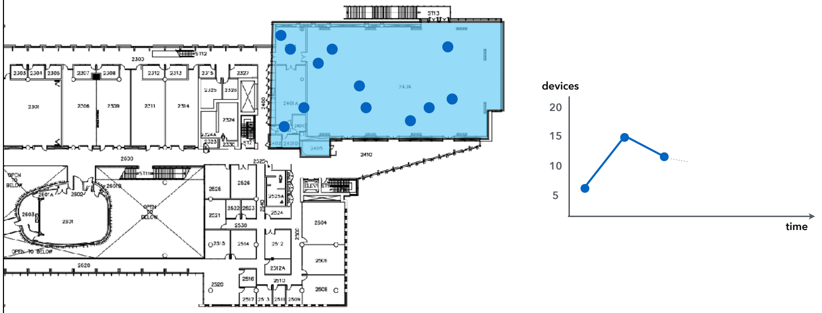


WiFi Connections: Location-Based Counts

WiFi Connections: Location-Based Counts



WiFi Connections: Location-Based Counts



WiFi Connections: Location-Based Counts

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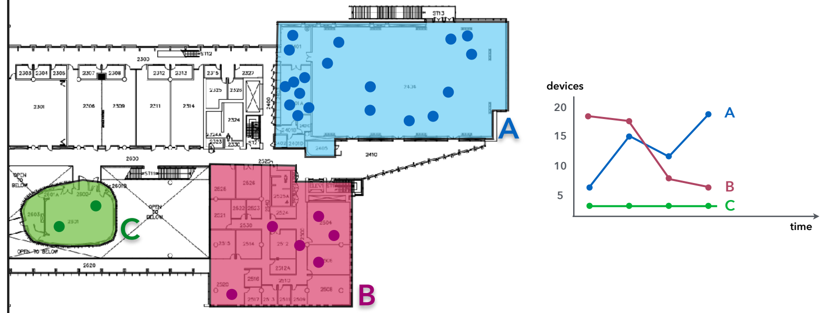
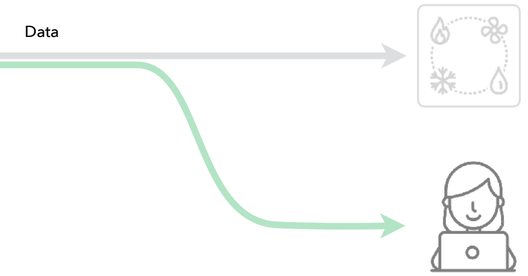


WiFi Connections: Location-Based Counts

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

Automated
HVAC control

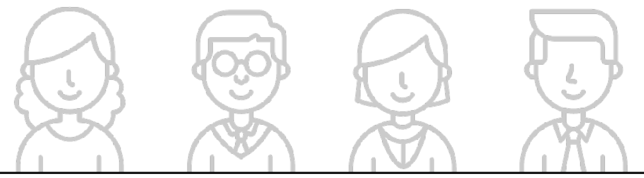


Decision
making

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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- Space planning
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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

Spatial and Temporal Data Granularities

Regions of interest

Periods of interest

Mondays · Weekdays · last 12 hours · Summer term · Fr 8-10am · Weekends

Visualization Prototypes

Sandbox
Data sketches, static data export

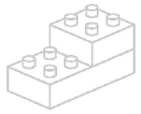
Campus Explorer
Live-data stream, cross-building analysis

Building Recent

Building Long-term

Region Compare

Time



Reusable Visualization Components

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

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)*

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)*
	Confidence band line chart	Aggregation	Typical utilization profiles

Reusable Visualization Components

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Reusable Visualization Components

