Entry Points to Visualization: Different Methods for Different Problems

Tamara Munzner
Department of Computer Science
University of British Columbia

Viz@UBC Kickoff: Lunchtime Lecture Series
12 March 2019

www.cs.ubc.ca/~tmm/talks.html#vizatubc19-entry

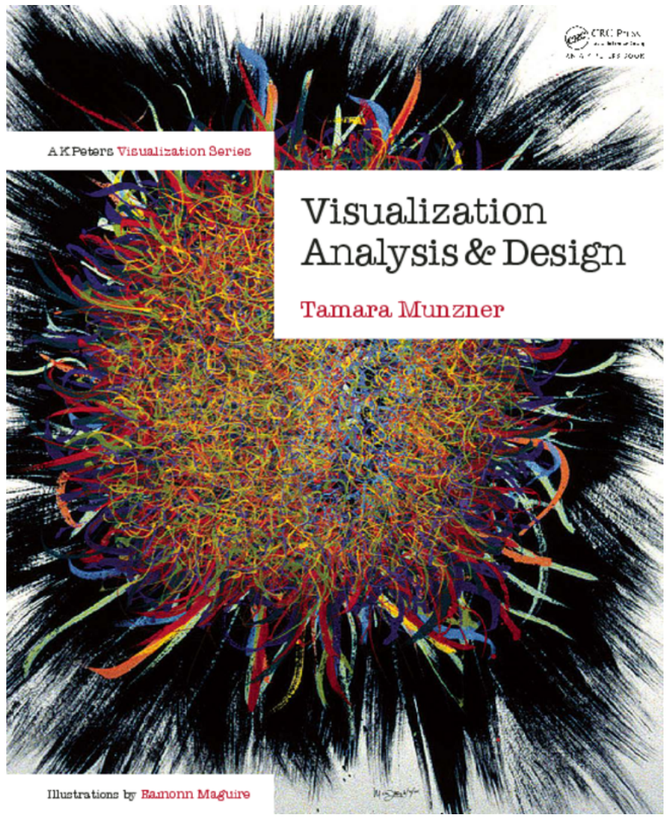
@tamaramunzner

Visualization (vis) defined & motivated

Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.

Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

- human in the loop needs details about data
  - *entry point:* exploratory data analysis
    - don't know exactly what questions to ask in advance
  - *entry point:* presentation of known results
  - *entry point:* interplay with automation
    - refining model, trustbuilding/monitoring, mixed-initiative
- external representation: perception vs cognition
- intended task, measurable definitions of effectiveness

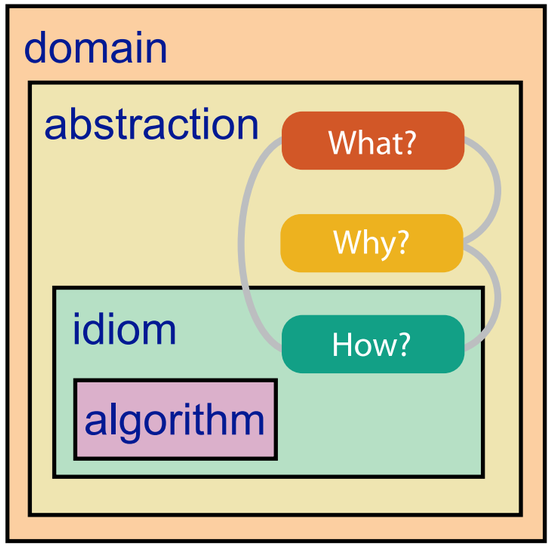


more at:
Visualization Analysis and Design, Chapter 1.
Munzner. AK Peters Visualization Series, CRC Press, 2014.

