Visualization Task Abstraction from Multiple Perspectives

Matthew Brehmer
VIS Doctoral Colloquium
14 / 11 / 08

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

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About Me

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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?

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[2012]

Evaluation and tasks: can we have a better understanding of user ***tasks*** across domains?

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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***?

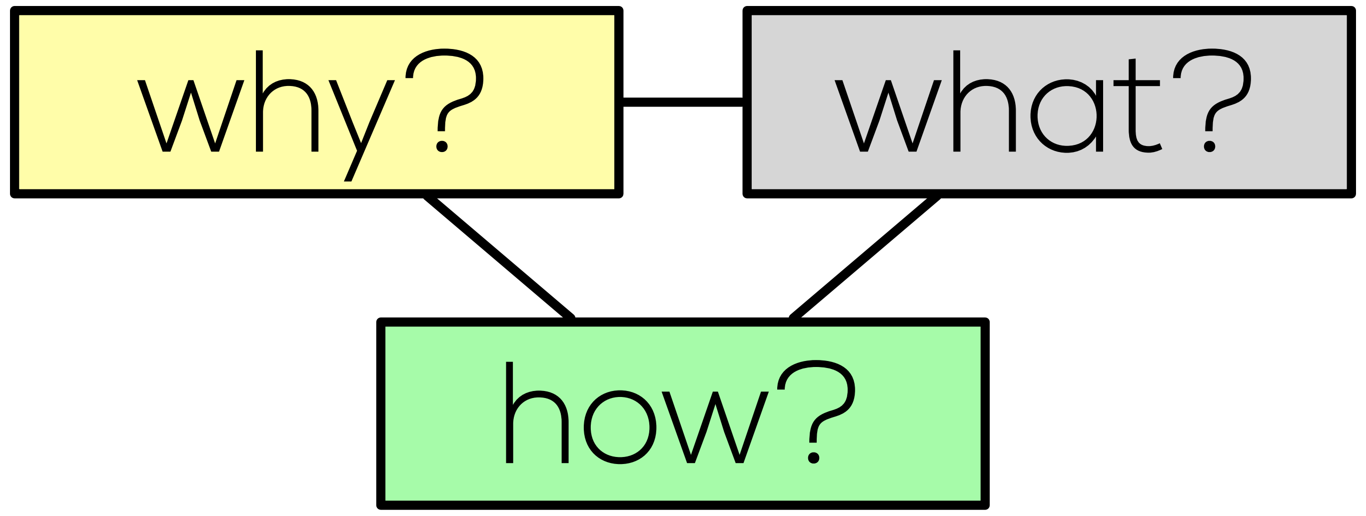
What is a Task?

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.



Characterizing visualization Tasks

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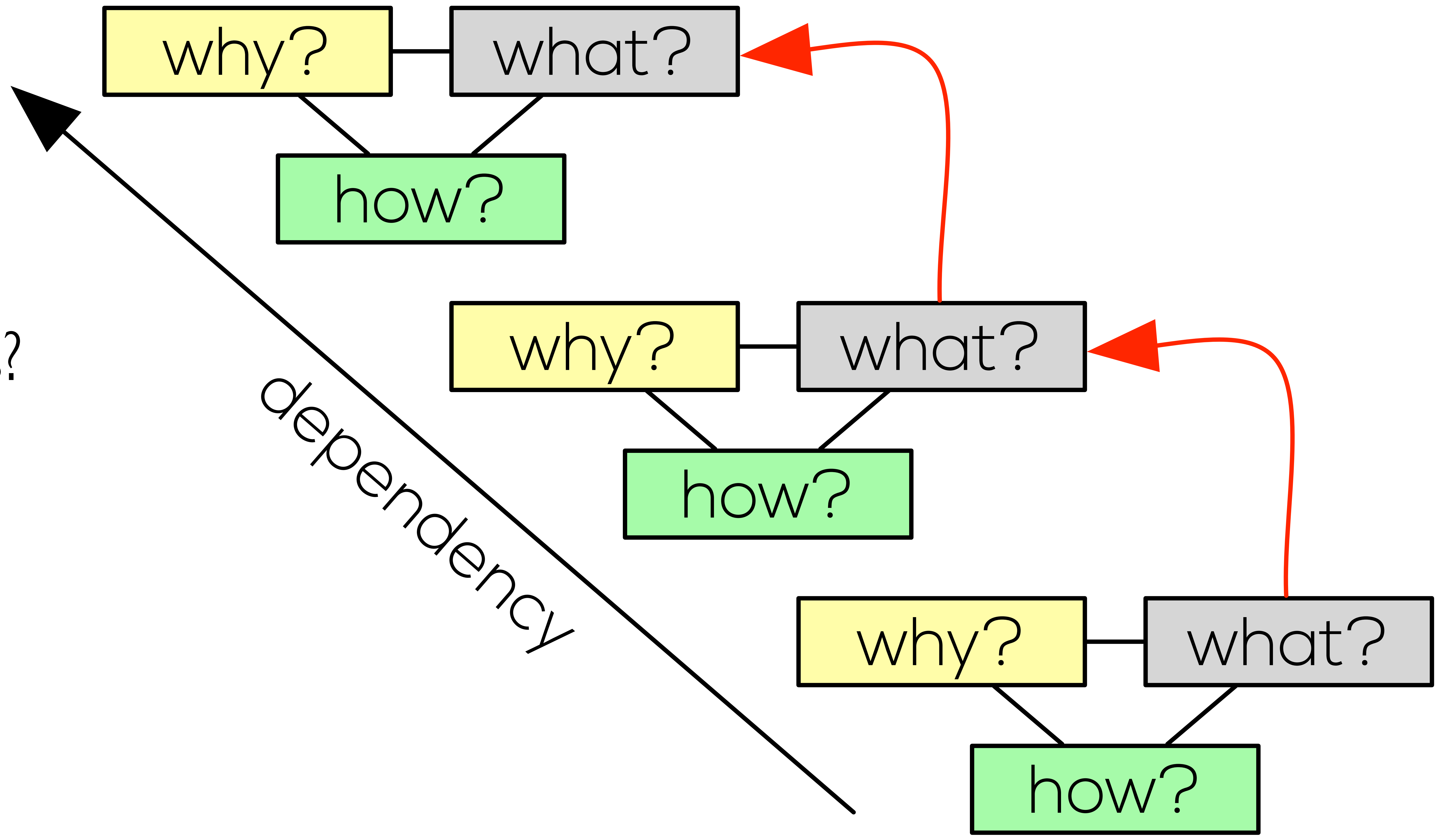

Characterizing visualization Tasks

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

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A Multi-Level Typology of Abstract Visualization Tasks — presented at IEEE InfoVis '13

Field Study:
Use of typology to **Evaluate** an existing system — to appear in IEEE InfoVis '14

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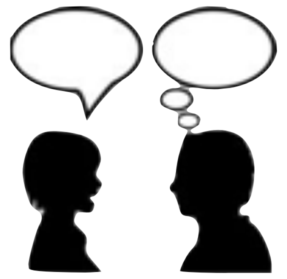

Interview Study:
Use of typology to **Analyze** behaviour across multiple domains — to appear at ACM BELIV '14

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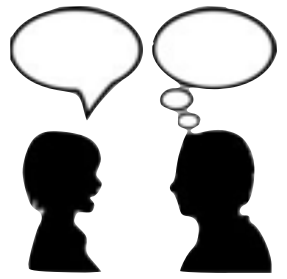

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Design Study:
Use of typology in requirements analysis for **Design** — work in progress

Perspective 1: Synthesis

A Multi-Level Typology of Abstract Visualization Tasks

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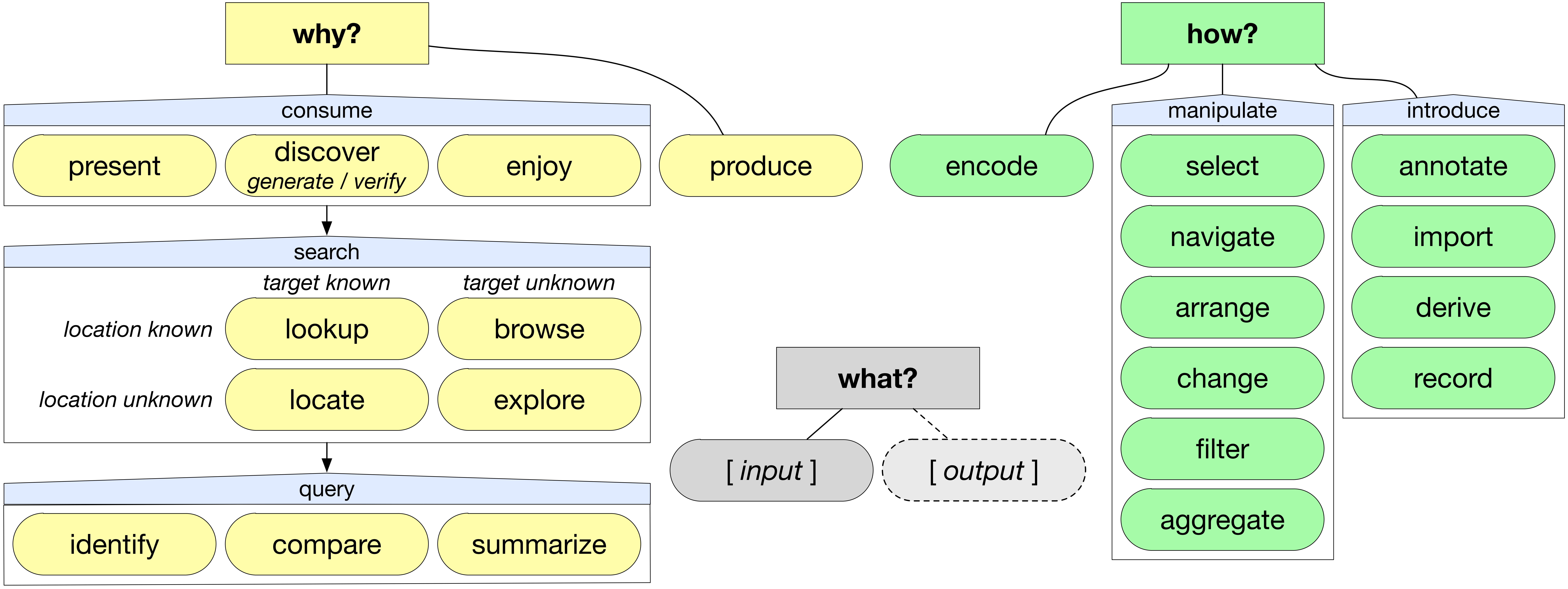
A Multi-Level Typology of Abstract Visualization Tasks



Brehmer & Munzner. IEEE TVCG / Proc. InfoVis 2013.

