

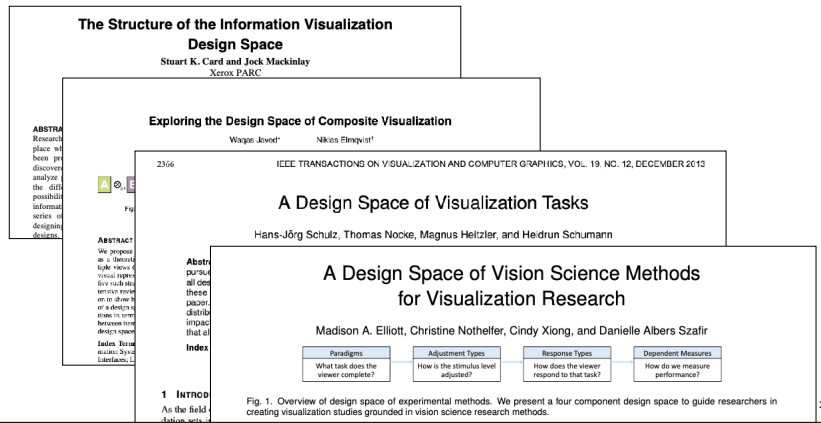
Developing Design Spaces for Visualization

Tamara Munzner
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 University of British Columbia



Autodesk LIVE Seminar
 27 June 2022, virtual
<http://www.cs.ubc.ca/~tmm/talks.html#autodesk22>
 @tamaramunzner

Design spaces: Continuing theme



Design spaces: What are they?

- impose **systematic structure** on set of possibilities for specific problem
 - to capture the key variables at play
 - to support **reasoning about design choices**
- delineate
 - cross-cutting** / independent / orthogonal
 - axes** / dimensions / categories
- many names
 - design spaces, taxonomies, typologies, classifications, frameworks, models, ...
 - space within which to express design patterns [Javed/Elmqvist]

Design spaces: What are they for?

- describe and analyze portions of design space to **understand differences** among designs & **suggest new** possibilities [Card & Mackinlay 1997]
- design spaces provide an **actionable** structure for systematically reasoning about solutions [Elliott et al 2020]
- taxonomies increase **cognitive efficiency** & support **inferences** [Ralph. Toward Methodological Guidelines for Process Theories & Taxonomies in Software Engineering. IEEE TSE 2020]
 - by grouping similar instances together to facilitate **reasoning about classes** rather than instances

Design spaces: How to assess?

- Michel Beaudoin-Lafon, *Designing Interaction, not Interfaces*. AVI 2004.
 - descriptive** power: ability to describe significant range of existing examples
 - evaluative** power: ability to help assess multiple design alternatives
 - generative** power: ability to help designers create new designs

Design spaces: How to create?

- open coding** source material
 - grounded theory / thematic analysis / qualitative analysis
- literature** review
 - synthesize across existing theories, compare & contextualize
- personal **reflection**
 - reflective synthesis
- complex combinations...

Design spaces: Multiple examples

- datatype: temporal, **timeline** visual encoding
- domain: **genomic epidemiology**, paper figure visual encoding
- domain: **journalism**, data **wrangling** activities
- domain agnostic: **abstract tasks**

Timelines

Timelines Revisited
 A Design Space and Considerations for Expressive Storytelling
<https://timelinesrevisited.github.io/>
<https://timelinestoryteller.com>

Timelines Revisited: A Design Space and Considerations for Expressive Storytelling
 Brehmer, Lee, Bach, Henry Riche, Munzner. IEEE TVCG 23(9):2151-2164

Matt Brehmer
 Bongshin Lee
 Benjamin Bach
 Nathalie Henry Riche

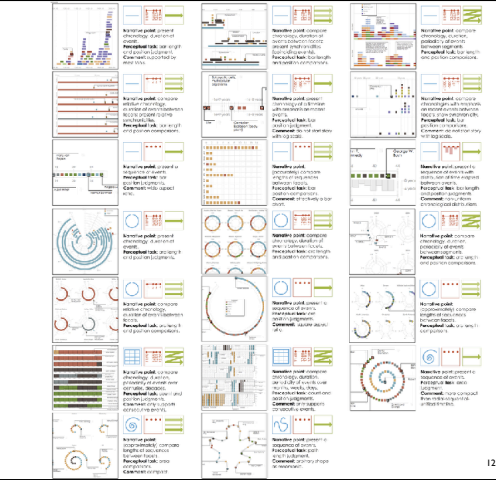
Design space with three axes

- representation
 - Linear
 - Radial
 - Grid
 - Spiral
 - Arbitrary
- scale
 - Chronological
 - Relative
 - Logarithmic
 - Sequential
 - Sequential + Interim Duration
- layout
 - Unified (single timeline)
 - Faceted (multiple timelines)
 - Segmented timeline
 - Faceted + Segmented

Combinations: Characterize narrative, perceptual

Viable combinations

- 20 out of 100
- criteria
 - purposeful
 - interpretable
 - generalizable



Process

- create** design space
 - assemble** source material corpus: 145 timeline visualizations & timeline tools
 - open code** group timelines together, select example for group, sketch alternatives
 - result: 3-axis design space
- analyze** design space
 - 24 unique combinations (of 100) found in corpus
 - 20 we deemed viable