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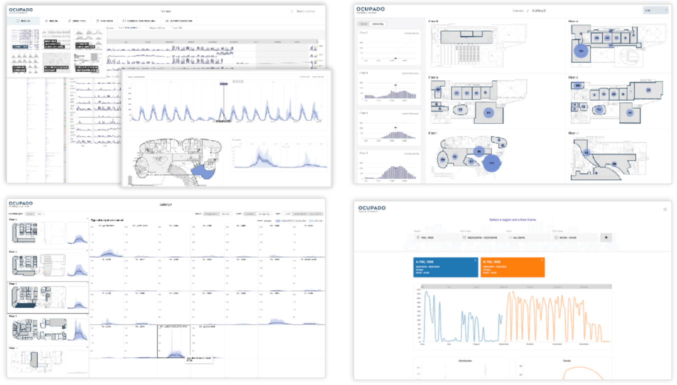
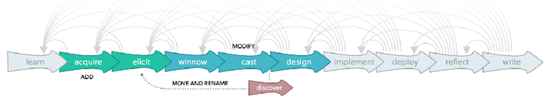
		Confidence band line chart	Aggregation	Typical utilization profiles
		Superimposed line chart	Superposition	Within-session patterns, outliers
Spatial		Floor plan with symbols	Superposition	Within local spatial neighborhood
		Spatial heatmap	Containment (nested)	Across distributed regions

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



Michael Oppermann

Data-First Design Studies

http://www.cs.ubc.ca/group/infovis/pubs/2020/data-first/

Data-First Design Studies.
Oppermann and Munzner. Proc. IEEE VIS BELIV Workshop 2020.

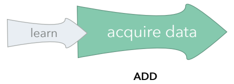
Original DSM framework

Original DSM framework

Data-first DSM framework

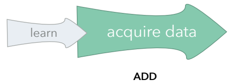
Original DSM framework

Data-first DSM framework



Original DSM framework

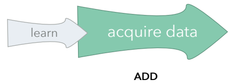
Data-first DSM framework



- What type of data am I working with?

Original DSM framework

Data-first DSM framework



- What type of data am I working with?
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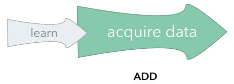
Original DSM framework

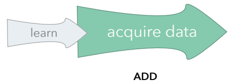
Data-first DSM framework



- What type of data am I working with?
- Are there any data quality challenges?
- What is special about this data?

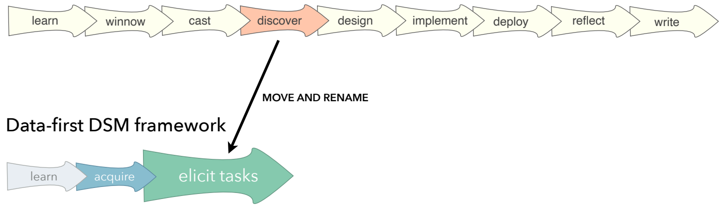
Original DSM framework

Data-first DSM framework

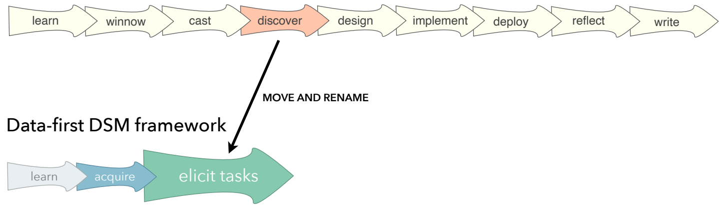


- What type of data am I working with?
- Are there any data quality challenges?
- What is special about this data?
- Who would benefit from seeing and exploring it?