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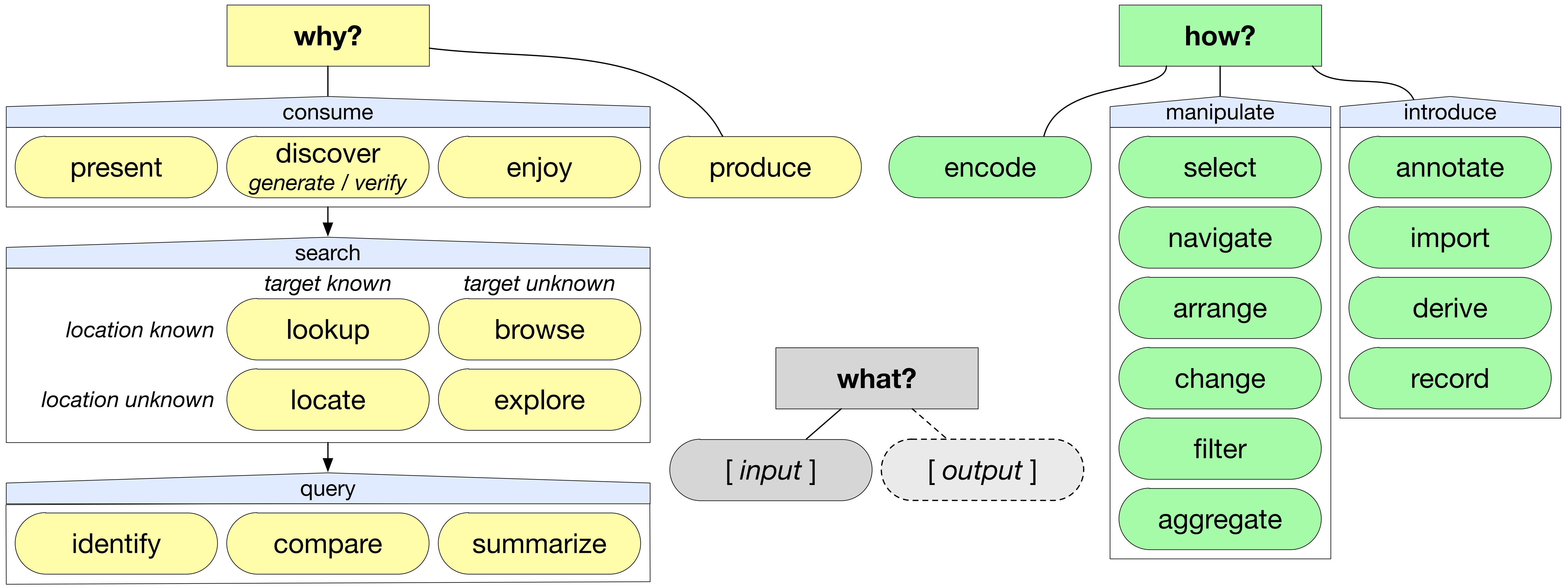


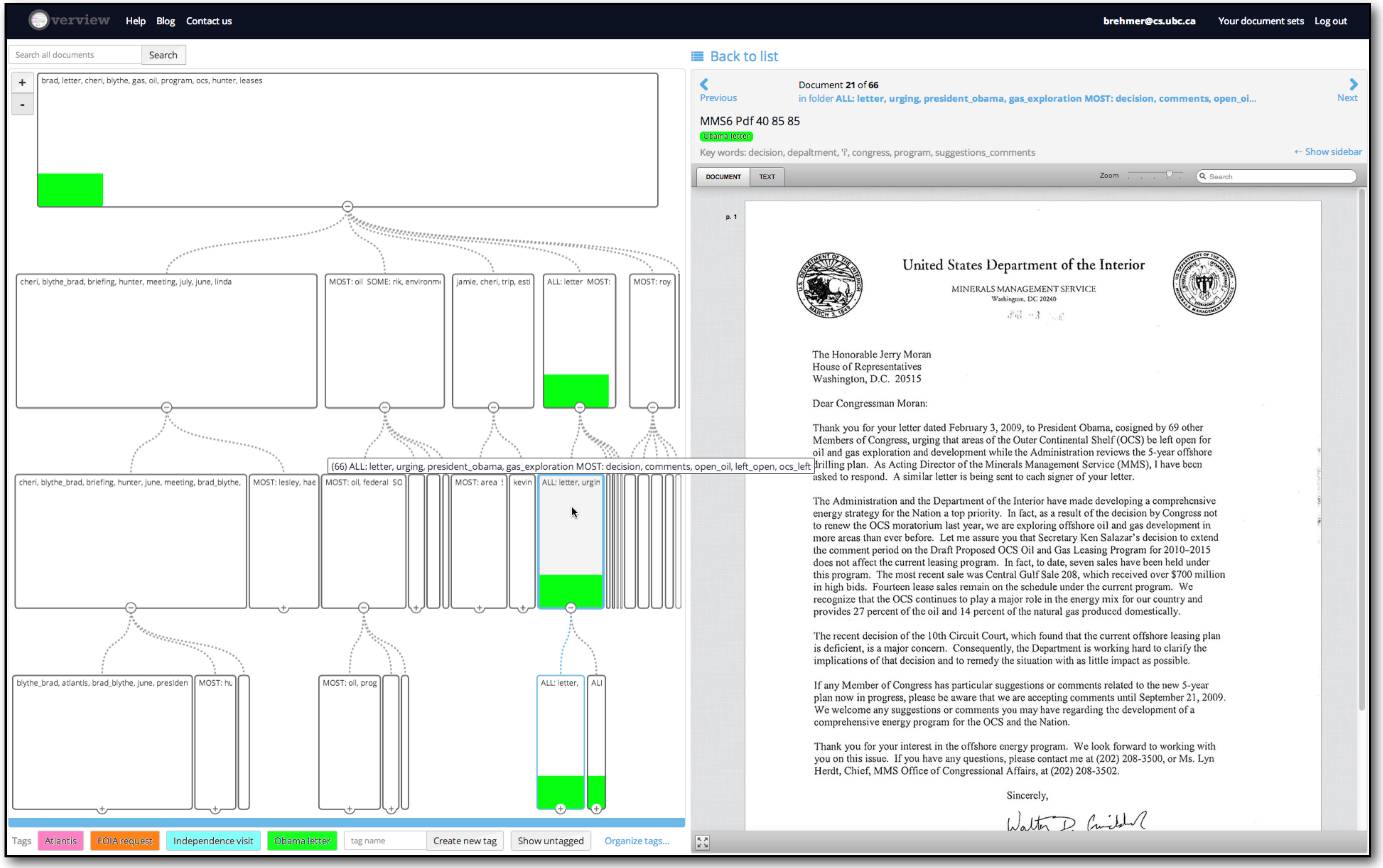
30 prior taxonomies,
20 additional references,
84 total references
5 disciplines
20 citations since VIS '13

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



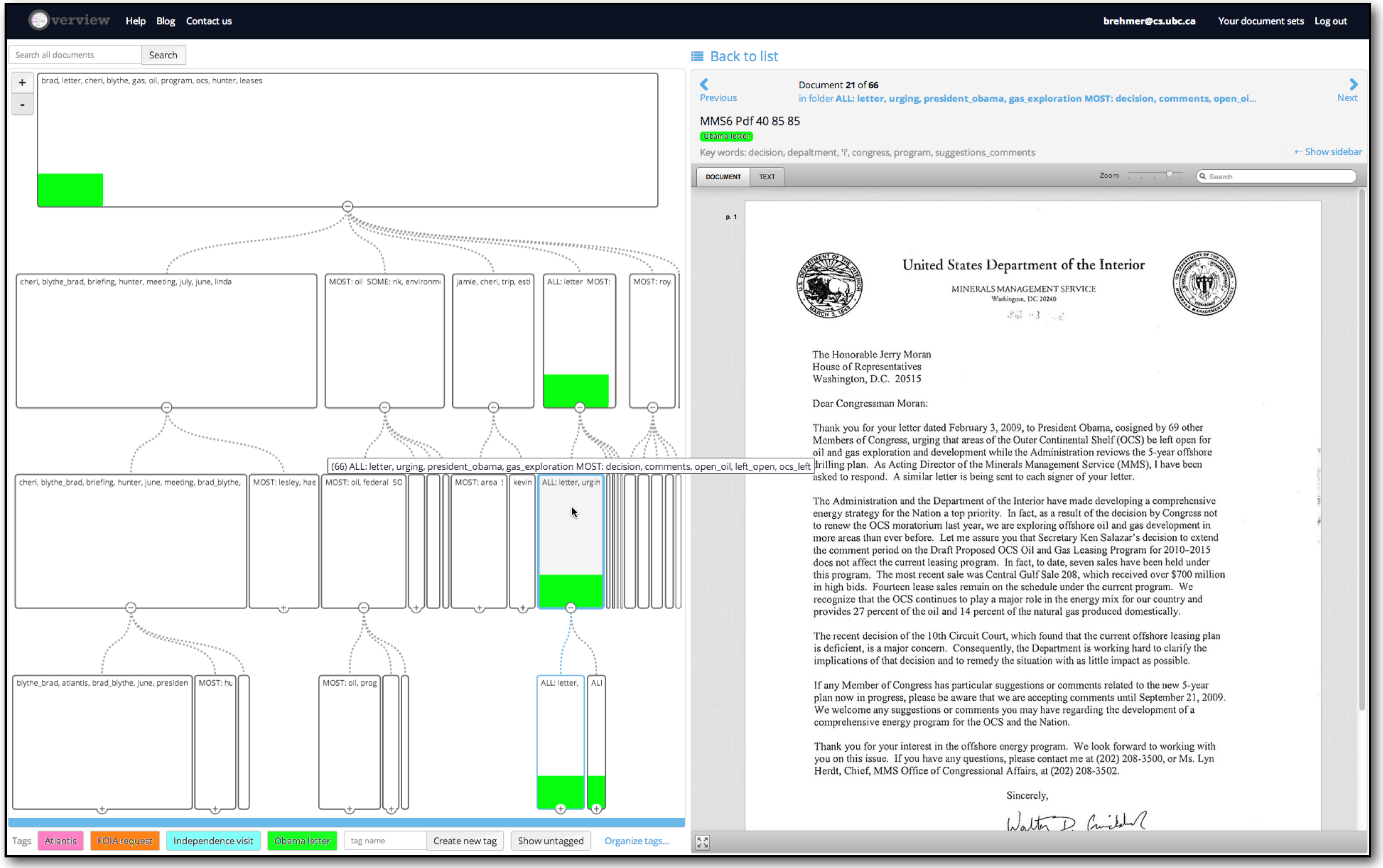
Adoption and appropriation are difficult to study

A need for an analysis framework

Brehmer, Ingram, Stray, & Munzner.
IEEE TVCG / Proc. InfoVis 2014.

Perspective 2: Field Study

case studies with 6 journalists



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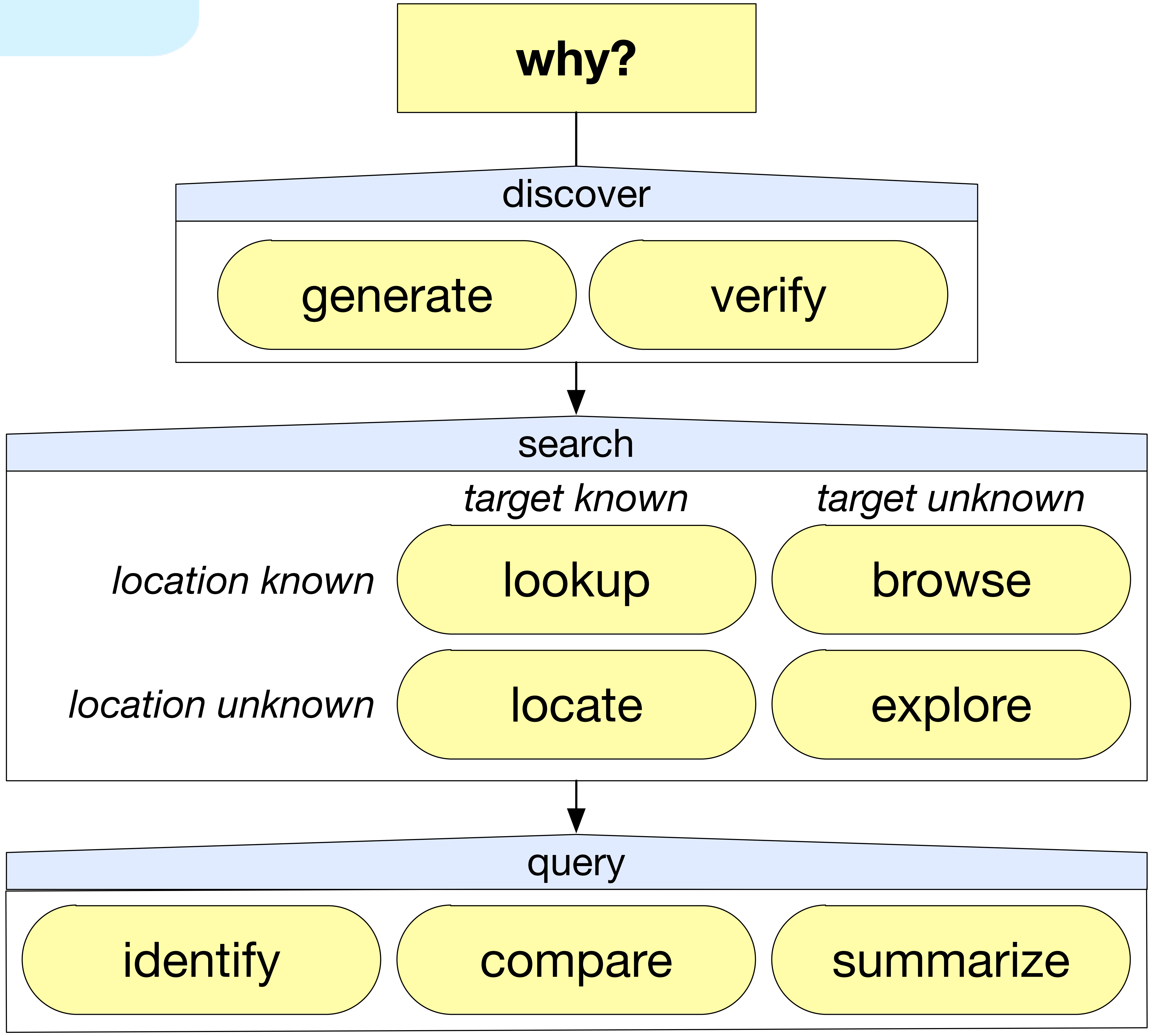
Perspective 2: Field Study