Assessment & adoption

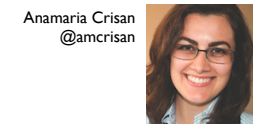
- descriptive power**
 - validated** coverage through checking 118 additional timelines ("test set")
 - all timelines can be described (263 total)
 - 253 characterized as viable
- generative power**
 - implemented** sandbox authoring software for 20 viable designs
 - & transitions between them
 - created** designs for 28 representative datasets
 - 7 full story videos
- adoption**
 - open sourced** & distributed as Microsoft **product**
 - free browser version at <https://timelinestoryteller.com/>
 - free add-on for PowerBI

Genomic Epidemiology

A systematic method for surveying data visualizations and a resulting genomic epidemiology visualization typology:

GEViT

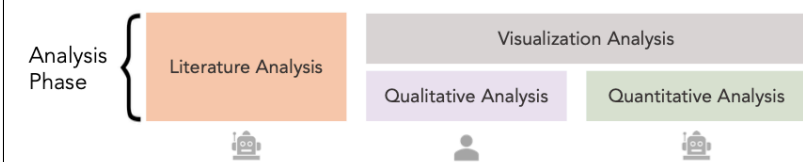
<https://amcrisan.github.io/gevit>



A systematic method for surveying data visualizations and a resulting genomic epidemiology visualization typology: GEViT. Crisan, Gardy, Munzner. Oxford Bioinformatics 35(10):1668-1676, 2018.

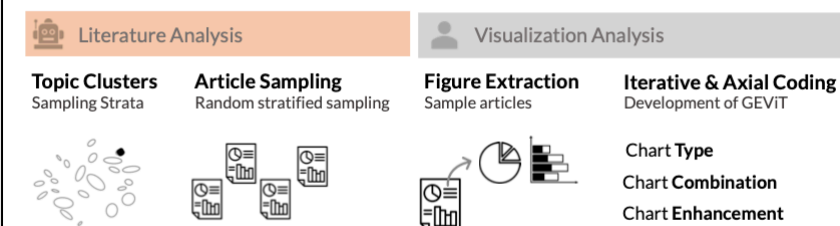
Propose typology creation method: mixed qual and quant

- Analyzed research articles
- Some analyses are automated (🤖) and others are manual (👤)

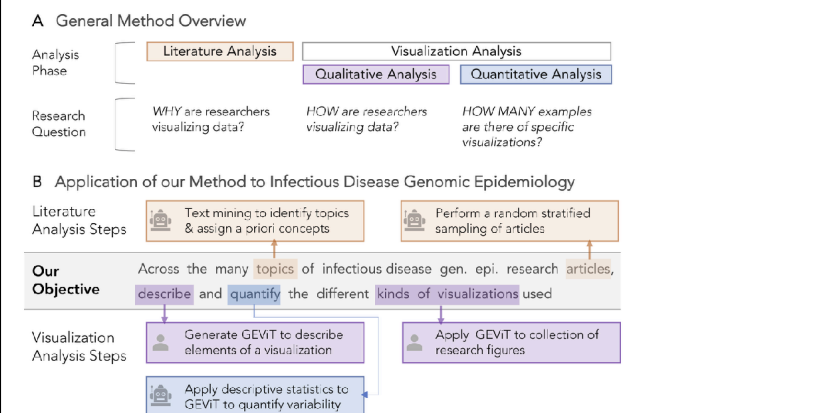


Use method to develop typology in specific domain

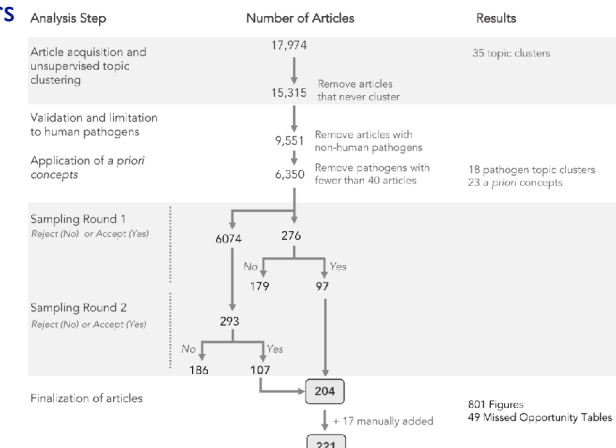
- Developed a Genomic Epidemiology Visualization Typology (GEViT)



