Visualization Task Abstraction from Multiple Perspectives
Visualization Task Abstraction from Multiple Perspectives

Matthew Brehmer
VIS Doctoral Colloquium
14/11/08
About Me
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[–2009]
B. Comp in **Cognitive Science**, Queen’s University, UX design in industry

[2009–2011]
M.Sc in **Human-Computer Interaction**, University of British Columbia (UBC)
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[May 2014]
Defended thesis proposal

[Fall 2015]
Expected thesis defence
Evolution of Research Question

[2011]

How could we better evaluate visualization systems beyond time and error?
Evolution of Research Question

[2011]
How could we better *evaluate* visualization systems beyond time and error?

[2012]
Evaluation and tasks: can we have a better understanding of user *tasks* across domains?
Evolution of Research Question

[2011]
How could we better evaluate visualization systems beyond time and error?

[2012]
Evaluation and tasks: can we have a better understanding of user tasks across domains?

[2013++]
Can this abstract analysis of tasks help with visualization design and evaluation?
What is a **Task**?

An event in which an **actor** attempts to accomplish some **ends** by some **means**, given some **constraints**.
Characterizing visualization **Tasks**

*Why* is a task being performed?
*What* are the inputs and outputs?
*How* is a task supported?

Characterizing *sequences* of interdependent tasks.
Why is a task being performed? What are the inputs and outputs? How is a task supported?

Characterizing sequences of interdependent tasks.
Characterizing visualization Tasks

**Why** is a task being performed?  
**What** are the inputs and outputs?  
**How** is a task supported?

Characterizing *sequences* of interdependent tasks.

**Thesis statement:**

this form of task abstraction will facilitate visualization analysis, design, and evaluation.
Four Perspectives
Four Perspectives

Synthesis:
A Multi-Level Typology of Abstract Visualization Tasks

presented at IEEE InfoVis ’13
Four Perspectives

Synthesis:
A Multi-Level Typology of Abstract Visualization Tasks

Field Study:
Use of typology to Evaluate an existing system

presented at IEEE InfoVis ’13
to appear in IEEE InfoVis ’14
Four Perspectives

**Synthesis:**
A Multi-Level Typology of Abstract Visualization Tasks

**Field Study:**
Use of typology to Evaluate an existing system

**Interview Study:**
Use of typology to Analyze behaviour across multiple domains

Presented at IEEE InfoVis '13

To appear in IEEE InfoVis '14

To appear at ACM BELIV '14
Four Perspectives

Synthesis:
A Multi-Level Typology of Abstract Visualization Tasks

to appear in IEEE InfoVis ’14

Field Study:
Use of typology to Evaluate an existing system

to appear in IEEE InfoVis ’14

Interview Study:
Use of typology to Analyze behaviour across multiple domains

to appear at ACM BELIV ’14

Design Study:
Use of typology in requirements analysis for Design

work in progress
Perspective 1: Synthesis

A Multi-Level Typology of Abstract Visualization Tasks
Perspective 1: Synthesis
A Multi-Level Typology of Abstract Visualization Tasks

why?
- present
- discover (generate/verify)
- enjoy

how?
- produce
- encode
  - manipulate
    - select
    - navigate
    - arrange
    - change
    - filter
    - aggregate
  - introduce
    - annotate
    - import
    - derive
    - record

what?
- [input]
- [output]

what?
- location known
  - lookup
  - browse
- location unknown
  - locate
  - explore

Perspective 1: **Synthesis**

A Multi-Level Typology of Abstract Visualization Tasks

30 prior taxonomies, 20 additional references, 84 total references, 5 disciplines, 20 citations since VIS ’13

Q: in what other ways can we validate this typology?
Perspective 2: **Field Study**

*Overview: The Design, Adoption, and Analysis of a Visual Document Mining Tool For Investigative Journalists*
Perspective 2: Field Study

Case studies with 6 journalists

Adoption and appropriation are difficult to study

A need for an analysis framework

Perspective 2: Field Study

Case studies with 6 journalists

Adoption and appropriation are difficult to study

A need for an analysis framework

Perspective 2: Field Study

Case studies with 6 journalists

Use of typology to analyze field data

2 tasks, not 1, not 6...