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?



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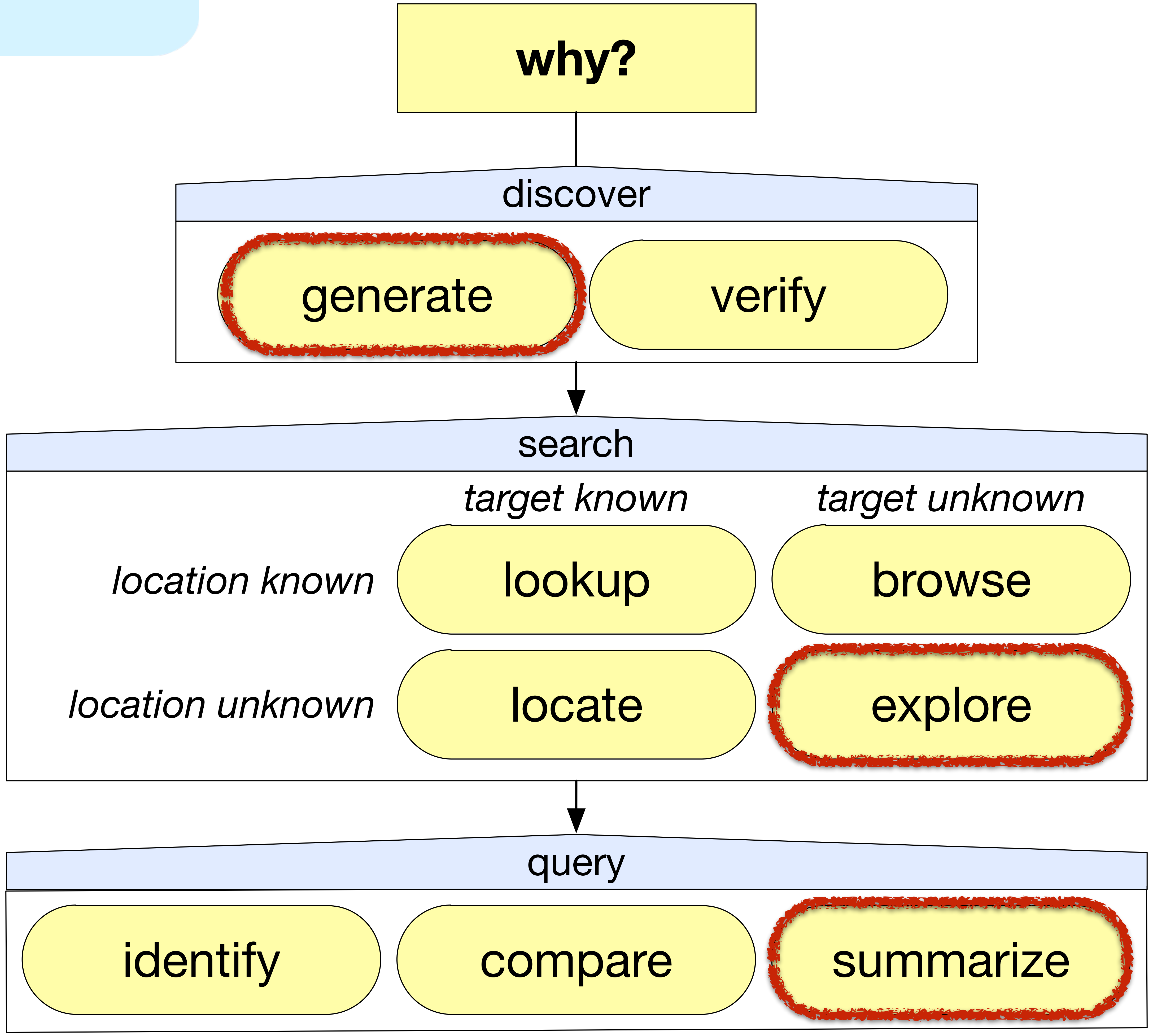

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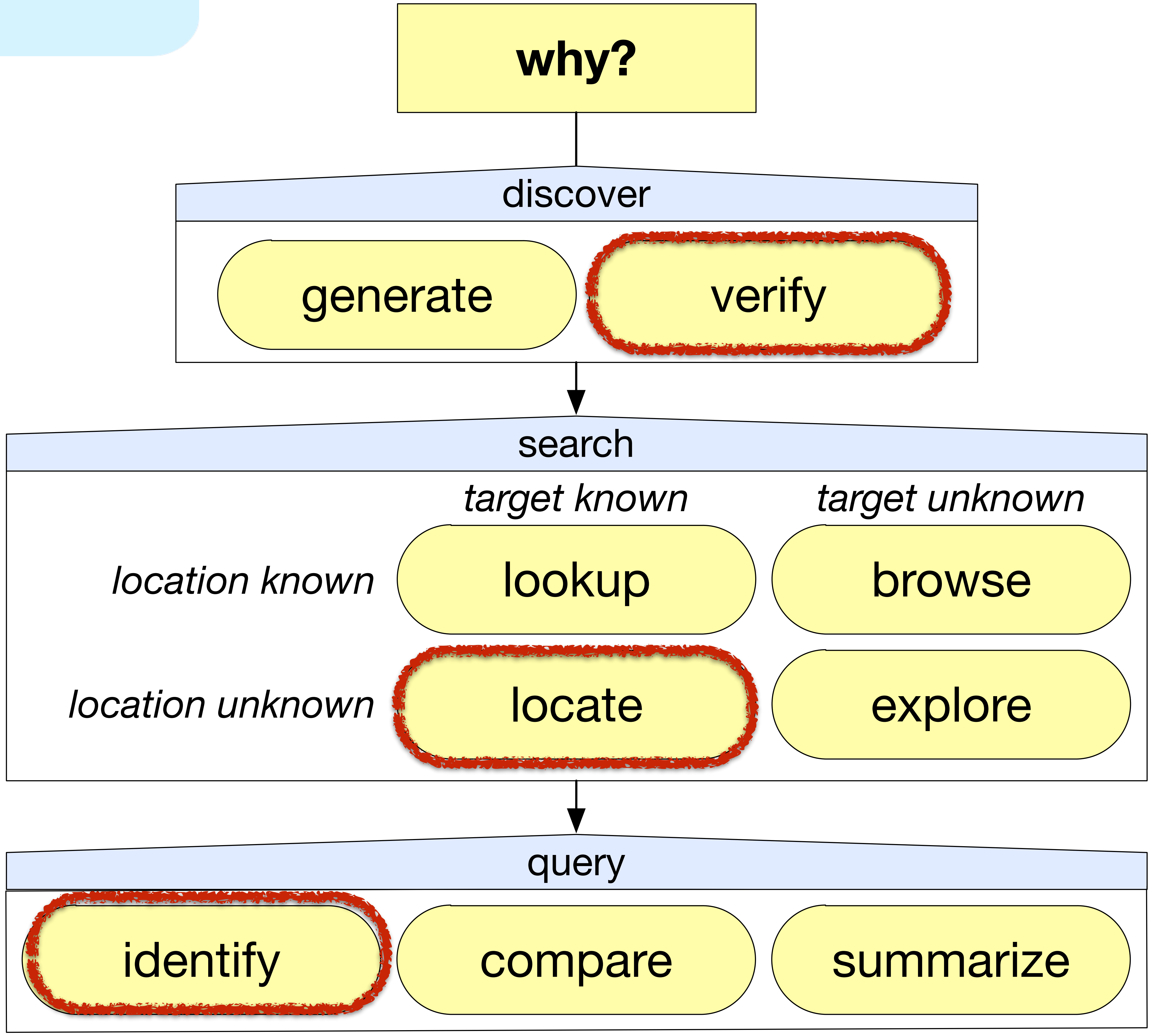

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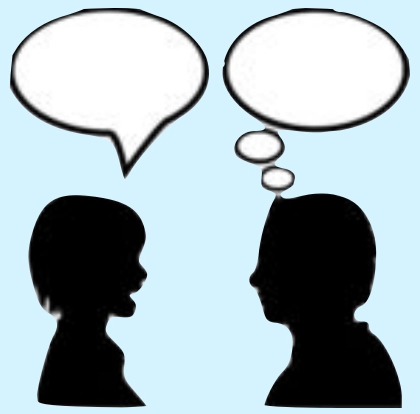


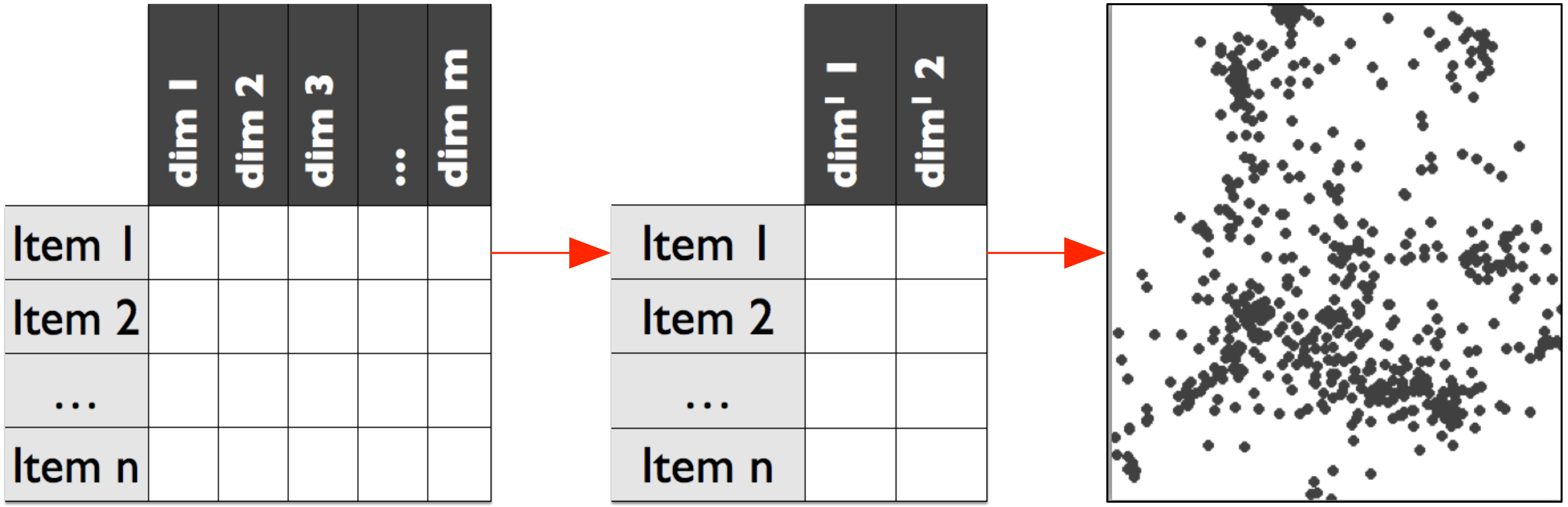
Perspective 3: Interview Study

Visualizing Dimensionally Reduced Data:

Interviews with Analysts and a Characterization of Task Sequences

Perspective 3: Interview Study

Interviews with 10 analysts from 6 domains

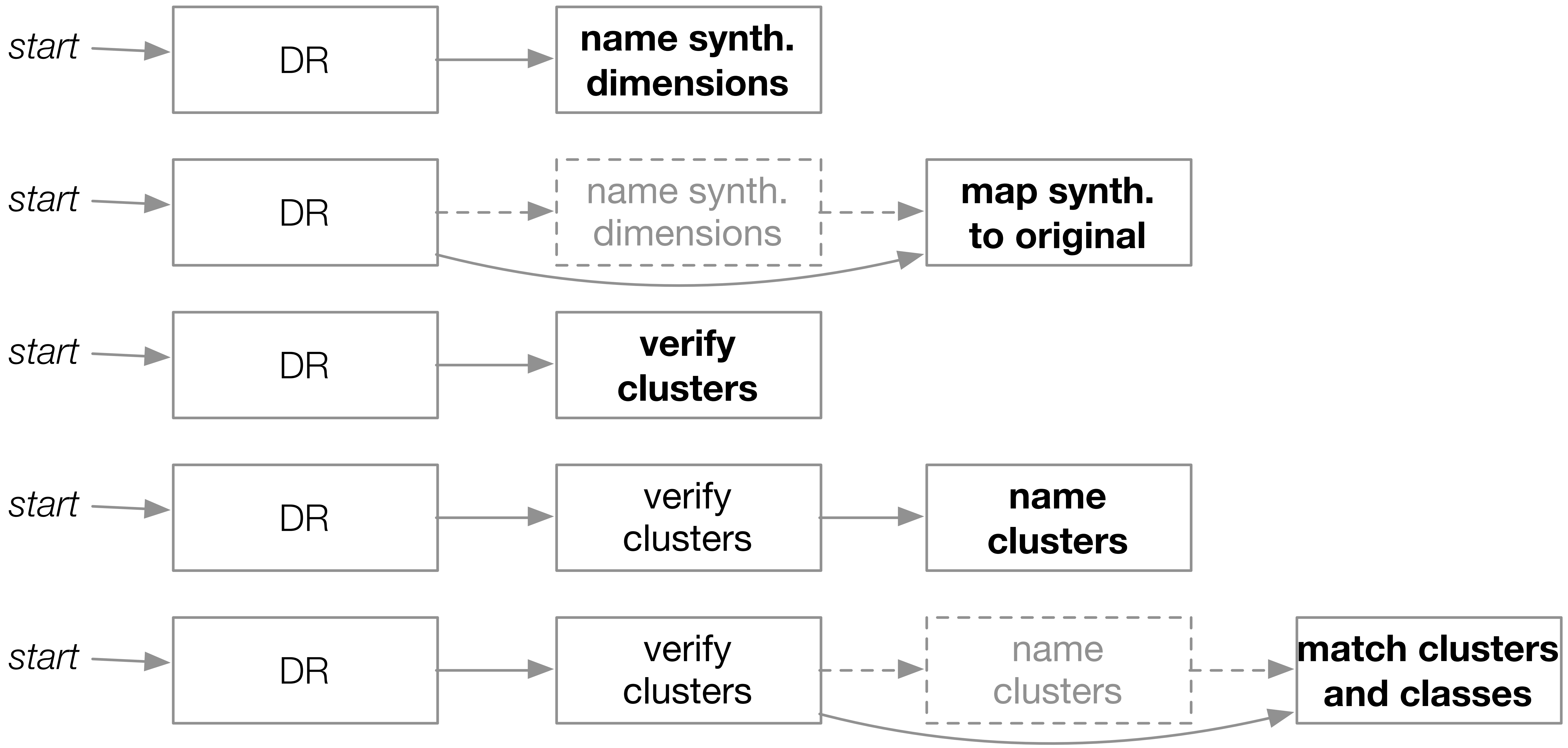


A **domain-independent** yet **data-abstraction-specific** task characterization…

…but in need of the right words.

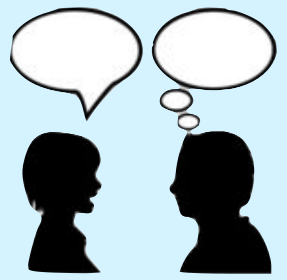
Brehmer, Sedlmair, Ingram, & Munzner. Proc. BELIV 2014.

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

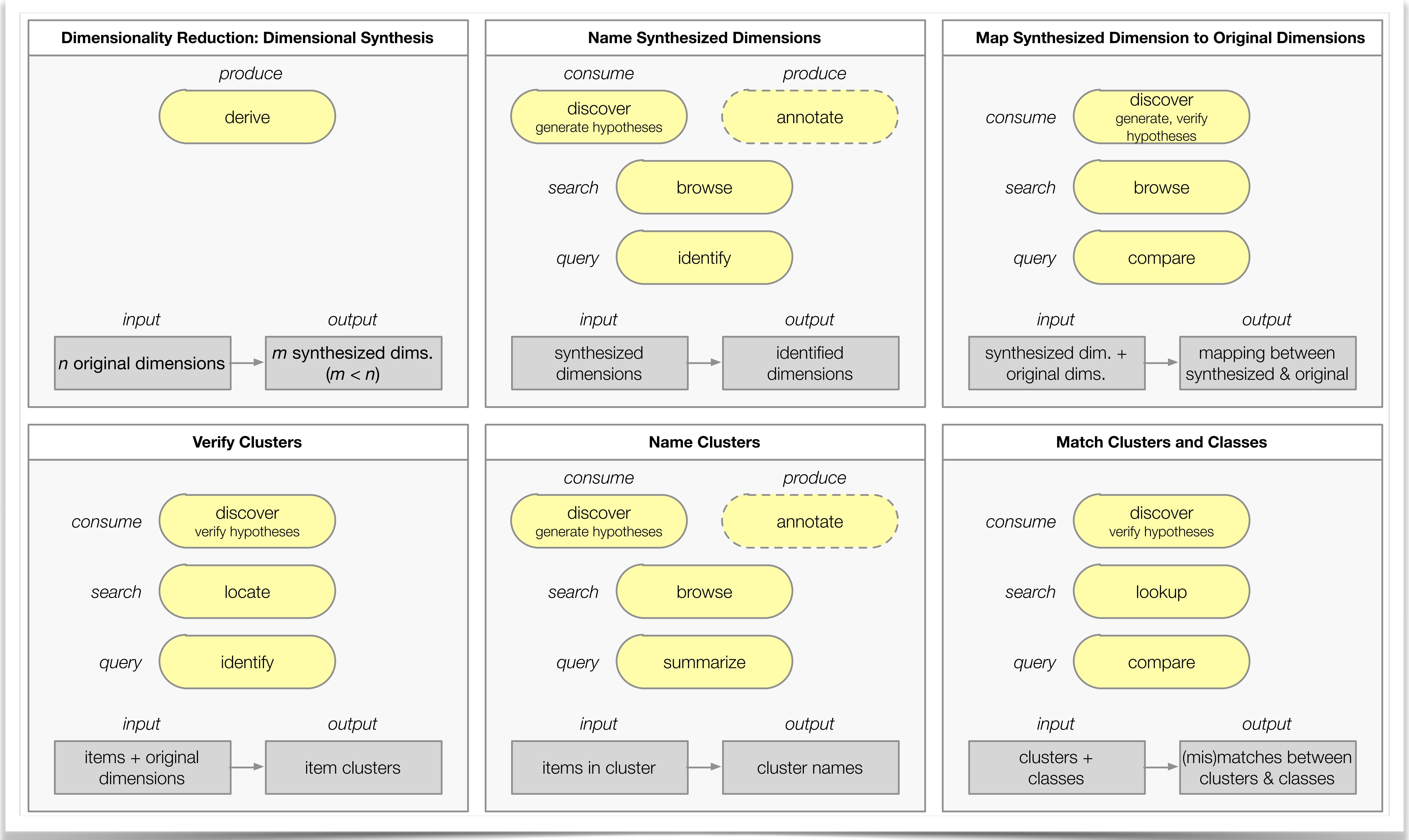


The task typology allowed us to compare tasks **across application domains**, those having a **common data abstraction**.

Brehmer, Sedlmair, Ingram, & Munzner. Proc. BELIV 2014.



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



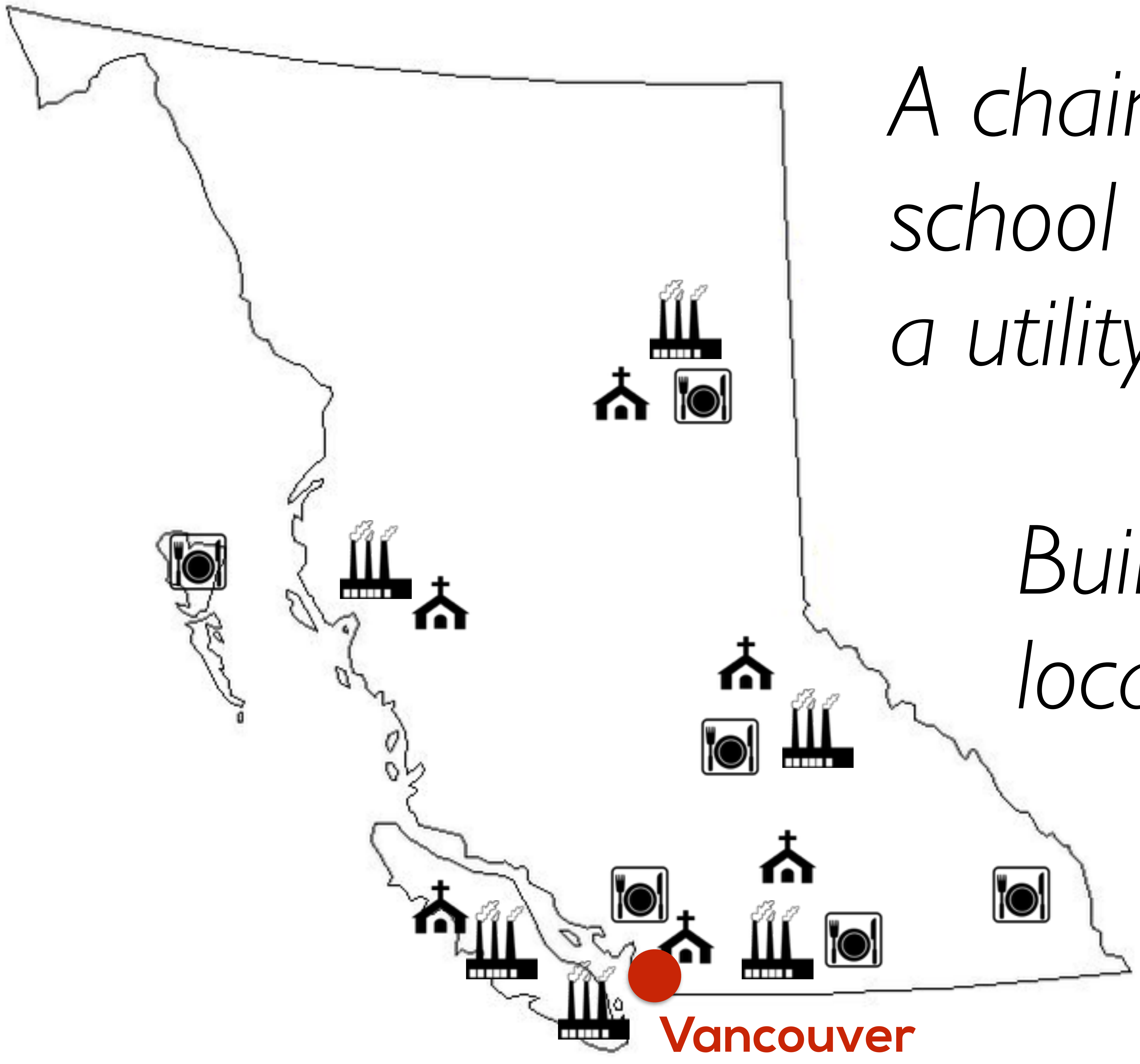
Q: as with the typology, how could I apply or validate this data-abstraction-specific task characterization?