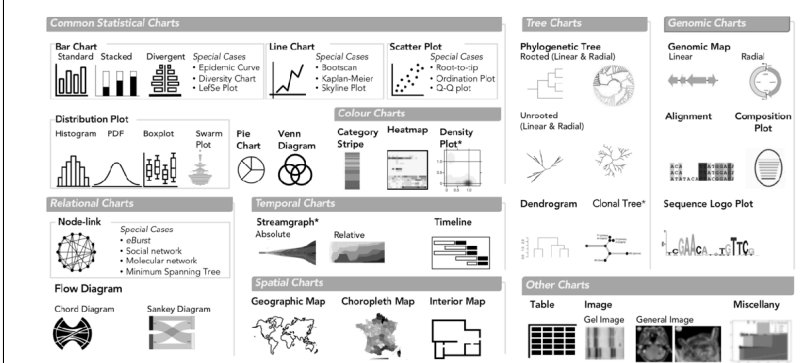
Domain prevalence design space



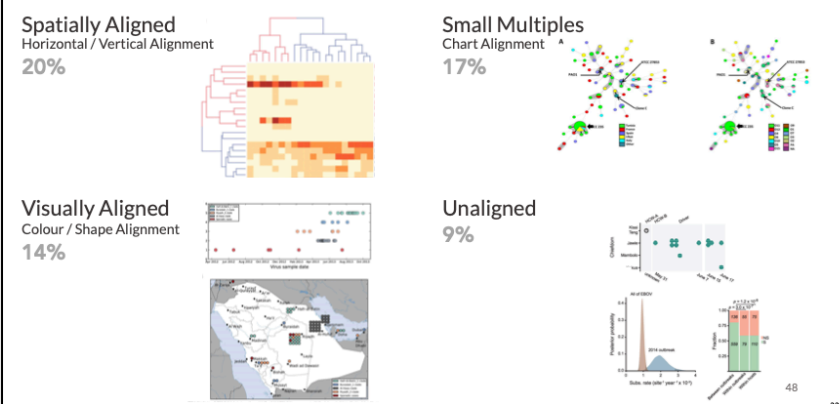
By the numbers



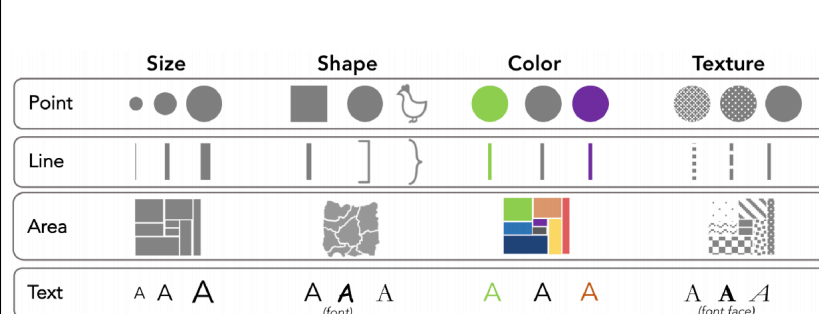
Design space axis: Chart types used in genEpi