Q: how to improve the study of adoption?

Perspective 2: Field Study
Case studies with 6 journalists

Use of typology to analyze field data

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Perspective 2: Field Study

Case studies with 6 journalists

Use of typology to analyze field data

2 tasks, not 1, not 6…

Q: how to improve the study of adoption?

Perspective 3: *Interview Study*

Visualizing Dimensionally Reduced Data: Interviews with Analysts and a Characterization of Task Sequences
Perspective 3: Interview Study
Interviews with 10 analysts from 6 domains

A domain-independent yet data-abstraction-specific task characterization...

...but in need of the right words.

Perspective 3: Interview Study

Why visualize dimensionally-reduced data?

The task typology allowed us to compare tasks across application domains, those having a common data abstraction.

Perspective 3: Interview Study
Why visualize dimensionally-reduced data?

Q: as with the typology, how could I apply or validate this data-abstraction-specific task characterization?

Perspective 4: Design Study

Visualization for Large-Scale Energy Consumption Analysis
Perspective 4: **Design Study**
Large-Scale Energy Consumption Analysis

A chain of restaurants or hotels... a school board... a university campus... a utility company portfolio...

Building use type, age, occupancy, location, size, climate data.

Real-time data, multiple resources
Perspective 4: Design Study
Large-Scale Energy Consumption Analysis

Complex data abstractions
Replacing existing software
Diverse user base, domain conventions
Perspective 4: **Design Study**

Interviews with 9 current users: diverse roles / skill sets

- Energy Manager / Analyst / Specialist / Efficiency Engineer
- Climate and Energy Engineer
- Student Energy Researcher
- Automation Maintenance Engineer
- Building Automation Software Specialist
## Perspective 4: Design Study

### Task Abstraction Analysis: the Why?

<table>
<thead>
<tr>
<th>Role</th>
<th>EM Use &amp; Frequency</th>
<th>Portfolio Size, Organization</th>
<th>Partial list of tasks (emphasis on Discover tasks: current and desirable)</th>
</tr>
</thead>
</table>
| climate and energy engineer  | infrequent (annual, semi-annual reports) | UBC campus, ~100 buildings and 2 zones in EM. LZ only interested in handful of CF,Op buildings |  - Lookup → Identify differential between actual and predicted performance  
  - Locate → Identify cumulative long-term savings  
  - Locate → Identify cause of long-term trend, alerts, baseline precisions / uncertainty  
  - Locate → Compare: actual to baseline, arbitrary time periods |
| energy manager                | day-to-day monitoring | 2 McGill campuses, 4 zones in Downtown campus (~70 buildings), McDonald campus, (~30 buildings), all in EM, zone on 30 steam meters |  - Locate → Compare | Summary: combined consumption of 4 Downtown zones  
  - Browse → Identify: contribution of individual buildings to combined consumption, anomalies  
  - Explore → Identify: causes of threshold events  
  - Locate → Identify: contributions of parameters to PAM baselines (weather, occupancy) |
| researcher                    | none, data export from API | (total campus steam consumption) |  - Lookup → Compare: predicted vs. actual consumption  
  - Lookup → Identify: future short-term consumption |
| energy efficiency engineer    | some exploratory analysis, most analysis done in Excel | (single-building focus or small group of buildings (e.g. 5)) |  - Explore | Browse  
  - Locate → Compare: within and across buildings, monthly and seasonal differences in consumption / schedule / demand, OAT vs. demand for occupied and unoccupied periods  
  - Lookup → Summarize: distribution of OAT, demand  
  - Locate → Identify: attribution of energy use within a building; Locate → Identify | Compare: effects of simulated ECMs on building performance |
| energy analyst                | several hours a week, additional analysis in Excel | UCB campus, ~100 buildings; 90% concentrated on single campus, subset in EM, departments cross-cuts buildings |  - Locate → Compare: ranked building performance  
  - Locate → Compare: before after ECMs; Locate → Compare (seasonal) regression curve before after ECMs  
  - Locate → Identify: attribution of energy use within a building; Locate → Identify: contribution of department(s) to building consumptions  
  - Locate → Compare: consumption of UCB to other universities; Locate → Identify: weather predictions, trends |
| head maintenance engineer     | daily email digest, follow-up in EM ~3-4 hrs / week | UBC campus, ~100 buildings and 2 zones in EM, monitors about 10 buildings / week |  - Lookup → Compare: ranked building performance  
  - Explore → Identify: anomalies, causes of threshold events / alerts  
  - Locate → Identify: attribution of energy use within a building; Locate → Identify: contributions of parameters to PAM baselines (weather, holidays, other events) |
| energy efficiency engineer    | some exploratory analysis, confirmatory analysis done in Excel | (single-building focus) |  - Lookup → Compare: month-to-month % in consumption, peak demand  
  - Locate → Identify: effects of simulated ECMs on a building based on previous success; Locate → Compare: effect of ECMs between buildings |
| energy specialist             | EM for data export; analysis done in Excel, EM analysis offloaded to student volunteers | ~130 schools; 2 accounts, 36 in EM (Electric, 2 submetered), 4 in EM (Natural Gas) |  - Lookup → Compare: ranked performance (multi-variate ranking), absolute and normalized performance  
  - Locate → Compare: ranked performance (multi-variate ranking), absolute and normalized performance  
  - Locate → Identify: anomalies (jumps in rankings), trends (consistent rankings) at macro-level between buildings  
  - Locate → Identify | Compare: single building performance, within-between: operating hours and between days  
  - Locate → Compare: single building performance for N time periods |
| building automation specialist | frequent setting up charts, baselines for clients | (client portfolios range in size, hierarchical structure) |  - Lookup → Compare: ranked performance (multi-variate ranking), absolute and normalized performance  
  - Locate → Compare: ranked performance (multi-variate ranking), absolute and normalized performance  
  - Locate → Identify (building portfolio); Locate → Identify: validated savings vs unvalidated saving  
  - Locate → Identify: effects of simulated ECMs on energy use within a building; Locate → Identify: contributions of parameters to multiple baselines (ECM, weather, outliers, holidays, other events); noise / confidence / uncertainty in baselines |
**Perspective 4: Design Study**