Brehmer, Sedlmair, Ingram, & Munzner. Proc. BELIV 2014.

Perspective 4: Design Study

Visualization for Large-Scale Energy Consumption Analysis

Perspective 4: Design Study
Large-Scale Energy Consumption Analysis

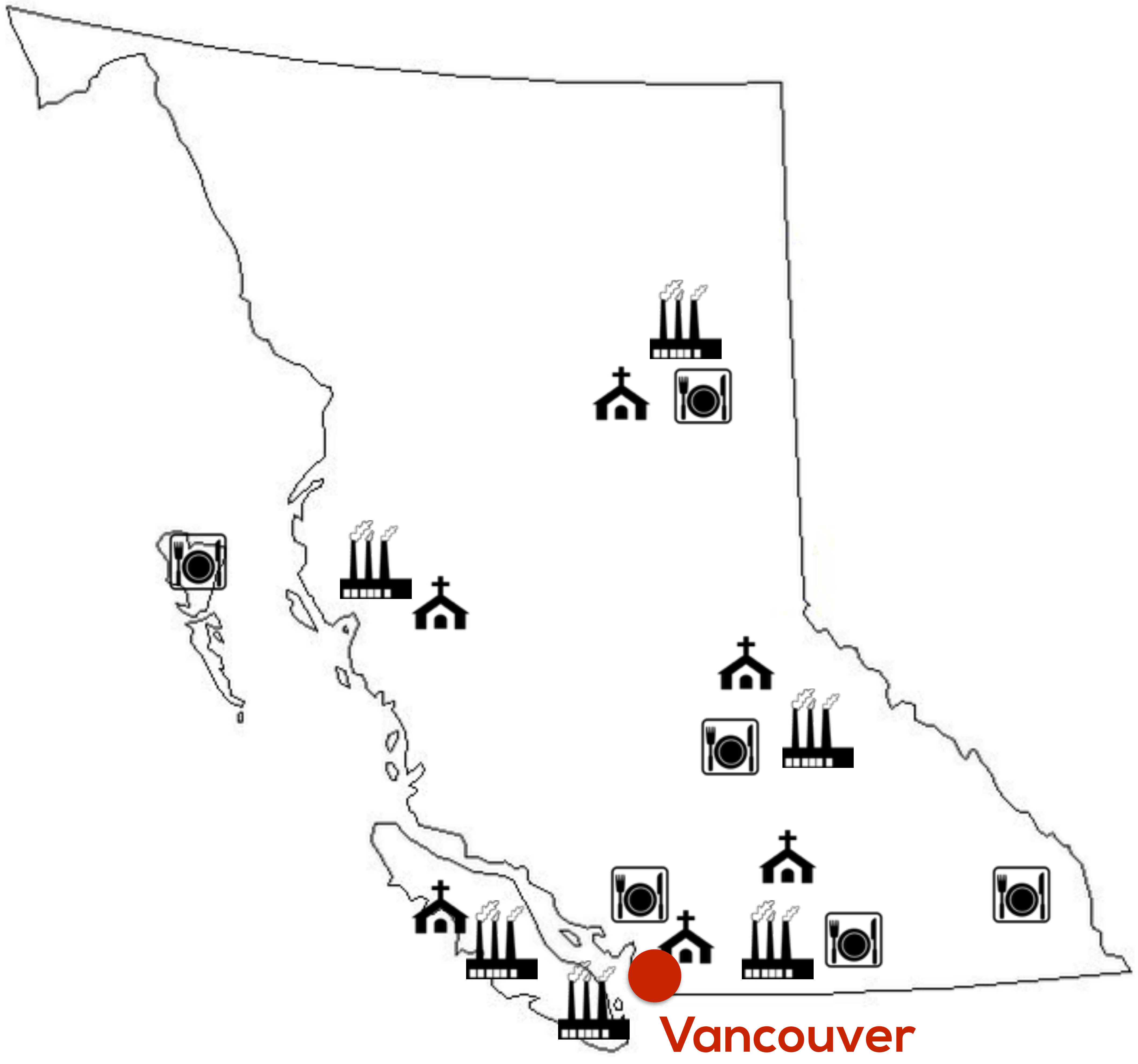


A chain of restaurants or hotels… a school board… a university campus… a utility company portfolio…

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

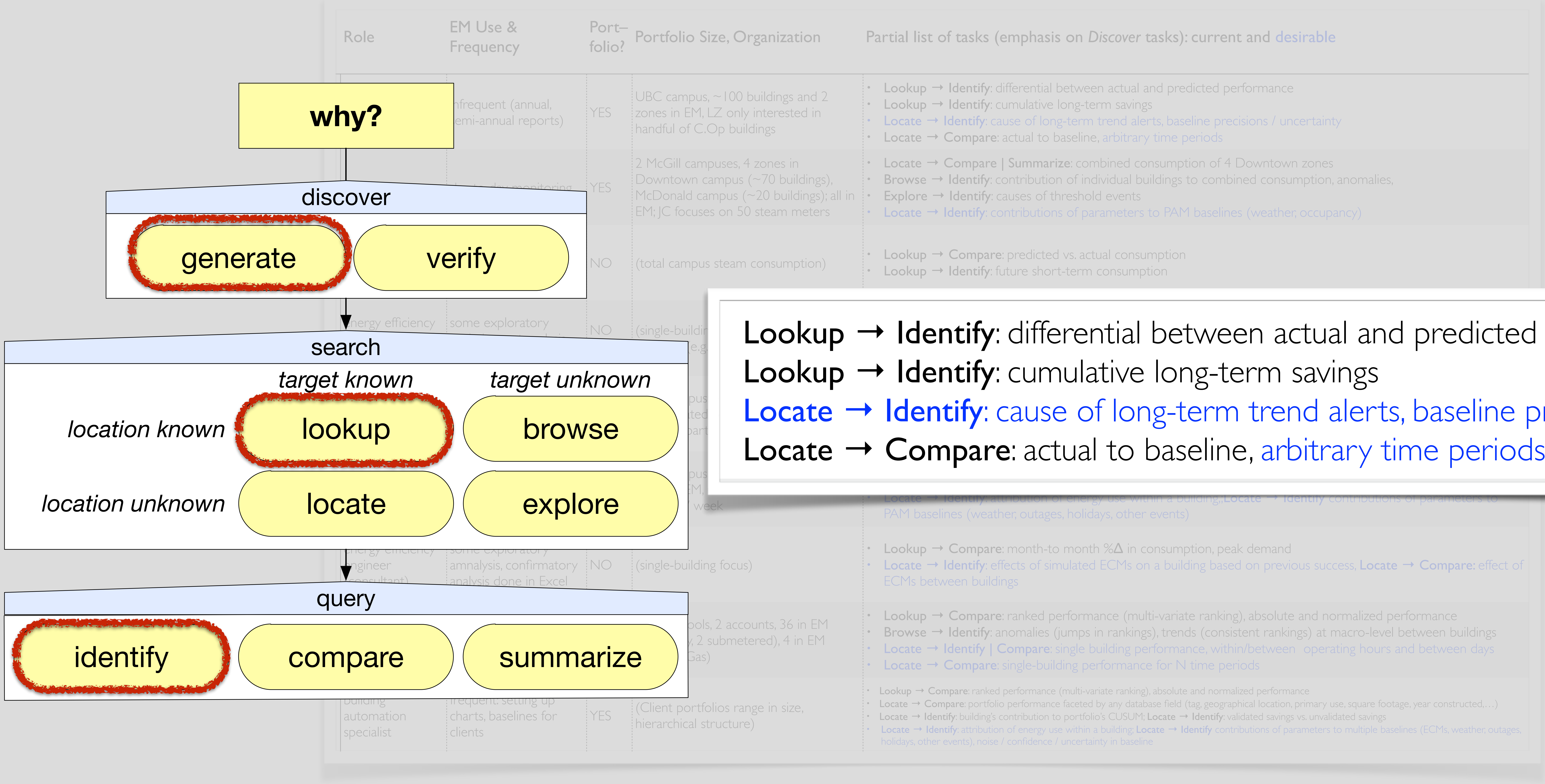
Building Automation Software Specialist

Perspective 4: Design Study

Task Abstraction Analysis: the *Why?*

Role	EM Use & Frequency	Port–folio?	Portfolio Size, Organization	Partial list of tasks (emphasis on *Discover* tasks): current and desirable
climate and energy engineer	infrequent (annual, semi-annual reports)	YES	UBC campus, ~100 buildings and 2 zones in EM, LZ only interested in handful of C.Op buildings	• **Lookup** → **Identify**: differential between actual and predicted performance • **Lookup** → **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	YES	2 McGill campuses, 4 zones in Downtown campus (~70 buildings), McDonald campus (~20 buildings); all in EM; JC focuses on 50 steam meters	• **Locate** → **Compare | Summarize**: 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	NO	(total campus steam consumption)	• **Lookup** → **Compare**: predicted vs. actual consumption • **Lookup** → **Identify**: future short-term consumption
energy efficiency engineer (consultant)	some exploratory analysis, most analysis done in Excel	NO (small)	(single-building focus or small group of buildings (e.g. 5))	• **Explore | Browse** → **Identify**: load profile of building, anomalies; • **Lookup | 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	YES	UCB campus: ~100 buildings (90% concentrated on single campus), subset in EM, departments cross-cuts buildings	• **Locate** → **Compare**: consumption of [largest buildings, libraries, mid-size buildings] • **Locate** → **Identify**: causes of threshold events in reference to OAT • **Lookup** → **Compare**: ranked building performance • **Locate** → **Compare**: before after ECMs, **Locate** → **Compare** OAT-demand regression curves before, after ECMs • **Locate** → **Identify**: attribution of energy use within a building; **Locate** → **Identify** contribution of department(s) to building consumption; • **Locate** → **Compare**: consumption of UCB to other universities; **Lookup** → **Identify**: weather predictions, trends
head maintenance engineer, automation	daily email digest, follow-up in EM ~3-4 hrs / week	YES	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, outages, holidays, other events)
energy efficiency engineer (consultant)	some exploratory amnalysis, confirmatory analysis done in Excel	NO	(single-building focus)	• **Lookup** → **Compare**: month-to month %Δ 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	YES	~130 schools, 2 accounts, 36 in EM (Electricity, 2 submetered), 4 in EM (Natural Gas)	• **Lookup** → **Compare**: ranked performance (multi-variate ranking), absolute and normalized performance • **Browse** → **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	YES	(Client portfolios range in size, hierarchical structure)	• **Lookup** → **Compare**: ranked performance (multi-variate ranking), absolute and normalized performance • **Locate** → **Compare**: portfolio performance faceted by any database field (tag, geographical location, primary use, square footage, year constructed,…) • **Locate** → **Identify**: building's contribution to portfolio's CUSUM; **Locate** → **Identify**: validated savings vs. unvalidated savings • **Locate** → **Identify**: attribution of energy use within a building; **Locate** → **Identify** contributions of parameters to multiple baselines (ECMs, weather, outages, holidays, other events), noise / confidence / uncertainty in baseline