Design space axis: Chart combinations of heterogeneous data

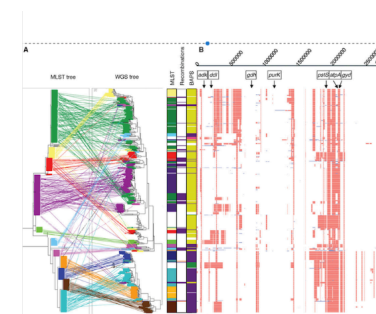


Design space axis: Enhancement choices, atop base chart types

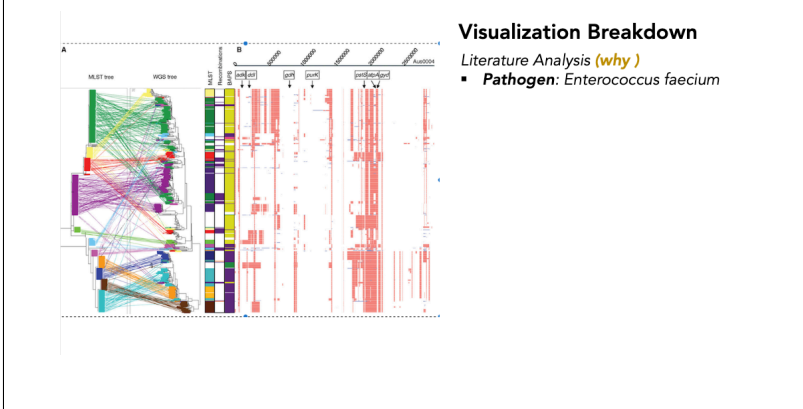


Current Practice >80% of all figures have some enhancement

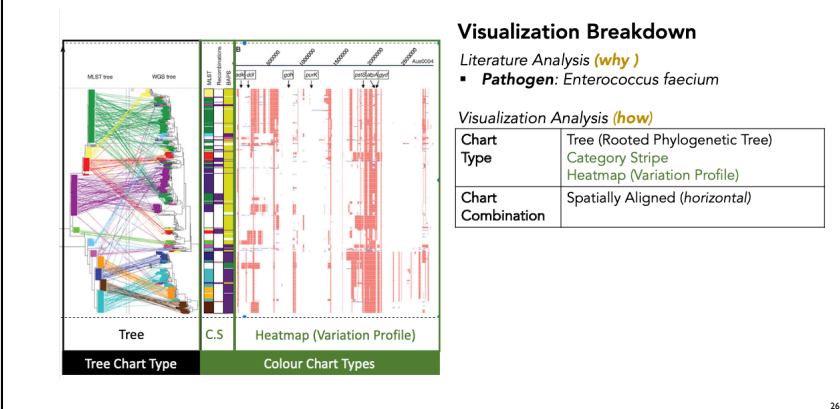
GEViT example



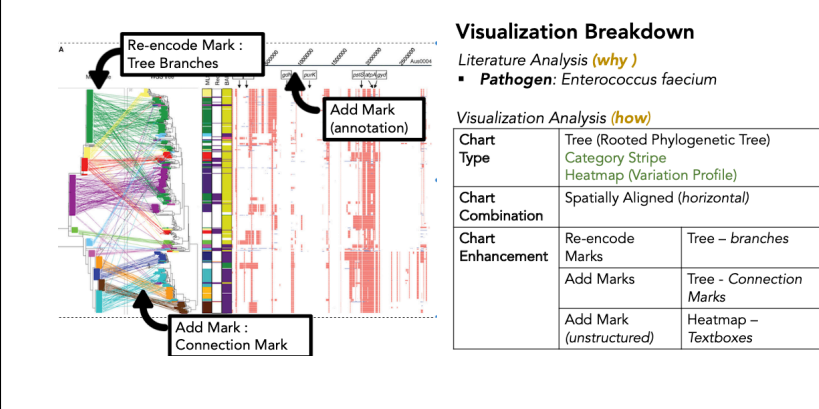
GEViT example



GEViT example



GEViT example



Assessment

- descriptive power
 - provided common language for describing data visualization in genEpi
 - established gap: **unmet tooling needs**
 - no existing tool handled full complexity of what people do manually
- evaluative power
 - revealed shortfalls** in practices of some genEpi stakeholders
 - eg overuse of text
- generative power
 - validated in followup GEViTRec work
 - build** automatic recommender system using domain prevalence design space

GEViTRec:

Data Reconnaissance Through Recommendation Using a Domain-Specific Visualization Prevalence Design Space

Anamaria Crisan @amcrisan

Shannah Fisher

Jenn Gardy @jennifergardy

<https://github.com/amcrisan/GEViTRec>

GEViTRec: Data Reconnaissance Through Recommendation Using a Domain-Specific Visualization Prevalence Design Space. Crisan, Fisher, Gardy, Munzner. IEEE TVCG to appear, 2022.

Data Wrangling

An Actionable Framework for Multi-Table Data Wrangling

From an Artifact Study of Computational Journalism

Steve Kasica @stevekasica

Charles Berret @cberret

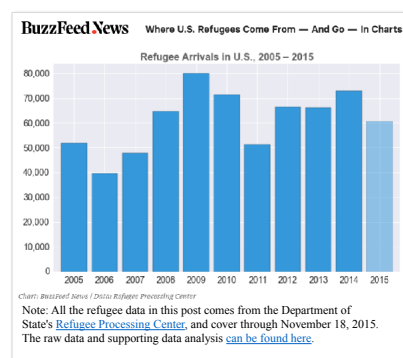
<http://www.cs.ubc.ca/group/infovis/pubs/2020/table-scraps/>

An Actionable Framework for Multi-Table Data Wrangling From an Artifact Study of Computational Journalism. Kasica, Berret, Munzner. IEEE TVCG 27(2):957-966 2021. (Proc. InfoVis 2020).

Journalists are data wranglers...

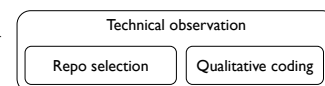
...who show their work publicly

- lots of wrangling behind the scenes
- enter the “**nerd box**”
 - article sidebars or snippet
 - provide / link
 - methods, analysis materials
- publish code/data to public **repos**
 - hundreds on GitHub & Observable
- editorial **transparency**
 - public can scrutinize
 - colleague can reproduce



Process overview

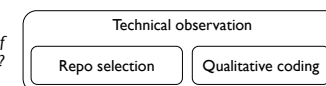
What are the wrangling practices of journalists with programming skills?



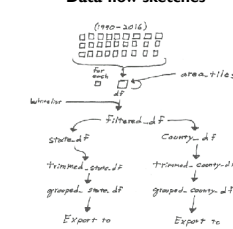
34

Process overview

What are the wrangling practices of journalists with programming skills?



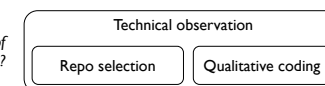
Data-flow sketches



35

Process overview

What are the wrangling practices of journalists with programming skills?

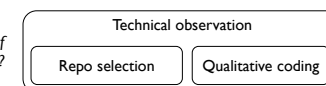


Taxonomies of data wrangling in computational journalism - initial

36

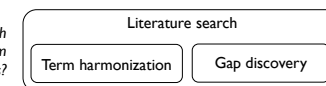
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Taxonomies of data wrangling in computational journalism - initial

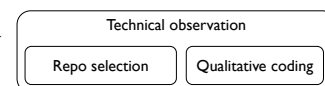
Which practices align with or diverge from existing characterizations?



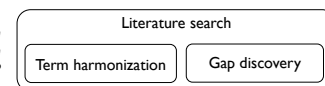
37

Process overview

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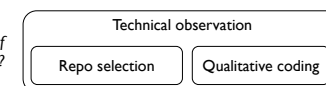


Taxonomies of data wrangling in computational journalism - finalized

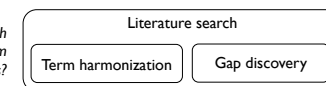
38

Process overview

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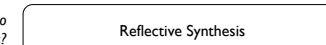


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Taxonomies of data wrangling in computational journalism

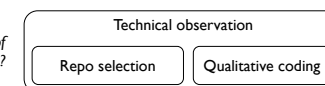
How to re-characterize wrangling to match the observed practices?