**Task Abstraction Analysis: the Why?**

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<th>Partial list of tasks (emphasis on Discover tasks): currents and desirable</th>
</tr>
</thead>
</table>
| Specialist | Automation (consultant) engineer | McGill campus, ~100 buildings and 2 zones in EM-LZ only interested in handful of C.Op buildings | - Look up → Identify differential between actual and predicted performance  
- Look up → Identify cumulative long-term savings  
- Locate → Identify cause of long-term trend alerts, baseline precisions / uncertainty  
- Locate → Compare actual to baseline, arbitrary time periods |
| EM Use & Frequency | Portfolio Size, Organization | Portfolio Size, Organization (single-building focus) | - Look up → Compare predicted vs. actual consumption  
- Look up → Identify future short-term consumption |
| Portfolio Size, Organization | Role | Portfolio Size, Organization (single-building focus) | - Locate → Identify effects of simulated ECMs on building consumption; cause of long-term trend alerts, baseline precisions / uncertainty  
- Locate → Compare: actual to baseline, arbitrary time periods |

- **Locate → Identify**: differential between actual and predicted performance  
  - Portfolio Size, Organization (single-building focus)  
  - Look up → Compare month-to-month %Δ in consumption, peak demand  
  - Locate → Identify effects of simulated ECMs on building consumption; cause of long-term trend alerts, baseline precisions / uncertainty  
  - Locate → Compare: actual to baseline, arbitrary time periods

- **Locate → Identify**: cumulative long-term savings  
  - Portfolio Size, Organization (single-building focus)  
  - Look up → Compare: actual to baseline, arbitrary time periods

- **Locate → Identify**: cause of long-term trend alerts, baseline precisions / uncertainty  
  - Portfolio Size, Organization (single-building focus)  
  - Look up → Compare short-term consumption; rank performance for N time periods

- **Locate → Compare**: actual to baseline, arbitrary time periods  
  - Portfolio Size, Organization (single-building focus)  
  - Look up → Compare: actual to baseline, arbitrary time periods