Perspective 4: Design Study
Task Abstraction Analysis: the *Why?*



Lookup → **Identify**: differential between actual and predicted performance
Lookup → **Identify**: cumulative long-term savings
Locate → **Identify**: cause of long-term trend alerts, baseline precisions / uncertainty
Locate → **Compare**: actual to baseline, arbitrary time periods

Perspective 4: Design Study
Data Abstraction Analysis: the *What?*

<u>**Data Abstractions**</u>: † = not configurable in EM | [possible extensions]

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)]

item [point] **[P]**
- **temporal quantitative attribute**
  - [point value]
- **categorical attributes**
  - [resource] (e.g. *electricity, steam*)
  - [quantity] (e.g. *energy, mass, avg. power*)
  - [type] (e.g. *monitored, conversion, baseline*)
  - [unit] (e.g. *kW, kWh, GJ, lb, lb/h*)
  - [direction] (consumption vs. generation)
- **static quantitative attributes**
  - [update frequency]
- **links**
  - [space i]
  - [datalogger j]
  - [connector k]

item [space-point dyad] **[S-P]**
- **static quantitative attributes**
  - [cost conversion ratio]
  - [energy conversion ratio]
  - [Green House Gas conversion ratio]
  - [normal range ±%]
    - [coarse-grained normal range ±%]
    - [fine-grained normal range ±%]

weather [W]
- **temporal quantitative attribute**
  - [OAT: outside air temperature]
  - [relative humidity]
  - [wind speed]
  - [precipitation]
  - …
- **temporal categorical attribute**
  - [wind direction]

temporal intervals [T]

derived attributes [D1] [items **[P]** + temporal interval **[T]**]
- **quantitative attribute**: average, sum, distribution, range, SD
  - [consumption]
  - [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 attribute**
  - [schedule: derivative of demand]

see CG Excel charts

derived attributes [D2] [item **[S]** + weather **[W]** + **[T]**]
- **quantitative attribute**
  - [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 baseload]
  - [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]~~

out of scope for now

derived attributes [D4] [multiple items **[S + P]** + **[D1, D2, D3]**]

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

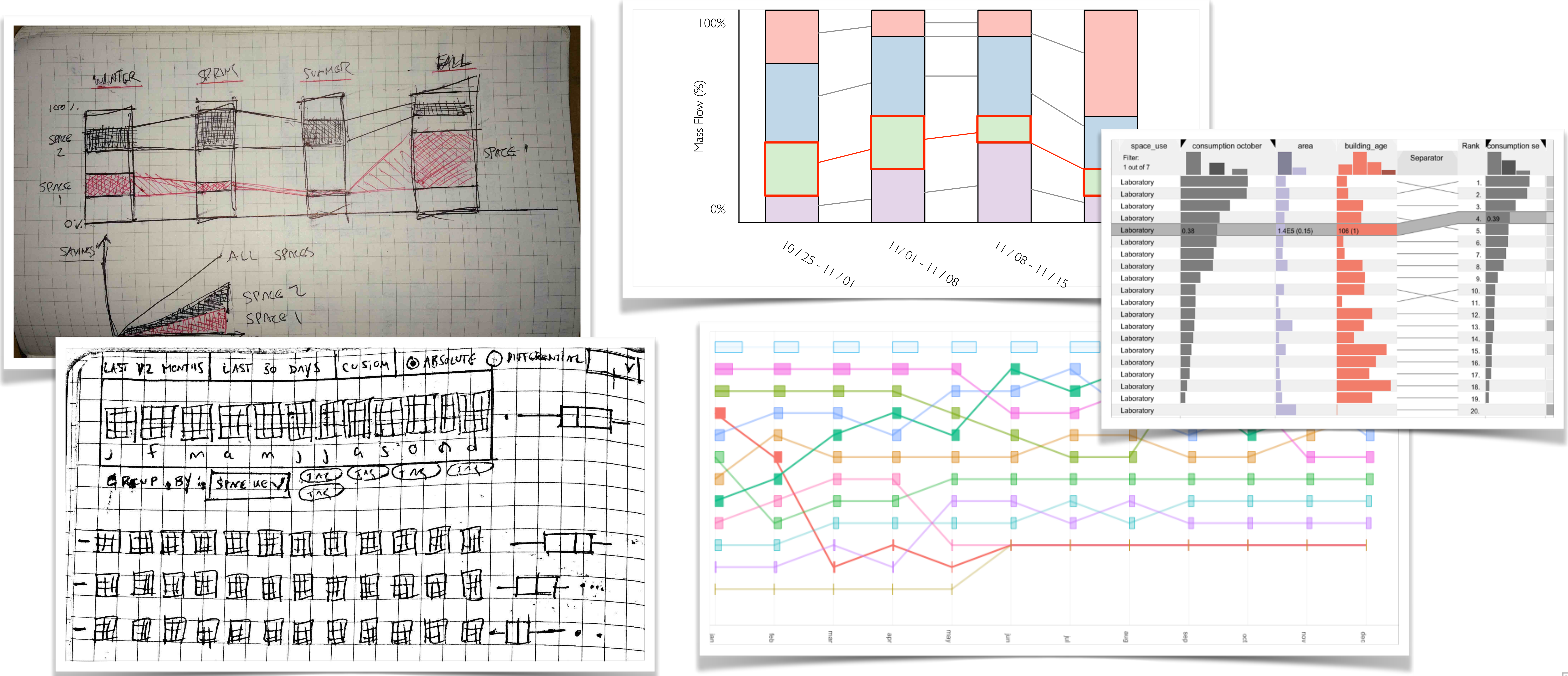
Perspective 4: Design Study
2 Analysis Tasks of focus (in domain language)

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

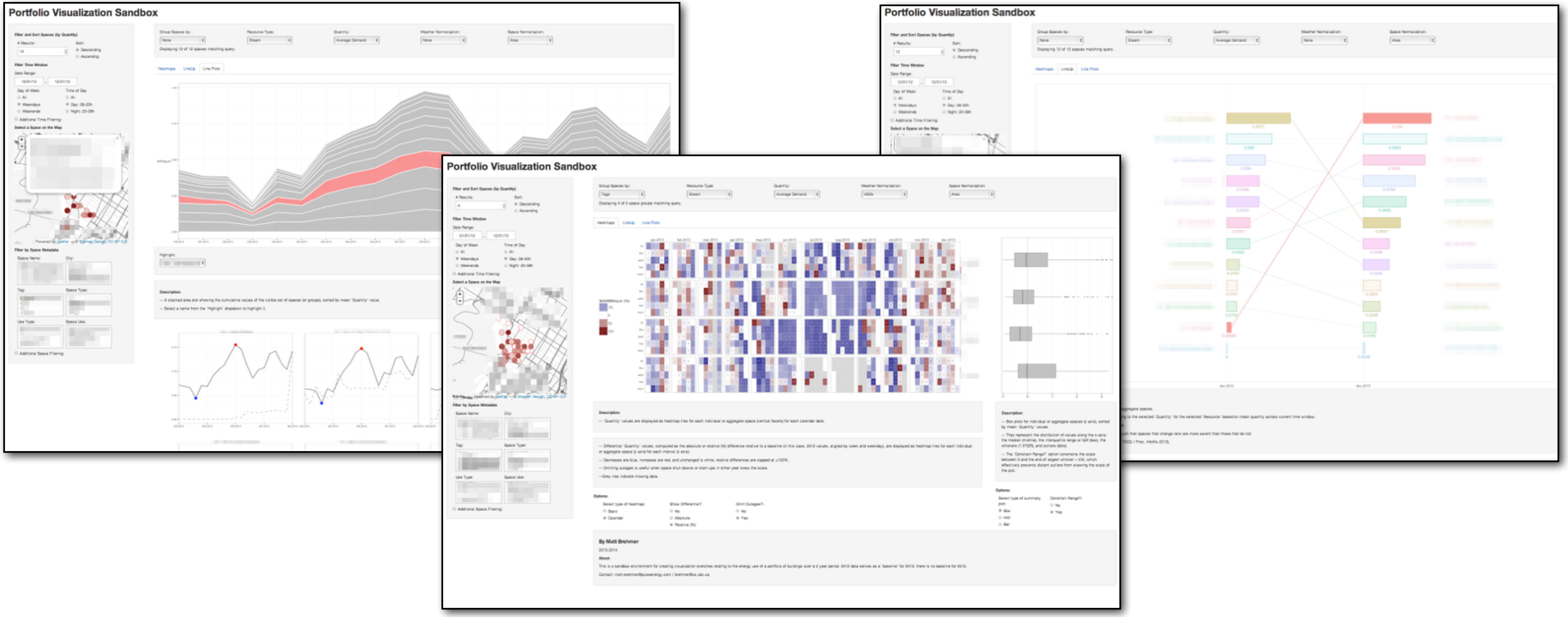
Compare individual building performance over time.

