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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• *domain* situation
  – **who** are the target users?
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• *abstraction*
  – translate from specifics of domain to vocabulary of vis

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[A Multi-Level Typology of Abstract Visualization Tasks

[A Nested Model of Visualization Design and Validation.
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- **algorithm**
  - efficient computation

Why is validation difficult?

• different ways to get it wrong at each level

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Domain situation
You misunderstood their needs

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You’re showing them the wrong thing

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  The way you show it doesn’t work

Why is validation difficult?

- different ways to get it wrong at each level

Domain situation
You misunderstood their needs

Data/task abstraction
You're showing them the wrong thing

Visual encoding/interaction idiom
The way you show it doesn’t work

Algorithm
Your code is too slow

Validation solution: use methods from appropriate fields at each level

Validation solution: use methods from appropriate fields at each level

- Algorithm
  Measure system time/memory
  Analyze computational complexity

Validation solution: use methods from appropriate fields at each level

Validation solution: use methods from appropriate fields at each level

- **Design**
  - 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*)

- **Computer Science**

- **Cognitive Psychology**

---

Validation solution: use methods from appropriate fields at each level

- **Domain situation**
  - Observe target users using existing tools

- **Data/task abstraction**
  - **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*)
  - Observe target users after deployment (*field study*)
  - Measure adoption

- **Design**
- **Computer science**
- **Cognitive psychology**
- **Anthropology/ethnography**

Validation solution: use methods from appropriate fields at each level

<table>
<thead>
<tr>
<th>anthropology/ethnography</th>
<th>design</th>
<th>computer science</th>
<th>cognitive psychology</th>
<th>anthropology/ethnography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain situation: Observe target users using existing tools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data/task abstraction:</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</table>

Validation solution: use methods from appropriate fields at each level

- avoid mismatches between level and validation

 anthroponomy/ethnography

design

computer science

cognitive psychology

anthropology/ethnography

- **Domain situation**
  Observe target users using existing tools

- **Data/task abstraction**

  - **Visual encoding/interaction idiom**
    Justify design with respect to alternatives

  - **Algorithm**
    Measure system time/memory
    Analyze computational complexity

  - **Analysis**
    Analyze results qualitatively
    Measure human time with lab experiment (*lab study*)

  - **Observation**
    Observe target users after deployment (*field study*)

  - Measure adoption

Visualization: Angles of attack

problem-driven work
Visualization: Angles of attack

- problem-driven work
- technique-driven work
Visualization: Angles of attack

Problem-driven work

Technique-driven work

Evaluation
Visualization: Angles of attack

- Problem-driven work
- Technique-driven work
- Theoretical foundations
- Evaluation
Visualization: Angles of attack

- problem-driven work
- technique-driven work
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Problem-driven visualization: Design studies
“A design study is a project in which visualization researchers analyze a specific real-world problem faced by domain experts...”
Problem driven visualization: Design studies

“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...”
Problem driven visualization: Design studies

“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.”

Design Study Methodology

Reflections from the Trenches and from the Stacks

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

Design Study Methodology: Reflections from the Trenches and from the Stacks.
Lessons learned from the trenches: 20+ between us

Cerebral genomics
MizBee genomics
Pathline genomics
MulteeSum genomics
Vismon fisheries management
QuestVis sustainability
WiKeVis in-car networks

MostVis in-car networks
Car-X-Ray in-car networks
ProgSpy2010 in-car networks
RelEx in-car networks
Cardiogram in-car networks
AutobahnVis in-car networks
VisTra in-car networks

Constellation linguistics
LibVis cultural heritage
Caidants multicast
SessionViewer web log analysis
LiveRAC server hosting
PowerSetViewer data mining
Design study methodology: definitions

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9-stage framework

9-stage framework

learn
winnow
cast

PRECONDITION

discovery

design

implement

deploy

reflect

write

CORE

ANALYSIS

9-stage framework

discover
design
implement
deploy

9-stage framework

• guidelines: confirm, refine, reject, propose
9-stage framework

iterative

32 pitfalls & how to avoid them

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 |
32 pitfalls & how to avoid them

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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 just on well 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               |

### 32 pitfalls & how to avoid them

![Diagram](design-study-flowchart.png)