Original DSM framework

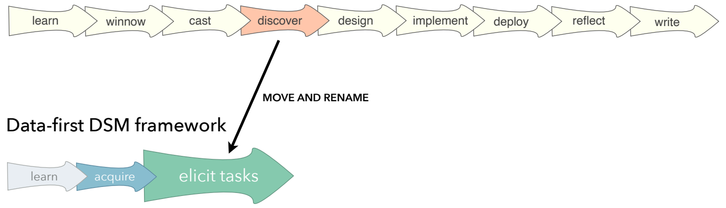


Original DSM framework



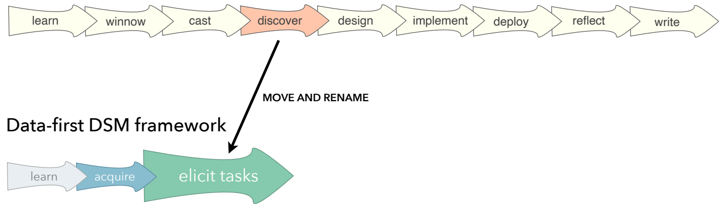
- Multiple potential stakeholders

Original DSM framework



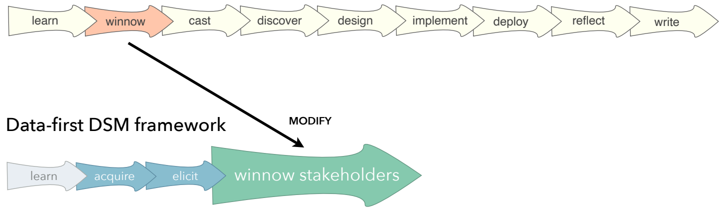
- Multiple potential stakeholders
- Explain initial data abstractions

Original DSM framework

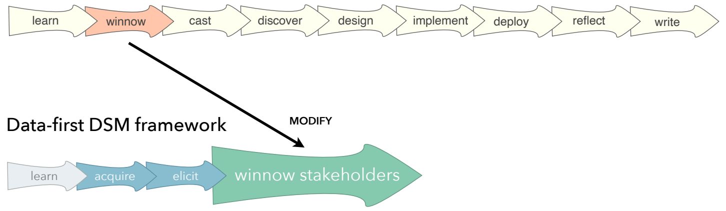


- Multiple potential stakeholders
- Explain initial data abstractions
- Learn about unsolved stakeholder needs

Original DSM framework

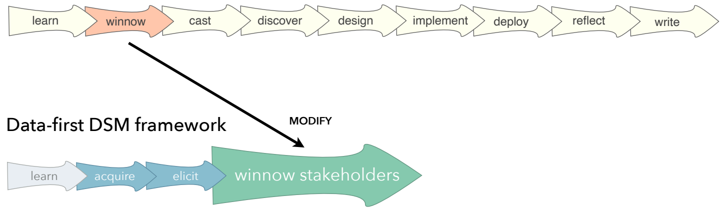


Original DSM framework



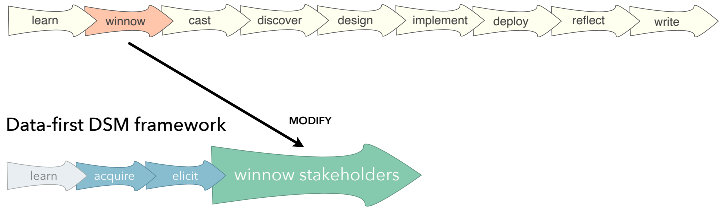
- How frequent are their data-relevant tasks?

Original DSM framework



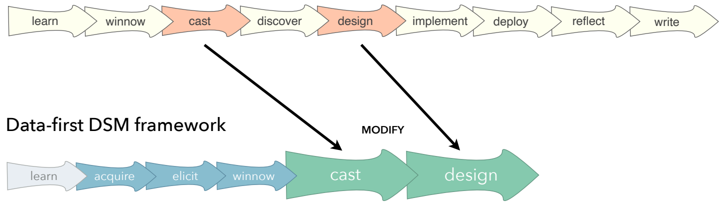
- How frequent are their data-relevant tasks?
- How central are these tasks to the stakeholder's primary mission?

Original DSM framework

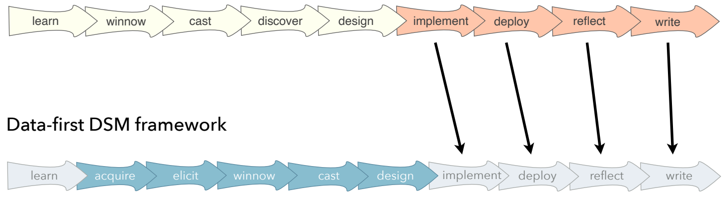


- How frequent are their data-relevant tasks?
- How central are these tasks to the stakeholder's primary mission?
- How many people in the organization deal with these tasks?