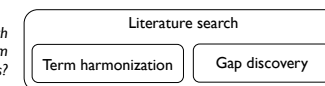
39

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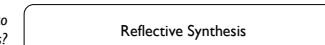


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Taxonomies of data wrangling in computational journalism

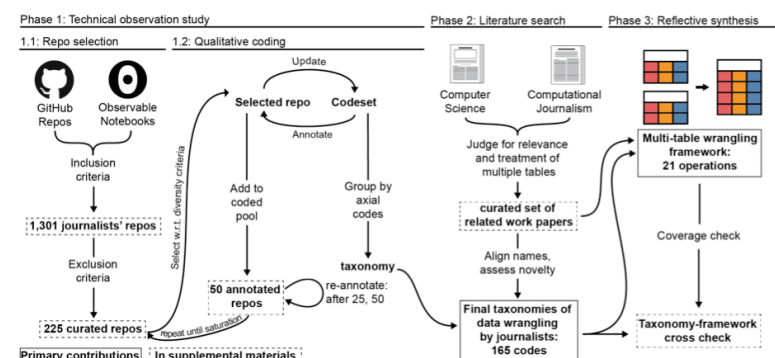
How to re-characterize wrangling to match the observed practices?



Multi-table framework of data wrangling

40

By the numbers



41

Two taxonomies of data wrangling in journalism

- Actions** taken by journalists
 - Import
 - Clean
 - Merge
 - Profile
 - Drive
 - Transform
 - Export
- Process** interpreted by researchers
 - **descriptive** power: excellent
 - total codes: 165
 - max depth: 5 levels
 - **generative** power: limited

Actions

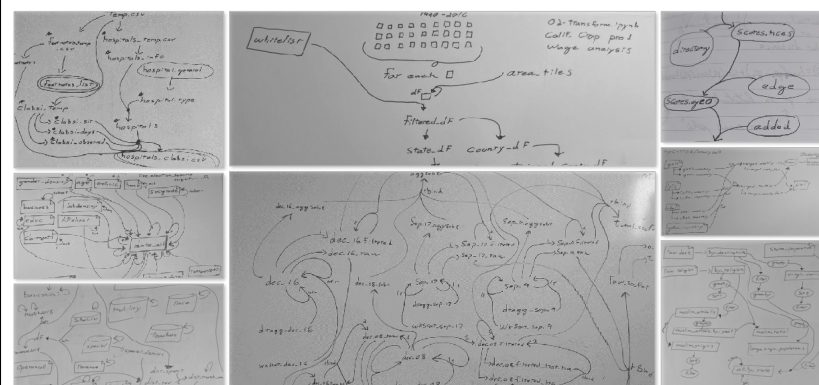
- Import
- Clean
- Merge
- Profile
- Drive
- Transform
- Export

Process

- Source
- Workflow
- Cause
- Themes
- Analysis
- Management
- Pain Points

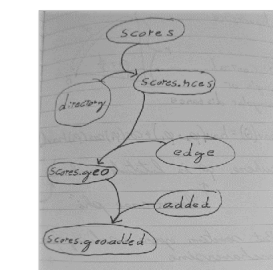
42

Key finding: journalists use many, many tables



Key finding: journalists use many, many tables

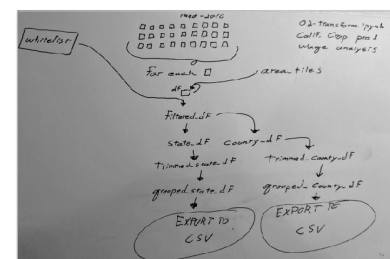
- workflow complexity varies greatly



44

Key finding: journalists use many, many tables

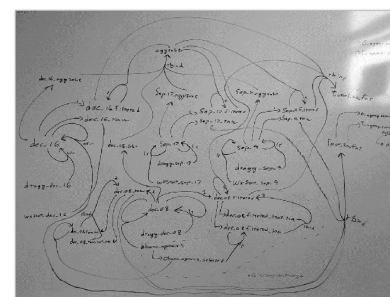
- workflow complexity varies greatly
- current interactive wrangling applications do not scale well



45

Key finding: journalists use many, many tables

- workflow complexity varies greatly
- current interactive wrangling applications do not scale well
- re-characterize wrangling design space to match these observed practices



46

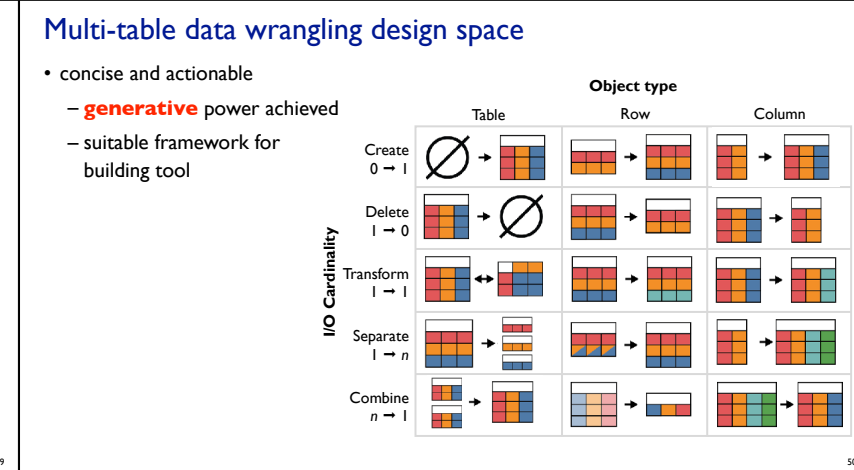
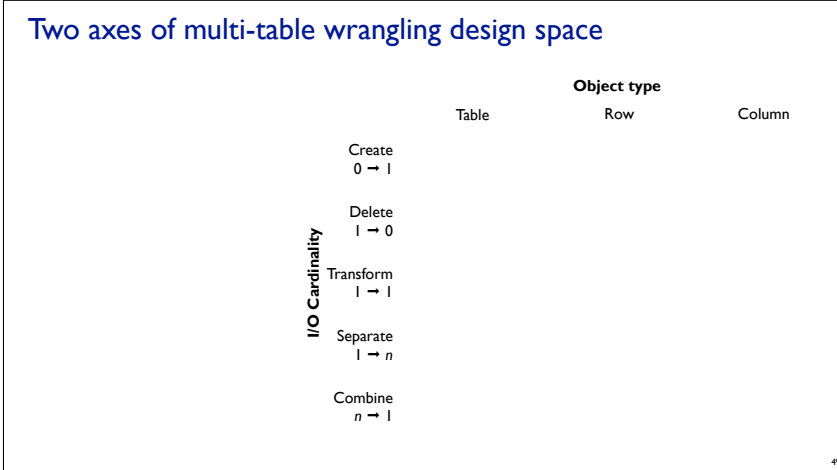
Two axes of multi-table wrangling design space