<table>
<thead>
<tr>
<th>Pitfall</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PF-1</strong> Premature advance: jumping forward over stages</td>
<td>General</td>
<td>General categories include: premature start, insufficient knowledge, etc.</td>
</tr>
<tr>
<td><strong>PF-2</strong> Premature start: insufficient knowledge of visualization</td>
<td>Learn</td>
<td>Learn categories include: insufficient knowledge, too much domain background, etc.</td>
</tr>
<tr>
<td><strong>PF-3</strong> Premature commitment: collaboration with wrong people</td>
<td>Winnow</td>
<td>Winnow categories include: collaboration, not identifying front line analyst, etc.</td>
</tr>
<tr>
<td><strong>PF-4</strong> No real data available (yet)</td>
<td>Winnow</td>
<td>Winnow categories include: data availability, not identifying front line analyst, etc.</td>
</tr>
<tr>
<td><strong>PF-5</strong> Insufficient time available from potential collaborators</td>
<td>Winnow</td>
<td>Winnow categories include: data availability, time constraints, etc.</td>
</tr>
<tr>
<td><strong>PF-6</strong> No need for visualization: problem can be automated</td>
<td>Winnow</td>
<td>Winnow categories include: visualization, automated solution, etc.</td>
</tr>
<tr>
<td><strong>PF-7</strong> Researcher expertise does not match domain problem</td>
<td>Winnow</td>
<td>Winnow categories include: expertise, domain problem, etc.</td>
</tr>
<tr>
<td><strong>PF-8</strong> No need for research: engineering vs. research project</td>
<td>Winnow</td>
<td>Winnow categories include: research need, engineering vs. research project, etc.</td>
</tr>
<tr>
<td><strong>PF-9</strong> No need for change: existing tools are good enough</td>
<td>Winnow</td>
<td>Winnow categories include: tool availability, existing tools, etc.</td>
</tr>
<tr>
<td><strong>PF-10</strong> No real/important/recurring task</td>
<td>Winnow</td>
<td>Winnow categories include: task importance, recurring task, etc.</td>
</tr>
<tr>
<td><strong>PF-11</strong> No rapport with collaborators</td>
<td>Winnow</td>
<td>Winnow categories include: rapport, collaborative efforts, etc.</td>
</tr>
<tr>
<td><strong>PF-12</strong> Not identifying front line analyst and gatekeeper before start</td>
<td>Cast</td>
<td>Cast categories include: front line analyst, gatekeeper, start of project, etc.</td>
</tr>
<tr>
<td><strong>PF-13</strong> Assuming every project will have the same role distribution</td>
<td>Cast</td>
<td>Cast categories include: role distribution, project similarity, etc.</td>
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<td><strong>PF-14</strong> Mistaking fellow tool builders for real end users</td>
<td>Cast</td>
<td>Cast categories include: tool builders, real end users, etc.</td>
</tr>
<tr>
<td><strong>PF-15</strong> Ignoring practices that currently work well</td>
<td>Discover</td>
<td>Discover categories include: practices, current work, etc.</td>
</tr>
<tr>
<td><strong>PF-16</strong> Expecting <em>just</em> talking or <em>fly on well</em> to work</td>
<td>Discover</td>
<td>Discover categories include: expectation, communication, etc.</td>
</tr>
<tr>
<td><strong>PF-17</strong> Experts focusing on visualization design vs. domain problem</td>
<td>Discover</td>
<td>Discover categories include: visualization, domain problem, etc.</td>
</tr>
<tr>
<td><strong>PF-18</strong> Learning their problems/language: too little / too much</td>
<td>Discover</td>
<td>Discover categories include: language, problem understanding, etc.</td>
</tr>
<tr>
<td><strong>PF-19</strong> Abstraction: too little</td>
<td>Design</td>
<td>Design categories include: abstraction, insufficient knowledge, etc.</td>
</tr>
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<td><strong>PF-20</strong> Premature design commitment: consideration space too small</td>
<td>Design</td>
<td>Design categories include: design commitment, space considerations, etc.</td>
</tr>
<tr>
<td><strong>PF-21</strong> Mistaking technique-driven for problem-driven work</td>
<td>Design</td>
<td>Design categories include: technique-driven, problem-driven, etc.</td>
</tr>
<tr>
<td><strong>PF-22</strong> Non-rapid prototyping</td>
<td>Implement</td>
<td>Implement categories include: prototyping, time constraints, etc.</td>
</tr>
<tr>
<td><strong>PF-23</strong> Usability: too little / too much</td>
<td>Implement</td>
<td>Implement categories include: usability, user experience, etc.</td>
</tr>
<tr>
<td><strong>PF-24</strong> Premature end: insufficient deploy time built into schedule</td>
<td>Deploy</td>
<td>Deploy categories include: deployment, insufficient time, etc.</td>
</tr>
<tr>
<td><strong>PF-25</strong> Usage study not case study: non-real task/data/user</td>
<td>Deploy</td>
<td>Deploy categories include: usage study, case study, etc.</td>
</tr>
<tr>
<td><strong>PF-26</strong> Liking necessary but not sufficient for validation</td>
<td>Deploy</td>
<td>Deploy categories include: liking, validation, etc.</td>
</tr>
<tr>
<td><strong>PF-27</strong> Failing to improve guidelines: confirm, refine, reject, propose</td>
<td>Reflect</td>
<td>Reflect categories include: guidelines, improvement, etc.</td>
</tr>
<tr>
<td><strong>PF-28</strong> Insufficient writing time built into schedule</td>
<td>Reflect</td>
<td>Reflect categories include: time constraints, writing, etc.</td>
</tr>
<tr>
<td><strong>PF-29</strong> No technique contribution ≠ good design study</td>
<td>Write</td>
<td>Write categories include: technique contribution, design study, etc.</td>
</tr>
<tr>
<td><strong>PF-30</strong> Too much domain background in paper</td>
<td>Write</td>
<td>Write categories include: domain background, paper, etc.</td>
</tr>
<tr>
<td><strong>PF-31</strong> Story told chronologically vs. focus on final results</td>
<td>Write</td>
<td>Write categories include: story telling, final results, etc.</td>
</tr>
<tr>
<td><strong>PF-32</strong> Premature end: win race vs. practice music for debut</td>
<td>Write</td>
<td>Write categories include: win race, practice music, etc.</td>
</tr>
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</table>