Original DSM framework



Original DSM framework



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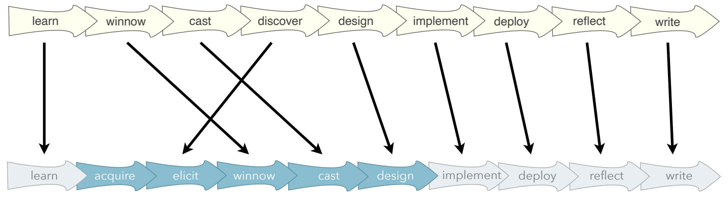


Data-first DSM framework

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

Zipeng Liu

Shing Hei Zhan

Aggregated Dendrograms

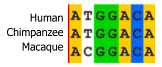
for Visual Comparison Between Many Phylogenetic Trees

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

Aggregated Dendrograms for Visual Comparison Between Many Phylogenetic Trees.
Liu, Zhan, Munzner. IEEE Trans. Visualization and Computer Graphics (TVCG) 26(9):2732-2747, 2019.

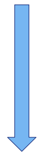
Phylogenetic tree

Evolutionary relationships of organisms

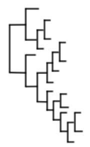


Genetic information

Computational workflow



Phylogenetic tree



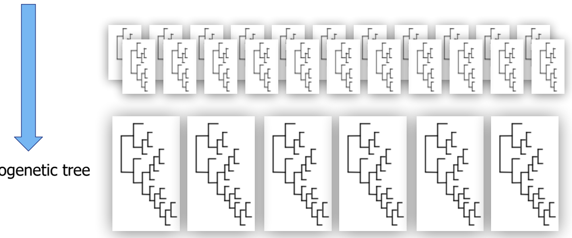
Many phylogenetic trees

- Understand relationships between genes and species trees
- Explore trees generated with different methods and data

Genetic information

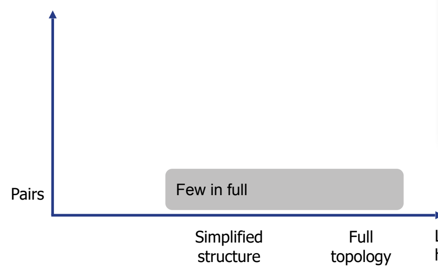
Computational workflow

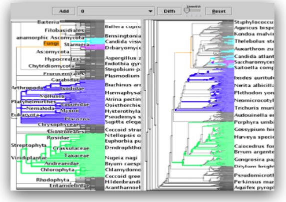
Phylogenetic tree



Scalability of Existing Tree Comparison Systems

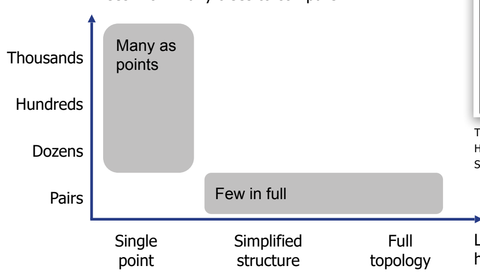
Scalability of Existing Tree Comparison Systems

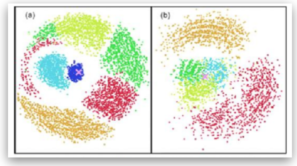




TreeJuxtaposer.
Munzner, Guimbretière, Zhang, Zhou.
SIGGRAPH 2003

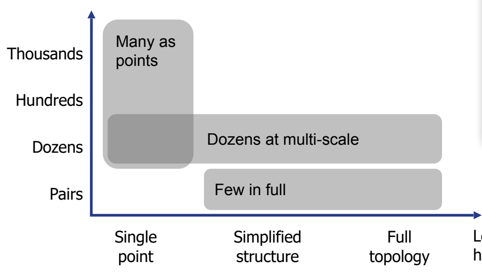
Scalability of Existing Tree Comparison Systems

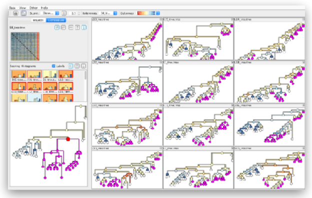




Tree space.
Hillis, Health, John.
Systematic Biology 2005.