Object type

Table Row Column

47

Two axes of multi-table wrangling design space



Assessment: Cross-check

- cross-check coverage of multi-table framework vs actions taxonomy
- verify descriptive power

Action Taxonomy	Multi-Table Framework														
	Create			Delete			Transform			Separate			Combine		
	T	C	R	T	C	R	T	C	R	T	C	R	T	C	R
Import															
Clean															
Merge															
Derive															
Transform															

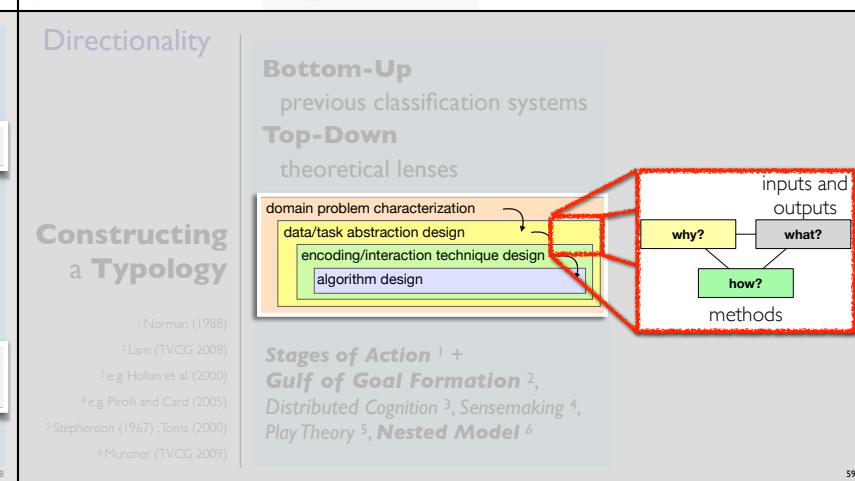
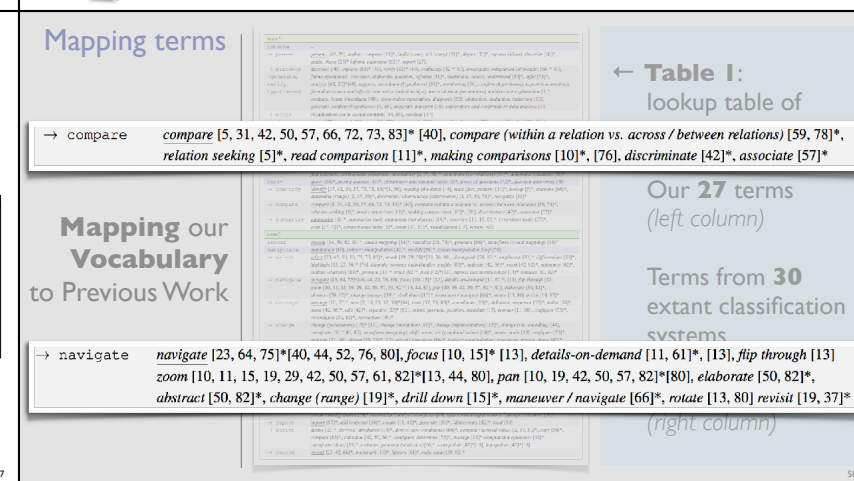
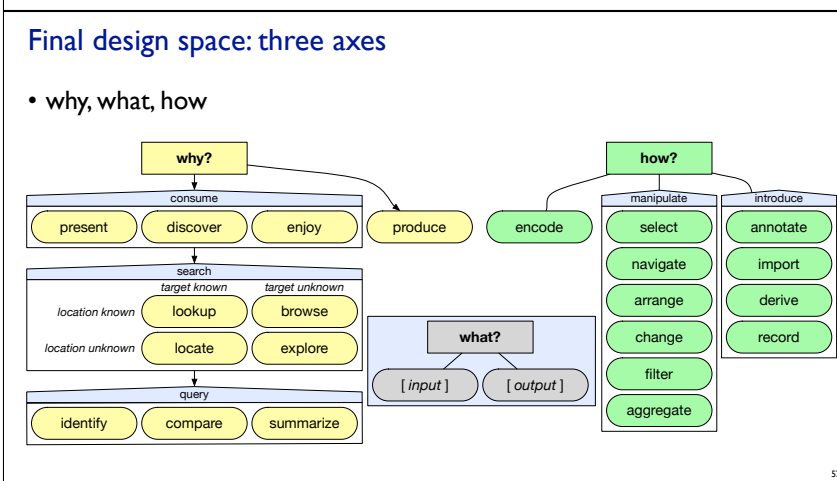
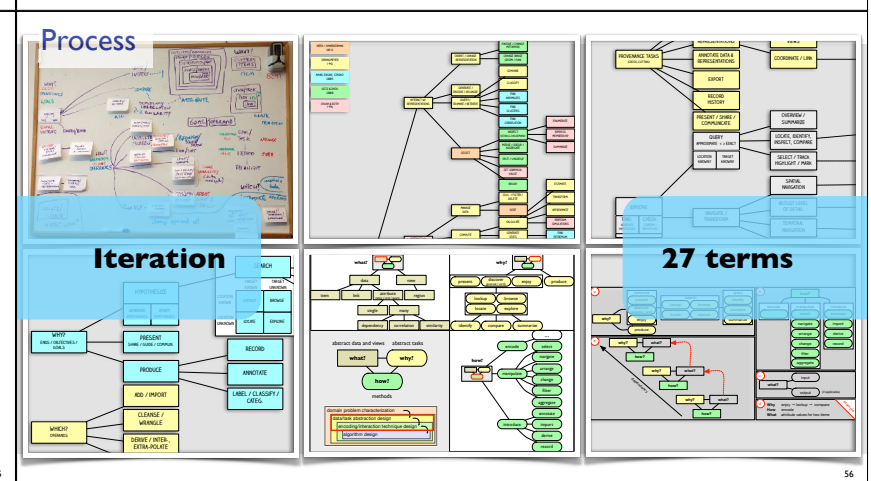
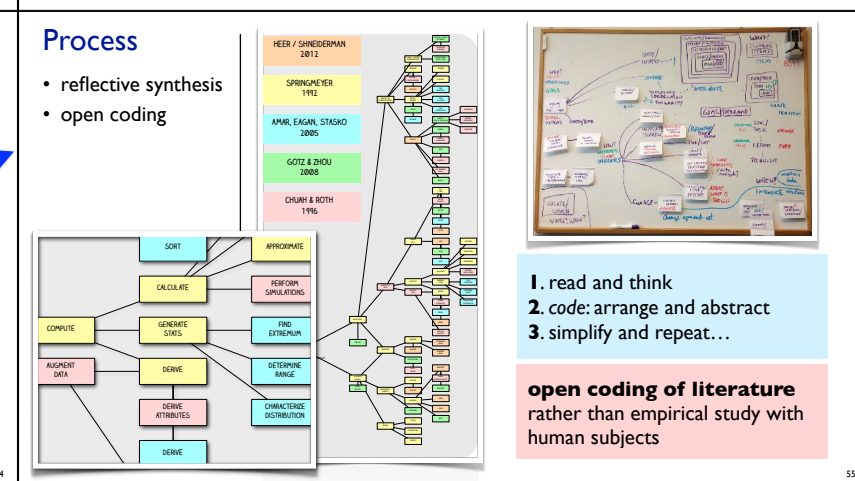
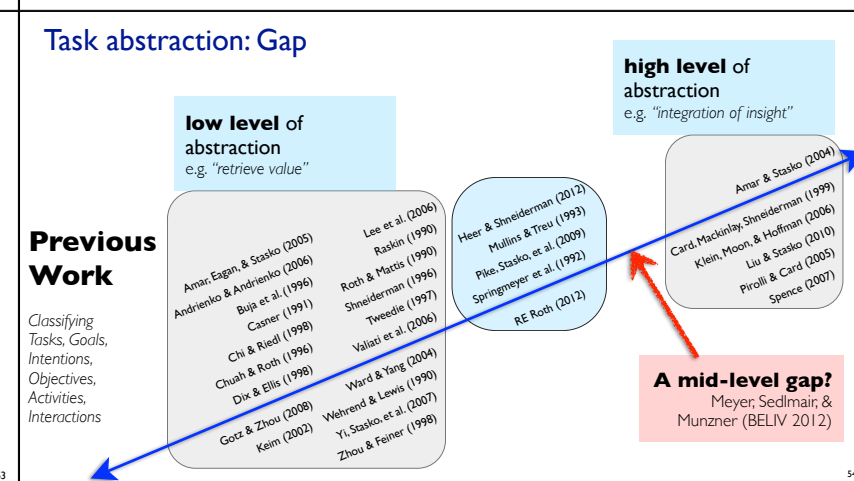
Abstract Tasks