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
Three case studies of problem-driven work

• e-commerce

• facilities management

• biology
Segmentifier

Interactive Refinement of Clickstream Data

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**?
What is Clickstream Data?
Data: *Actions*
Data: Action Attributes
Data: Action Types

E-commerce
- addToCart
- removeFromCart
- search
- purchase

Site Functionality
- appStart
- appDisplayError
- offlineModeUsed

Pageviews
- pageview

Action Types:
- Action
- Client ID
- Time
Action Hierarchy
Action Hierarchy

Roll-up
- account_group
- browse_group
- cart_group
- checkout_group
- info_group
- other_group

Mid-Level
- pv_account
- pv_login
- pv_elitereward
- pv_register
- pv_home
- pv_plp
- pv_pdp
- pv_specialoffers
- pv_explore
- pv_search
- pv_cart
- pv_confirmation
- pv_checkout
- pv_policy
- pv_storelocator
- pv_other_info
- pv_other

Pageviews
- 62
Data: Sequences
Data: Sequences
Data: *Client Sequences*

*Client Sequences*: all actions performed by a single user
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**

- : 1
- : 1
- : 5
- : 1
- : 1
- : 1
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
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

Segment

Behavior: set of attribute constraints

Viewed 4 pages
Purchased
Between 9 - 10 am
Start time
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

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

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

- 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

- 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 refined segments for further downstream analysis, to more specific tools:
  - Pattern mining
  - Clustering
High-Level Segmentifier Analysis Model

- Discover actionable insight by viewing segment
By viewing the segment, analyst \textit{abandons} if:

\begin{itemize}
  \item No actionable insights
  \item No further ways to \textit{refine}
  \item Not suitable for \textit{export}
\end{itemize}
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
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

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Ocupado

Visualizing Location-Based Counts Over Time Across Buildings


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

Location-Based Counts
Previous measurement required physical counting or installation of additional hardware.
Previous measurement required physical counting or installation of additional hardware.

Previous visualization attempts were limited in space and time.
Design Study
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
Data
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
Focus Domains

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

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
Visualization Prototypes

- 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

Periods of interest

Zone
Floor
Building

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**
Reusable Visualization Components
## Reusable Visualization Components

<table>
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<th>Comparisons</th>
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<td>Floor plan with symbols</td>
<td>Superposition</td>
<td>Within local spatial neighborhood</td>
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<td></td>
<td>Spatial heatmap</td>
<td>Containment (nested)</td>
<td>Across distributed regions</td>
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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
Data-First Design Studies

Original DSM framework
Original DSM framework

Data-first DSM framework

learn winnow cast discover design implement deploy reflect write

learn
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?
- Are there any data quality challenges?
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

learn  winnow  cast  discover  design  implement  deploy  reflect  write

Data-first DSM framework

learn  acquire  elicit tasks

MOVE AND RENAME
Original DSM framework

Data-first DSM framework

- Multiple potential stakeholders
Original DSM framework

- learn
- winnow
- cast
- discover
- design
- implement
- deploy
- reflect
- write

Data-first DSM framework

- learn
- acquire
- elicit tasks

- Multiple potential stakeholders
- Explain initial data abstractions
Original DSM framework

- learn
- winnow
- cast
- discover
- design
- implement
- deploy
- reflect
- write