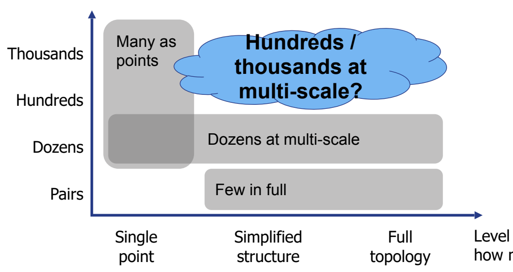
Scalability of Existing Tree Comparison Systems





Interactive visual comparison of multiple trees.
Bremm, Landesberger, Heß, Schreck, Weil, Hamacher.
VAST 2011.

Comparing many phylogenetic trees



Contributions include idiom & algorithm levels

- Data and task abstractions for comparison of phylogenetic trees

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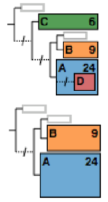
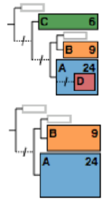
- Data and task abstractions for comparison of phylogenetic trees
- A new visual encoding: **Aggregated Dendrogram**
  - Compact tree representation that focuses on selected subtrees
  - Adapts to available screen space



Contributions include idiom & algorithm levels

- Data and task abstractions for comparison of phylogenetic trees
- A new visual encoding: **Aggregated Dendrogram**
  - Compact tree representation that focuses on selected subtrees
  - Adapts to available screen space
- A multi-view interactive tool: **ADView**
  - Covers multiple levels of details for tree comparison

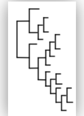


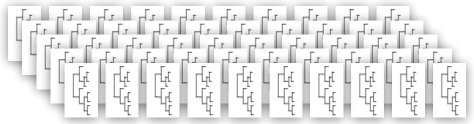
Data & Tasks

- Tree data
- Two crucial tasks

Tree data

Reference tree vs. Tree collection





Two crucial tasks

Topological relationships between subtrees / leaf nodes

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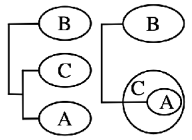
Topological relationships between subtrees / leaf nodes

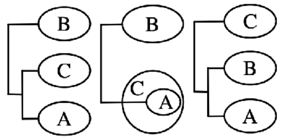


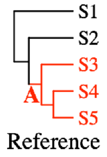
Two crucial tasks

Topological relationships between subtrees / leaf nodes

- Topological distance

Leaf node memberships compared to reference tree





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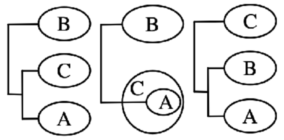

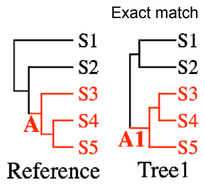

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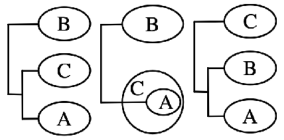
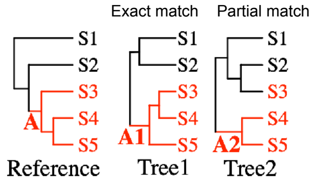


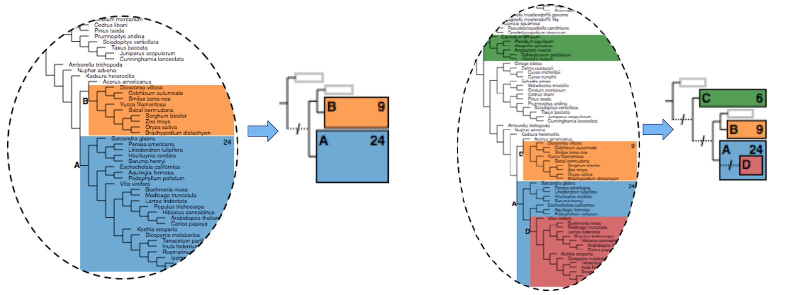


Aggregated Dendrogram (AD)