A Multi-Level Typology of Abstract Visualization Tasks

Matt Brehmer @mattbrehmer

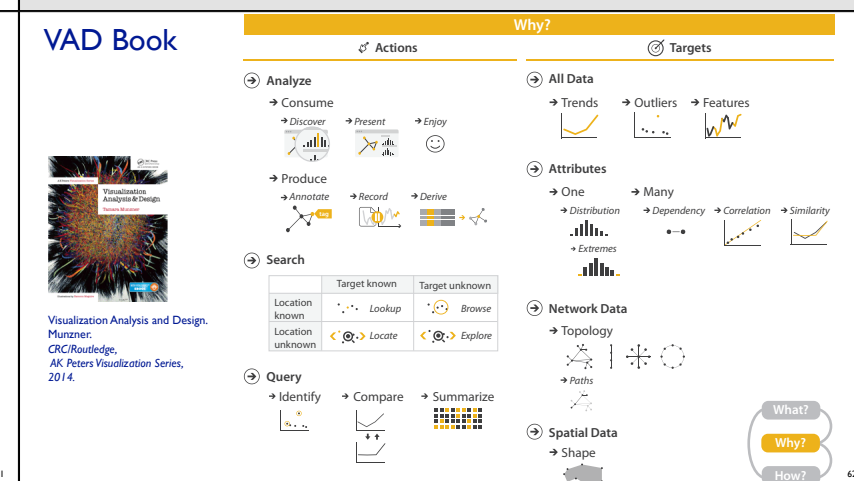
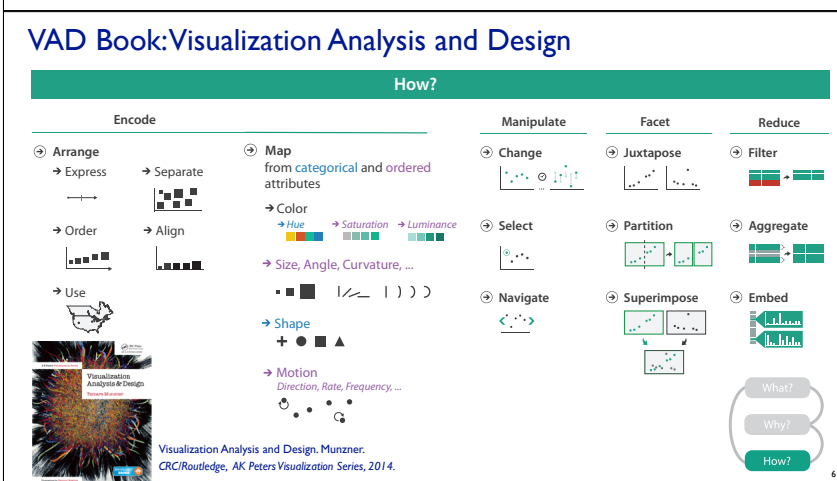
<https://www.cs.ubc.ca/labs/imager/tr/2013/MultiLevelTaskTypology/>

A Multi-Level Typology of Abstract Visualization Tasks. Brehmer, Munzner. IEEE TVCG 19(12):2376-2385 (Proc. InfoVis 2013).



Assessment & adoption

- descriptive power
 - analyze & compare task sequences, clarify means and ends
- generative power
 - early stages of problem-driven work: abstracting & requirements gathering
- evaluative power
 - codeset for field studies, task set for lab studies
- adoption
 - hundreds of papers



Bridging From Goals to Tasks

with Design Study Analysis Reports

<http://www.cs.ubc.ca/labs/imager/tr/2017/GoalsToTasks/>

design space: analysis goals

source material: analysis reports extracted from design study papers

Specificity	Explore	Describe	Explain	Confirm
Single	Discover Observation	Describe Observation	Identify Main Cause	Collect Evidence
Multiple		Compare Entities	Explain Differences	Evaluate Hypothesis

Heidi Lam

Melanie Tory @vizstudylady

Summary: Multiple design spaces

Design Space	Open Coding Source Material	Sampling Strategy	Reflective Synthesis Timing	Vis Research Literature	
timeline	visual encoding	standalone timelines	assembled corpus	early	some source material
genEpi	visual encoding	figures from papers	stratified random sampling with topic clusters	-	-
wrangling activities	software from repos	diversity criteria		late	terms: light mapping
abstract tasks	tasks from papers	comprehensive		early	terms: thorough mapping

Summary: Multiple design spaces

Design Space	Descriptive Power	Generative Power	Descriptive vs Generative	Evaluative Power
timeline visual encoding	validated against test set	software implementation of authoring system, used to create example gallery/videos	analysis to characterize viable subset	
genEpi visual encoding	systematic method yields comprehensive coverage	software implementation of automatic recommender (followup)	<i>same (detailed)</i>	
wrangling activities	high precision, gaps / divergence found for domain	concise framework (followup implementation TBD)	develop entirely new framework	
abstract tasks	widespread adoption	widespread adoption	<i>same (concise)</i>	widespread adoption

65

Design spaces: How to assess? Larger context: theory types

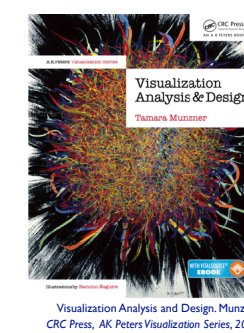
- Ben Shneiderman, *Designing the User Interface*: descriptive, explanatory, prescriptive, predictive
- Paul Ralph, *Toward Methodological Guidelines for Process Theories & Taxonomies in Software Engineering, IEEE TSE 2020*
 - theory types
 - theories for **understanding**: organizing what is happening into useful categories (taxonomies)
 - **process** theories: how something happens (often taxonomies++)
 - **variance** theories: why something happens, causal relationships between constructs
 - predictive
 - relevant criteria for taxonomies
 - **yes**: parsimony, transferability, theoretical saturation
 - **sometimes**: utility, originality, resonance/believability, testability
 - **no**: statistical generalizability, construct validity, internal validity, conclusion validity

66

More information

- this talk
<http://www.cs.ubc.ca/~tmm/talks.html#autodesk22>
- book
<http://www.cs.ubc.ca/~tmm/vadbook>
- full courses, papers, videos, software, talks
<http://www.cs.ubc.ca/group/infovis>
<http://www.cs.ubc.ca/~tmm>

@tamaramunzner



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

67