Data-first DSM framework

- learn
- acquire
- elicit tasks

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

Data-first DSM framework

MODIFY

winnow stakeholders
Original DSM framework

Data-first DSM framework

- How frequent are their data-relevant tasks?
Original DSM framework

Learn → Winnow → Cast → Discover → Design → Implement → Deploy → Reflect → Write

Data-first DSM framework

Learn → Acquire → Elicit

Winnow Stakeholders

- How frequent are their data-relevant tasks?
- How central are these tasks to the stakeholder’s primary mission?
Original DSM framework

Data-first 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

Data-first DSM framework

Original DSM framework:
- learn
- winnow
- cast
- discover
- design
- implement
- deploy
- reflect
- write

Data-first DSM framework:
- learn
- acquire
- elicit
- winnow
- cast
- design

MODIFY
Original DSM framework

Data-first DSM framework
Original DSM framework

- learn
- winnow
- cast
- discover
- design
- implement
- deploy
- reflect
- write

Data-first DSM framework

- learn
- acquire
- elicit
- winnow
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- write
Three case studies of problem-driven work

- e-commerce
- facilities management
- biology
Aggregated Dendrograms for Visual Comparison Between Many Phylogenetic Trees


Phylogenetic tree

Evolutionary relationships of organisms

Human
Chimpanzee
Macaque

Genetic information

Computational workflow

Phylogenetic tree
Many phylogenetic trees

- Understand relationships between genes and species trees
- Explore trees generated with different methods and data
Scalability of Existing Tree Comparison Systems

#Trees: how many trees to compare

Level of detail (LoD): how much details are visible
Scalability of Existing Tree Comparison Systems

#Trees: how many trees to compare

Pairs

Simplified structure

Full topology

Level of detail (LoD):
how much details are visible

TreeJuxtaposer.
Munzner, Guimbretière, Zhang, Zhou.
SIGGRAPH 2003
Scalability of Existing Tree Comparison Systems

#Trees: how many trees to compare

- Thousands: Many as points
- Hundreds: Few in full
- Dozens: Many as points
- Pairs: Few in full

Level of detail (LoD): how much details are visible

- Single point
- Simplified structure
- Full topology

Tree space.
Hillis, Health, John.
Systematic Biology 2005.
Scalability of Existing Tree Comparison Systems

#Trees: how many trees to compare

- Thousands: Many as points
- Hundreds: Dozens at multi-scale
- Dozens: Few in full
- Pairs: Single point, Simplified structure, Full topology

Level of detail (LoD): how much details are visible

Comparing many phylogenetic trees

# Trees: how many trees to compare

- Thousands: Many as points
- Hundreds: Dozens at multi-scale
- Dozens: Few in full
- Pairs: Single point

Level of detail (LoD): how much details are visible

Hundreds / thousands at multi-scale?
Contributions include idiom & algorithm levels

- Data and task abstractions for comparison of phylogenetic trees
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
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
Two crucial tasks

**Topological** relationships between subtrees / leaf nodes
Two crucial tasks

**Topological** relationships between subtrees / leaf nodes
- Topological distance

**Leaf** node memberships compared to reference tree

---

Separation | Nested
---|---

B
C
A

---

S1
S2
S3
A
S4
S5
Reference
Two crucial tasks

**Topological** relationships between subtrees / leaf nodes
- Topological distance

**Leaf** node memberships compared to reference tree

Separated  

Nested

Exact match

Reference

Tree 1
Two crucial tasks

**Topological** relationships between subtrees / leaf nodes
- Topological distance

Leaf node memberships compared to reference tree

Separated

- B
- C
- A

Nested

- B
- C
- A

Exact match

- S1
- S2
- S3
- S4
- S5

Partial match

- S1
- S2
- S3
- S4
- S5

Reference

- A

Tree 1

- A1

Tree 2

- A2
Aggregated Dendrogram (AD)

- Intuition
- Visual design
Use glyphs to compress a tree according to user selections
Visual design: focus + context
Visual design: focus + context

- Focus
  - Selected subtrees

- Hide inner structures and leaf nodes
- Partial match of leaf set
- Exact match of leaf set

(Leaf task)
Visual design: focus + context

- Focus
  - Selected subtrees

Proportion of matching leaves

# leaf nodes

(Leaf task)
Visual design: focus + context

- Focus
  - Selected subtrees
  - Topological relationships between them

(Topology task)
Visual design: focus + context

- Focus
  - Selected subtrees
  - Topological relationships between them
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

- Tree collection
- Subset of trees
- Tree collection
- Subset of trees
- Individual tree
- Subtree
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
Validation with many biologists

- Work closely with a biology PhD student (second author)
- Demos, interviews and discussions
  - 10 biologists at different times throughout project
- User study sessions
  - 5 biologists
  - Using their own datasets
Validation with many biologists

- Work closely with a biology PhD student (second author)
- Demos, interviews and discussions
  - 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.

• 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