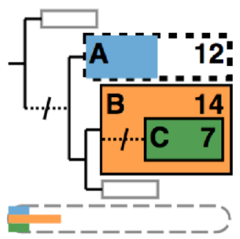
- Intuition
- Visual design

Intuition

Use glyphs to compress a tree according to user selections



Visual design: focus + context



Visual design: focus + context

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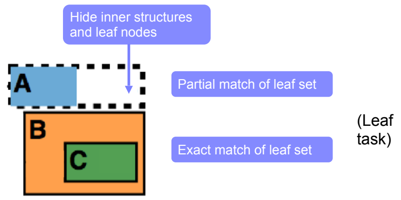
  - Selected subtrees



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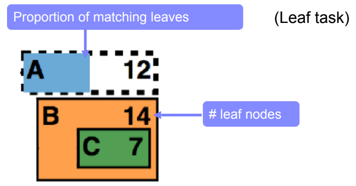
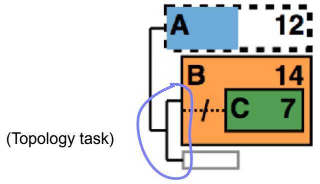


Visual design: focus + context

- Focus
  - Selected subtrees
  - Topological relationships between them



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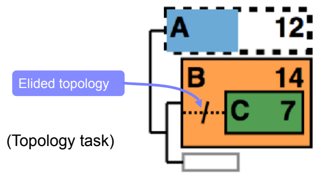
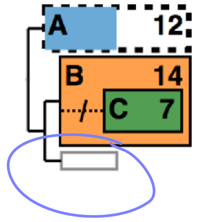


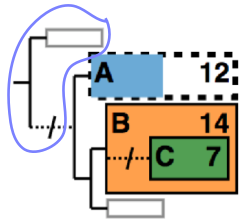
Visual design: focus + context

- Focus
  - Selected subtrees
  - Topological relationships between them
- Context
  - Neighboring subtrees



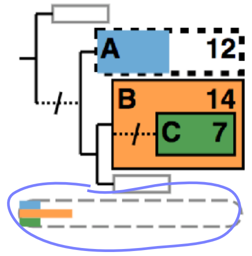
Visual design: focus + context

- Focus
  - Selected subtrees
  - Topological relationships between them
- Context
  - Neighboring subtrees
  - Upstream topology and root



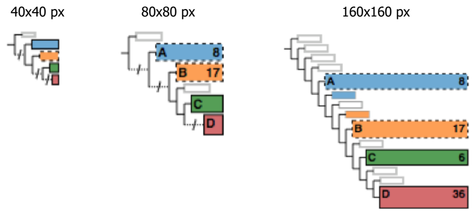
Visual design: focus + context

- Focus
  - Selected subtrees
  - Topological relationships between them
- Context
  - Neighboring subtrees
  - Upstream topology and root
  - Missing leaf nodes