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Matthew Brehmer
Data Abstractions

aggregate item [portfolio] [S*]
  - (aggregate items [groups of spaces])
    - individual item [space] [S]
      - (partial item [space submeter])
        - links
          • [point 1]
          • [point 2]
          • ...
          • [point n]
    - categorical attributes
      - [primary use]
      - [space type]
      - [use_type]†
      - [weather station ID]
      - [TMY (Typical Meteorological Year) data source]
      - [floor space unit]
      - [custom descriptor tag(s)]
        - [end-use(s)]
      - spatial attributes
        • [address (location)]
        • [city]†
        • [province]†
        • [latitude]†
        • [longitude]†
        • [time zone]†
    - static quantitative attributes
      • [# occupants]
        - [# occupants subdivided by descriptor tag]
        - [year constructed (space age)]
      • [floor space subdivided by descriptor tag]
      • [point value]
      • [point value 1]
      • [point value 2]
      • [point value n]
      • [cost]
      • [average demand]
      • [peak demand]
      • [absolute savings / waste: point value 1 – point value 2]
      • [relative savings / waste: point value 1 / point value 2]
      • [cumulative savings]
    - temporal quantitative attributes
      • [update frequency]
      • links
        • [space 1]
        • [datalogger 1]
        • [connector k]
    - derived attributes [D1] [items [P] + temporal interval [T]]
      • [cost conversion ratio]
      • [energy conversion ratio]
      • [Green House Gas conversion ratio]
      • [normal range ±%]
        - [coarse-grained normal range ±%]
        - [fine-grained normal range ±%]
    - derived attributes [D2] [item [S] + weather [W] + [T]]
      • [HDD: base temperature – OAT]
      • [CDD: OAT – base temperature]
    - derived attributes [D3] [item [S+ P] + derived attributes [D1,D2] + temporal interval [T]]
      • [quantitative attribute]
        • [attribute [D1] per area]
          - (e.g. energy intensity: consumption normalized by square footage)
        • [average baseline]
        • [attribute [D1] normalized by HDDs, CDDs]
        • [attribute [D1] normalized by # occupants]
        • [attribute [D1] normalized by # operating hours]
        • [attribute [D1] faceted by schedule interval]
        • [end use disaggregation]
      • [change in ranking]
        • contribution to aggregate derived attribute
    - derived attributes [D4] [multiple items [S + P] + [D1, D2, D3]]
      • [average baseload]
      • [cost conversion ratio]
      • [energy conversion ratio]
      • [Green House Gas conversion ratio]
      • [normal range ±%]
        - [coarse-grained normal range ±%]
        - [fine-grained normal range ±%]
      • [relative savings / waste: point value 1 / point value 2]
      • [cumulative savings]
      • [peak demand]
      • [absolute savings / waste: point value 1 – point value 2]
      • [relative savings / waste: point value 1 / point value 2]
      • [cumulative savings]
      • [change in ranking]
        • contribution to aggregate derived attribute

Data Abstraction Analysis: the Perspective 4: Design Study

Data Abstraction Analysis: the perspective 4: Design Study

What?
Perspective 4: **Design Study**

Data Abstraction Analysis: the *What?*

Hierarchies: portfolios of buildings

Items have spatial, categorical, quantitative metadata

Each item has multiple time-varying attributes

Multiple time granularities of interest

Many derived attributes
Perspective 4: Design Study
2 Analysis Tasks of focus (in domain language)

Compare absolute and relative performance for a portfolio of buildings over time, faceted by building or by grouping buildings with shared attributes.

Compare individual building performance over time.
Perspective 4: Design Study
Early Visualization Design Sketching
Perspective 4: Design Study
Later: Visualization Design Sketching
Perspective 4: Design Study
Designing Workflows

1. Begin by filtering the time window and by selecting, filtering and aggregating spaces. Select units and optionally previous years or baselines to serve as differential comparison points.

2. Group-Level. Small multiple time series line plots for showing multiple spaces along common scales. Click-through on a single space to drill down to (3).