Perspective 4: Design Study

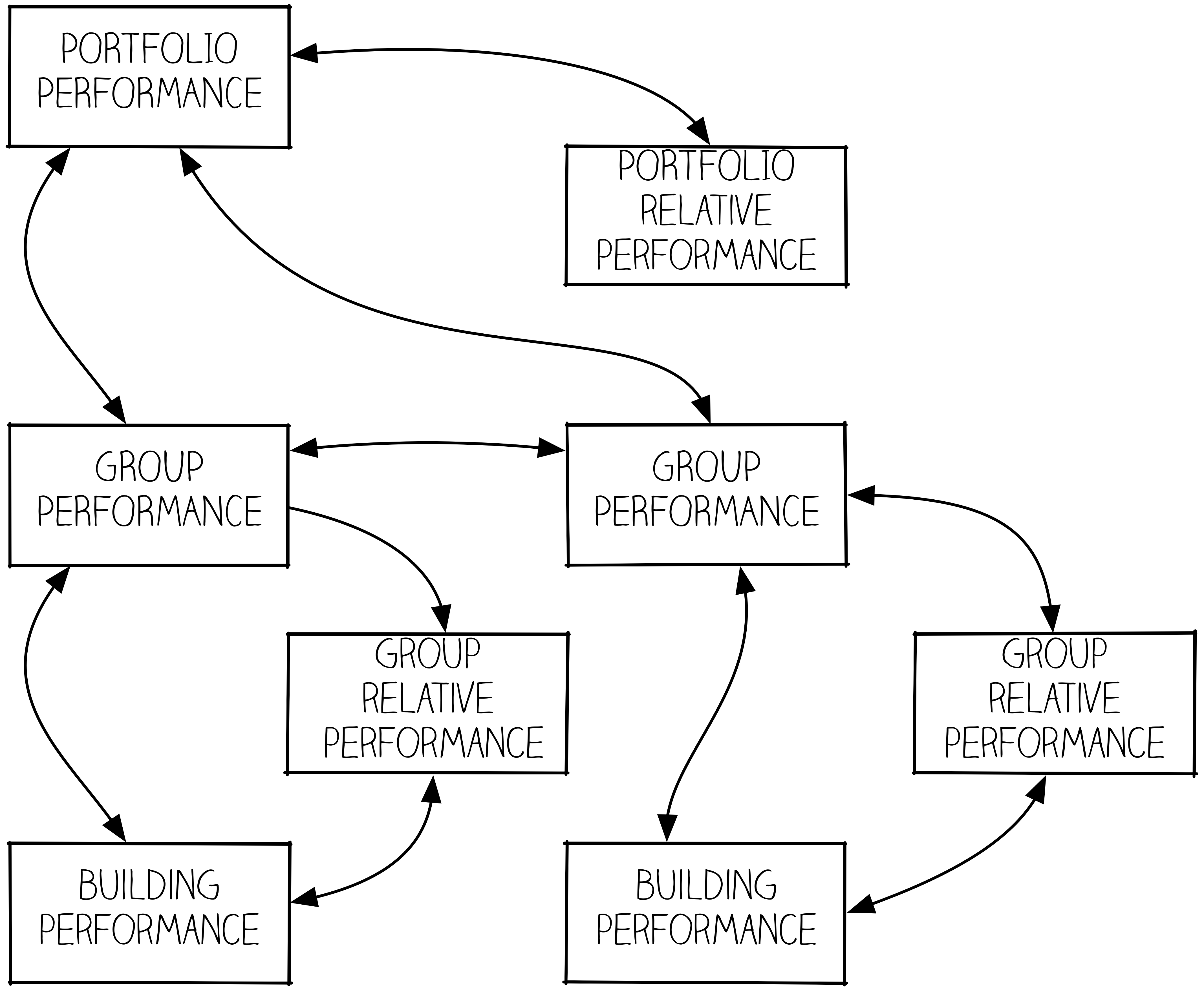
Early Visualization Design Sketching

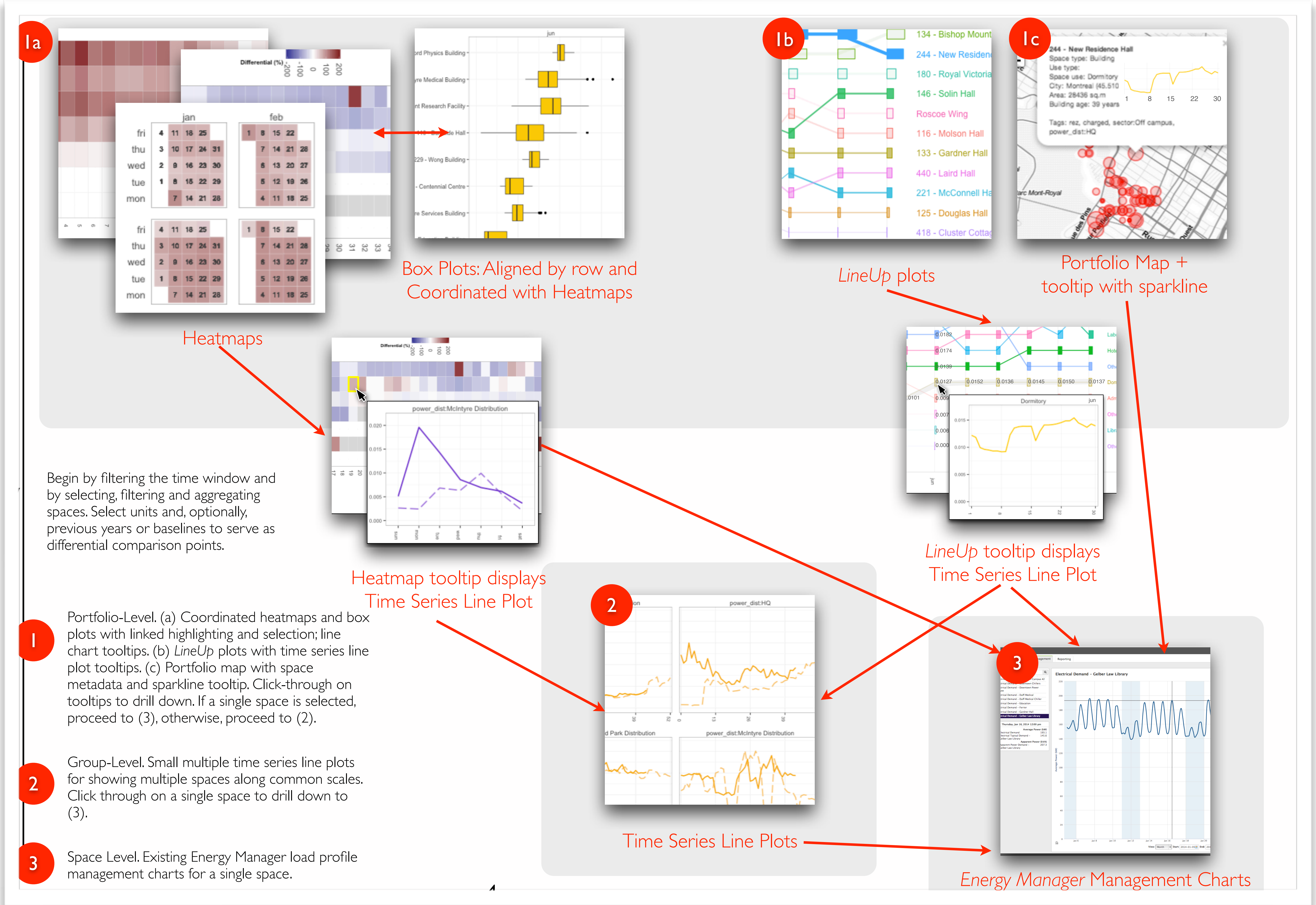


Perspective 4: Design Study
Later: Visualization Design Sketching



Perspective 4: Design Study
Designing Workflows





Perspective 4: Design Study
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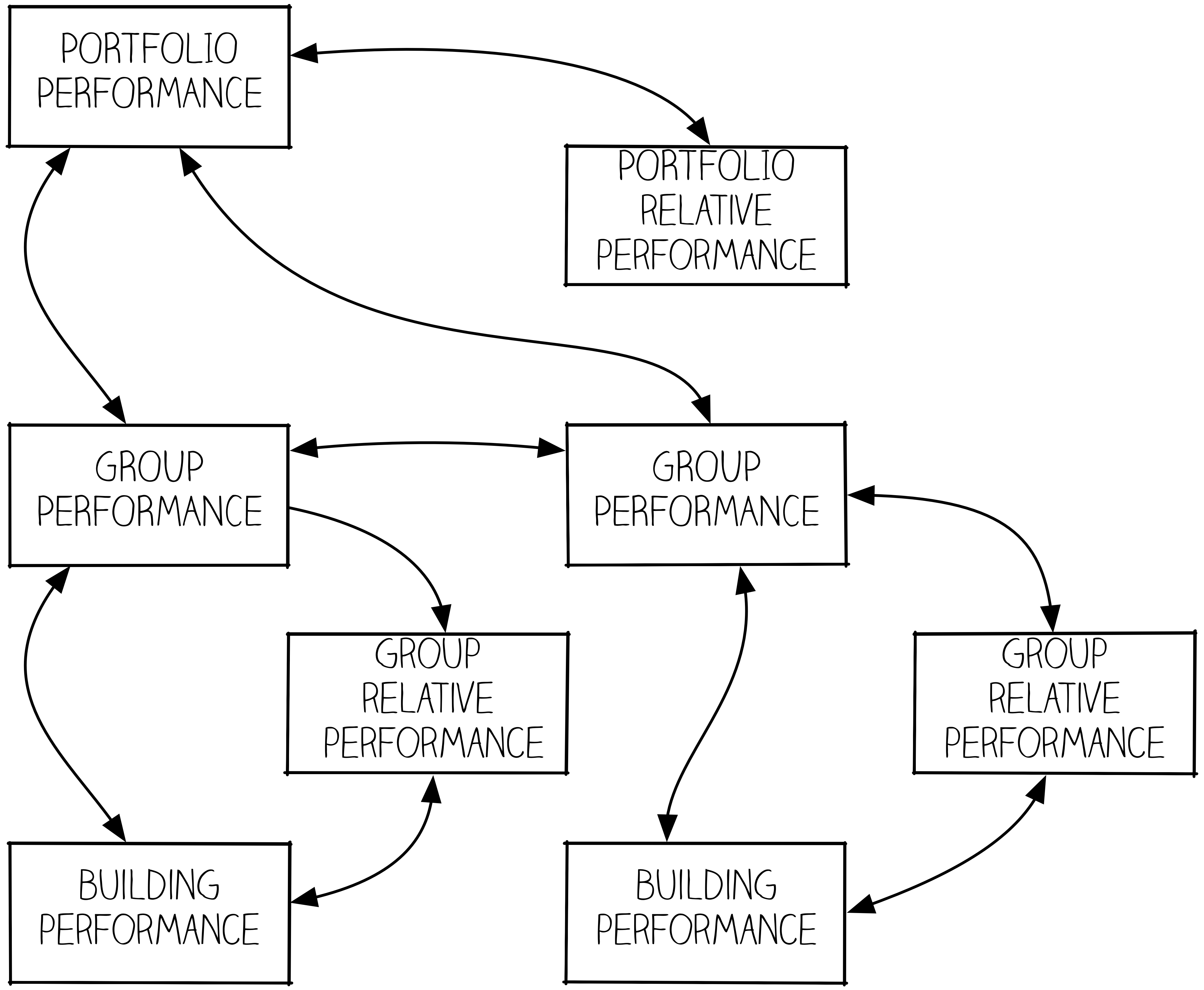

Q: How do I combine visual encoding and interaction design choices into coherent workflows for a diverse user population?

Q: How do I confront legacy software bias and domain convention?

Summary

Four Perspectives Revisited

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?

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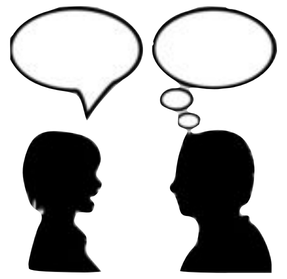

Interview Study:
How should I validate domain-agnostic data-abstraction-specific task characterization?

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

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

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

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Stephen Ingram, Jonathan Stray, Pulse Energy