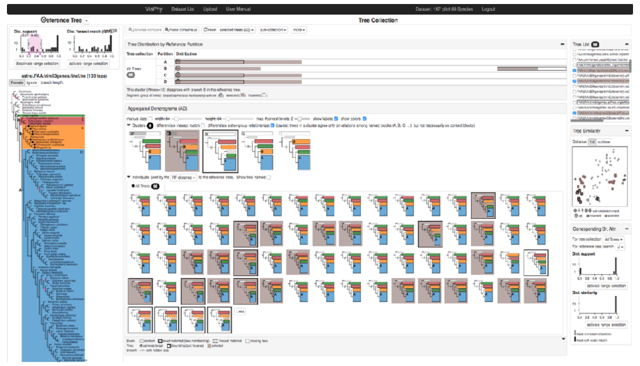


Visual design: algorithm adapts to space

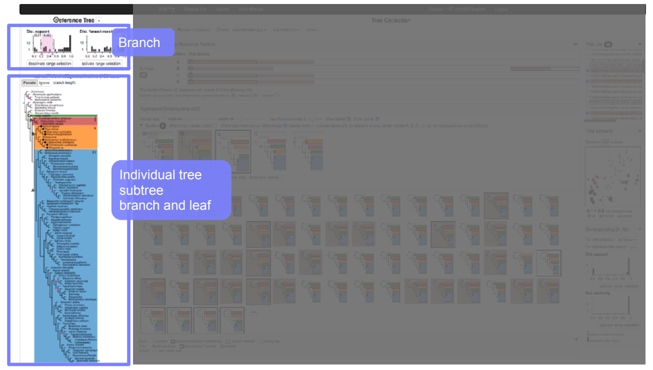
- Show more info when space permitted
  - Labels
  - #leaf nodes
  - Neighboring blocks



ADView Interface: Multi-level structure across views

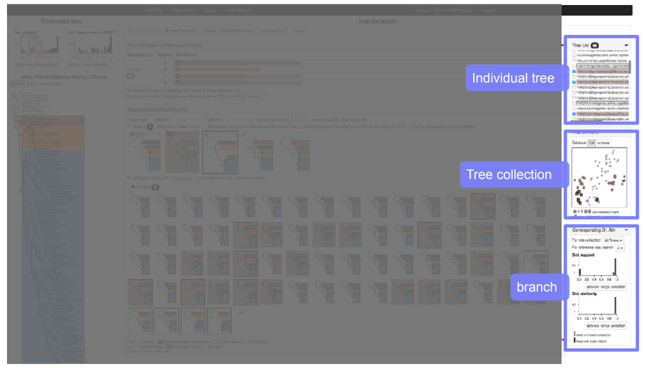


Multi-level structure across views



Interface walkthrough: tree collection main views

Interface walkthrough: tree collection aux. views



Validation with many biologists

- Work closely with a biology PhD student (second author)
- Demos, interviews and discussions
  - 10 biologists at different times throughout project

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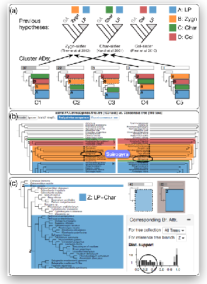

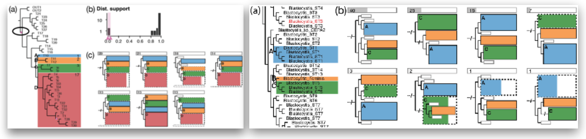

Validation with many biologists

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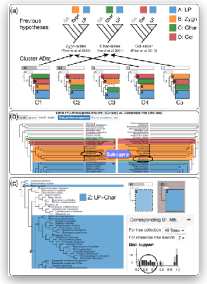
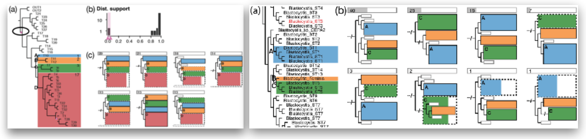
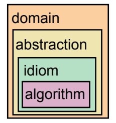
  - 10 biologists at different times throughout project
- User study sessions
  - 5 biologists
  - Using their own datasets
- Biologists confirmed
  - Validity of data and task abstractions
  - Utility of ADView





Problem-driven visualization through design studies

- methodology matters
  - identify abstractions
    - crucial & difficult, iterative process
  - select appropriate idioms
    - or create new ones if necessary

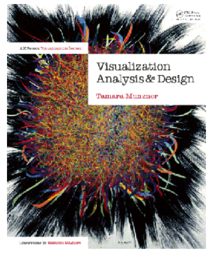


- three examples
  - different domains
  - different methods

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.



@tamaramunzner

- papers, videos, software, talks, courses
  http://www.cs.ubc.ca/group/infovis
  http://www.cs.ubc.ca/~tmm

- this talk

http://www.cs.ubc.ca/~tmm/talks.html#chinavis20