Portfolio-Level. (a) Coordinated heatmaps and box plots with linked highlighting and selection; line chart tooltips; (b) LineUp plots with time series line plot tooltips; (c) Portfolio map with space metadata and sparkline tooltip. Click-through on tooltips to drill down. If a single space is selected, proceed to (3); otherwise, proceed to (2).

Based on feedback collected from:
- Jerome Conraud [JC] (McGill Jan 22)
- Kevin Ng [KN] (UCB, Jan 27)
- Andy Constant [AC] (Centrica / BG, Jan 28)
- Pulse: Harish R. [HR], James C. [JaC], Kevin T. [KT], Fritz L. [FL], Callie C. [CC], Reetu M. [RM], Bruce C. [BC] (throughout Jan)

For detailed JC and KN workflows, see supplemental slides.
Perspective 4: Design Study
Designing Workflows

Q: How do I combine visual encoding and interaction design choices into coherent workflows for a diverse user population?

Q: How do I confront legacy software bias and domain convention?
Summary
Four Perspectives Revisited
Synthesis:
How should I validate this visualization task typology?
Four Perspectives Revisited

Synthesis:
How should I validate this visualization task typology?

Field Study:
How should I study the adoption and appropriation of visualization in the wild?
Four Perspectives Revisited

**Synthesis:**
How should I validate this visualization task typology?

**Field Study:**
How should I study the adoption and appropriation of visualization in the wild?

**Interview Study:**
How should I validate domain-agnostic data-abstraction-specific task characterization?
Four Perspectives Revisited

**Synthesis:**
How should I validate this visualization task typology?

**Field Study:**
How should I study the adoption and appropriation of visualization in the wild?

**Interview Study:**
How should I validate domain-agnostic data-abstraction-specific task characterization?

**Design Study:**
How should I effectively combine visualizations into coherent workflows for diverse users?
Big Picture Questions
Q: The typology: *do you buy it?* What else might I do to validate or apply the typology? Where else should we extend it?
Big Picture Questions

Q: The typology: do you buy it? What else might I do to validate or apply the typology? Where else should we extend it?

Q: How can I continue to apply this typology and task-centred design and evaluation methods post-PhD?
Big Picture Questions

Q: The typology: *do you buy it?* What else might I do to validate or apply the typology? Where else should we extend it?

Q: How can I continue to apply this typology and task-centred design and evaluation methods post-PhD?

Q: Given my interests, I am attracted to design studies. How (and where) can I do design study-flavoured work in industry?
Thanks:

Tamara Munzner, Joanna McGrenere, Ron Rensink, Michelle Borkin, Johanna Fulda, Heidi Lam, Michael Sedlmair, Stephen Ingram, Jonathan Stray, Pulse Energy
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Supplemental
Perspective 4: Design Study
Process: Design and Feedback Cycle
Q: If rapidly-developed “data sketches” serve to explore the space of visual encoding design, is there an analogous way to develop “interaction sketches” with real underlying data that serve to explore the space of possible interactive workflows?
Q: do effective combinations of visual encoding and interaction techniques exist for facilitating multiple simultaneous comparisons of statistical summaries and time-varying values?
Q: do effective combinations of visual encoding and interaction techniques exist for facilitating multiple simultaneous comparisons of statistical summaries and time-varying values?
Cross-Cutting Questions

A question for you to keep in the back of your mind while I continue this talk is the question of how we as visualization practitioners can apply and validate this contribution.

how do we effectively study the adoption and use of deployed systems in the field?

One of the discussion points of this paper is the relationship between task characterization and different forms of evaluation, and I’d like to hear your feedback on how to strengthen and highlight these relationships in future paper submissions. OR: From the interview study perspective: How can emphasize the importance of task characterization for evaluation?

Q: do effective combinations of visual encoding and interaction techniques exist for facilitating multiple simultaneous comparisons of statistical summaries and time-varying values?

However, with novel visual encodings I’m running into problems of visualization legacy bias and domain convention, and visualization literacy issues in general. I’m curious to hear about what you think with respect to this issue.

Q: If rapidly-developed “data sketches” serve to explore the space of visual encoding design, is there an analogous way to develop “interaction sketches” with real underlying data that serve to explore the space of possible interactive workflows?

I like design studies. How can I do design study-flavoured work in industry?