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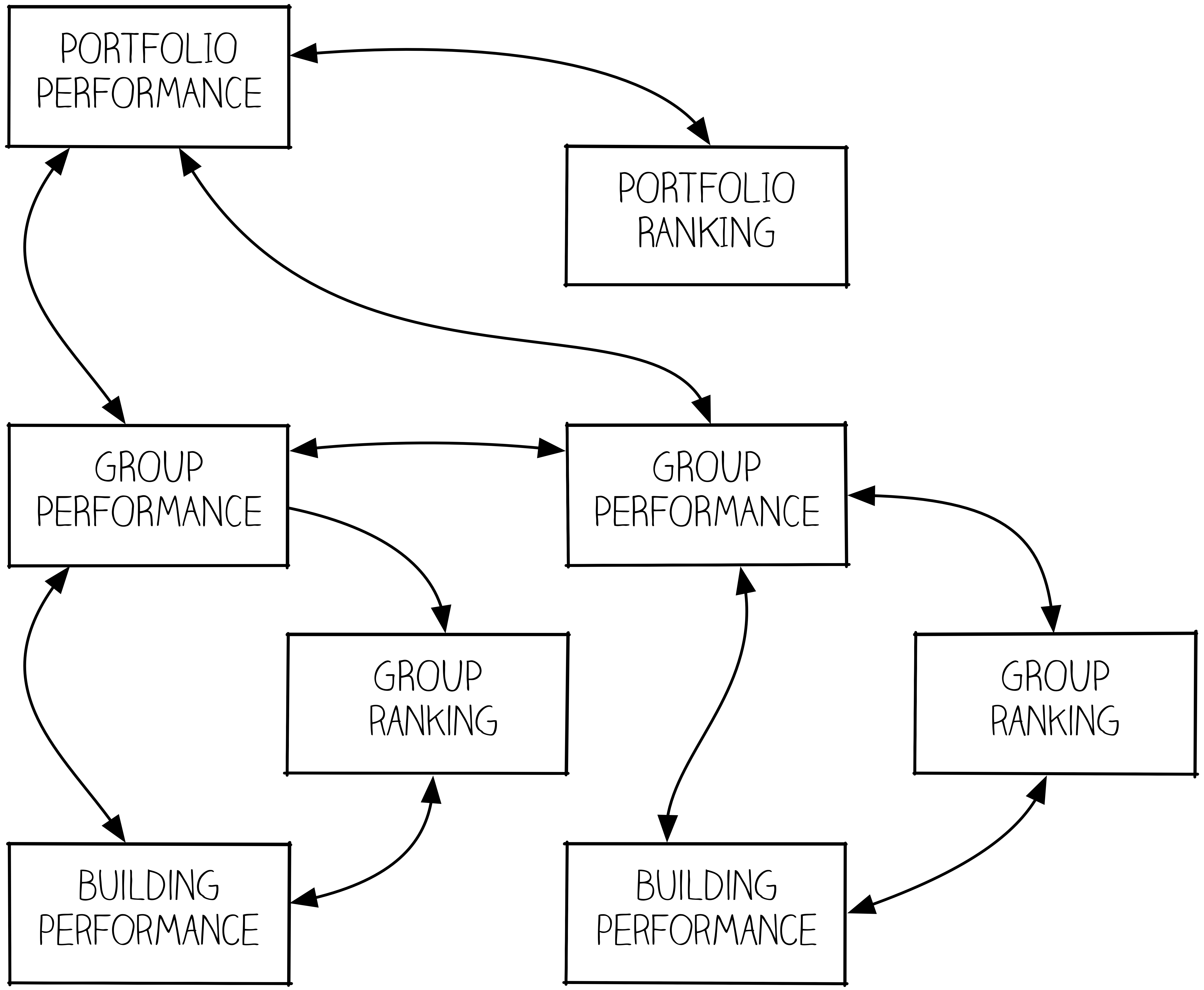
Supplemental

Perspective 4: Design Study
Process: Design and Feedback Cycle

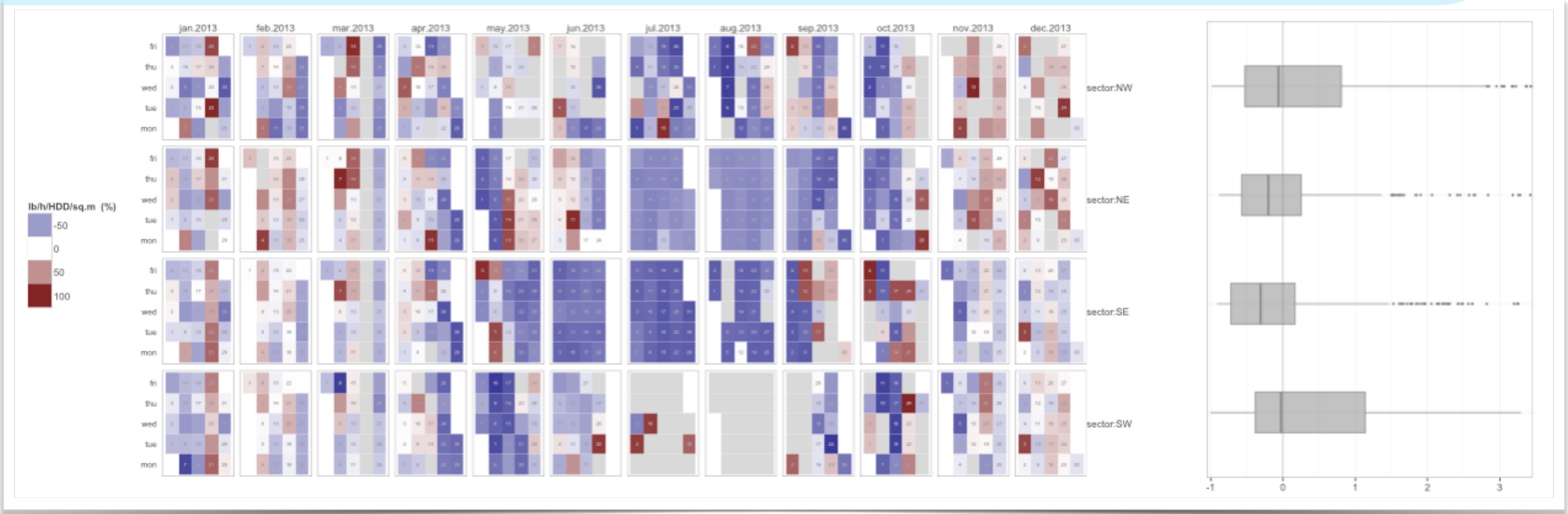
- Project Scope Discussion
- For Internal Feedback (Collaborator)
- For External Feedback (Original Interviewees)
- For External Feedback (New Prospective Users)

Perspective 4: **Design Study**
Open Questions



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?*

Perspective 4: Design Study
Open Questions



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

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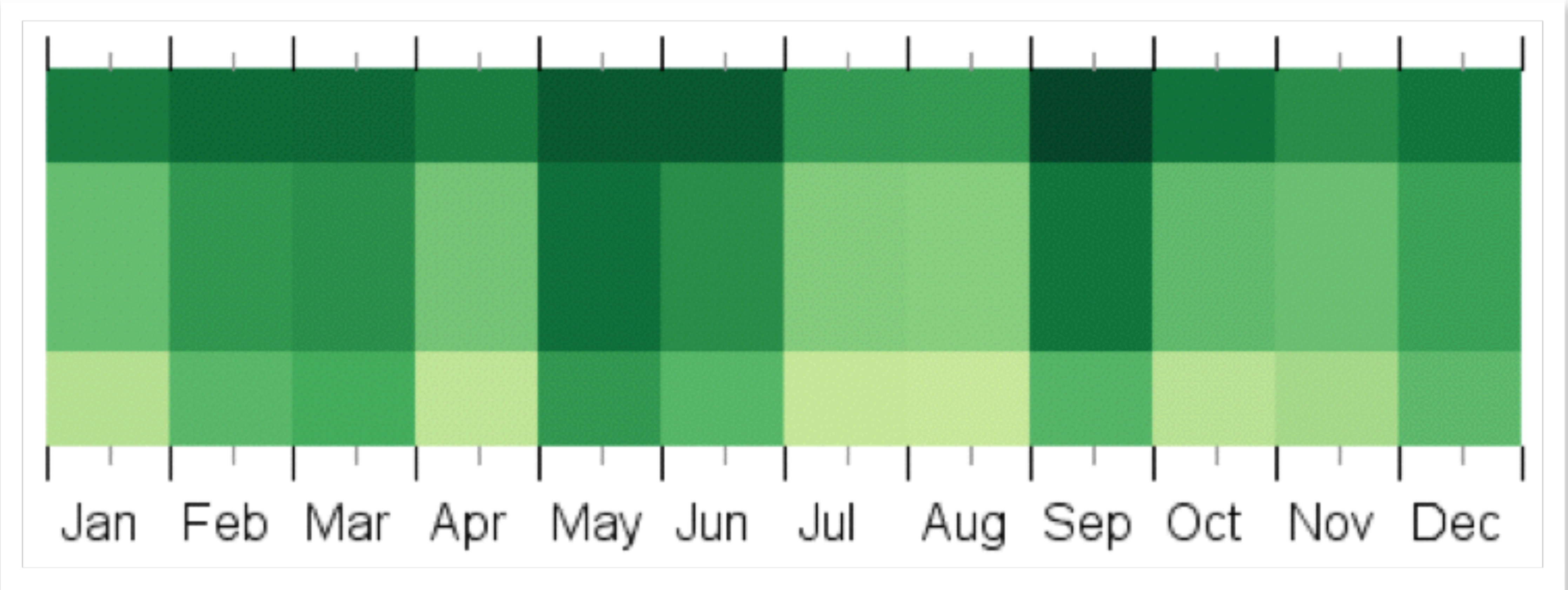
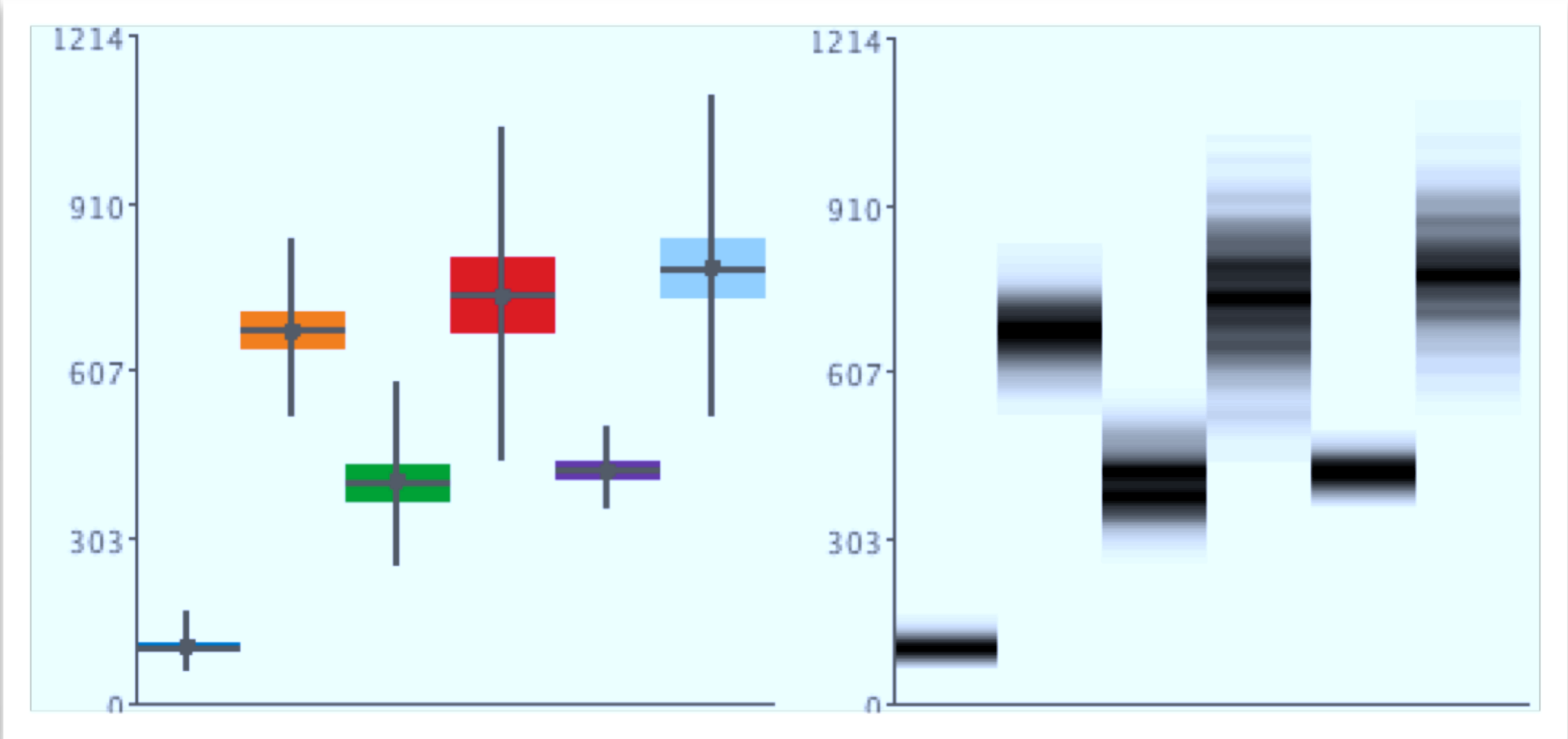


Albers et al. Proc. CHI '14



Booshehrian et al. Proc. EuroVis '12

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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?