Analysis framework: Four levels, three questions

- *domain situation*
  - who are the target users?
- *abstraction*
  - translate from specifics of domain to vocabulary of visualization
    - **what** is shown? **data** abstraction
    - **why** is the user looking at it? **task** abstraction
- *idiom*
  - **how** is it shown?
    - **visual encoding** idiom: how to draw
    - **interaction** idiom: how to manipulate
- *algorithm*
  - efficient computation

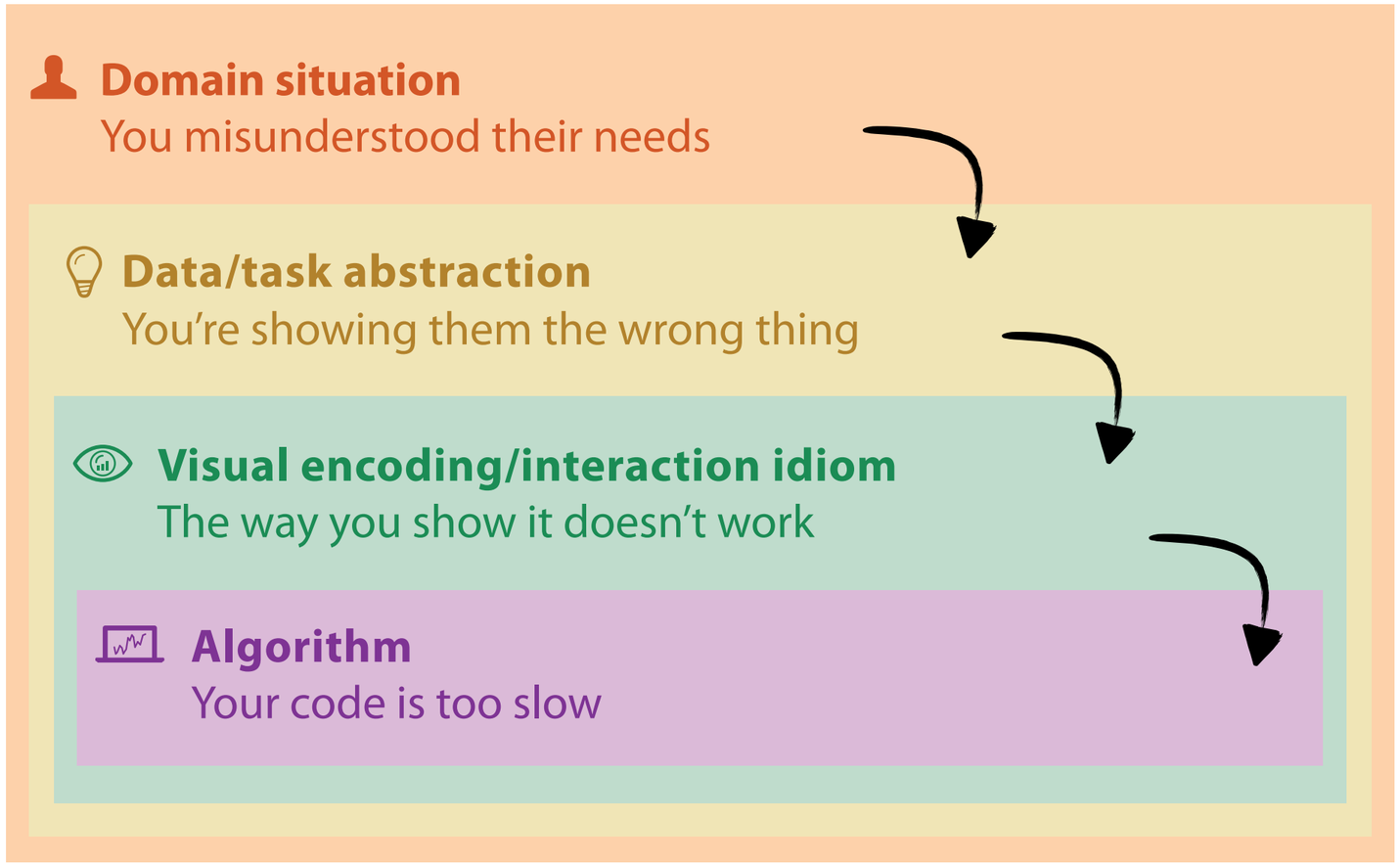
[A Nested Model of Visualization Design and Validation.
Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]



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

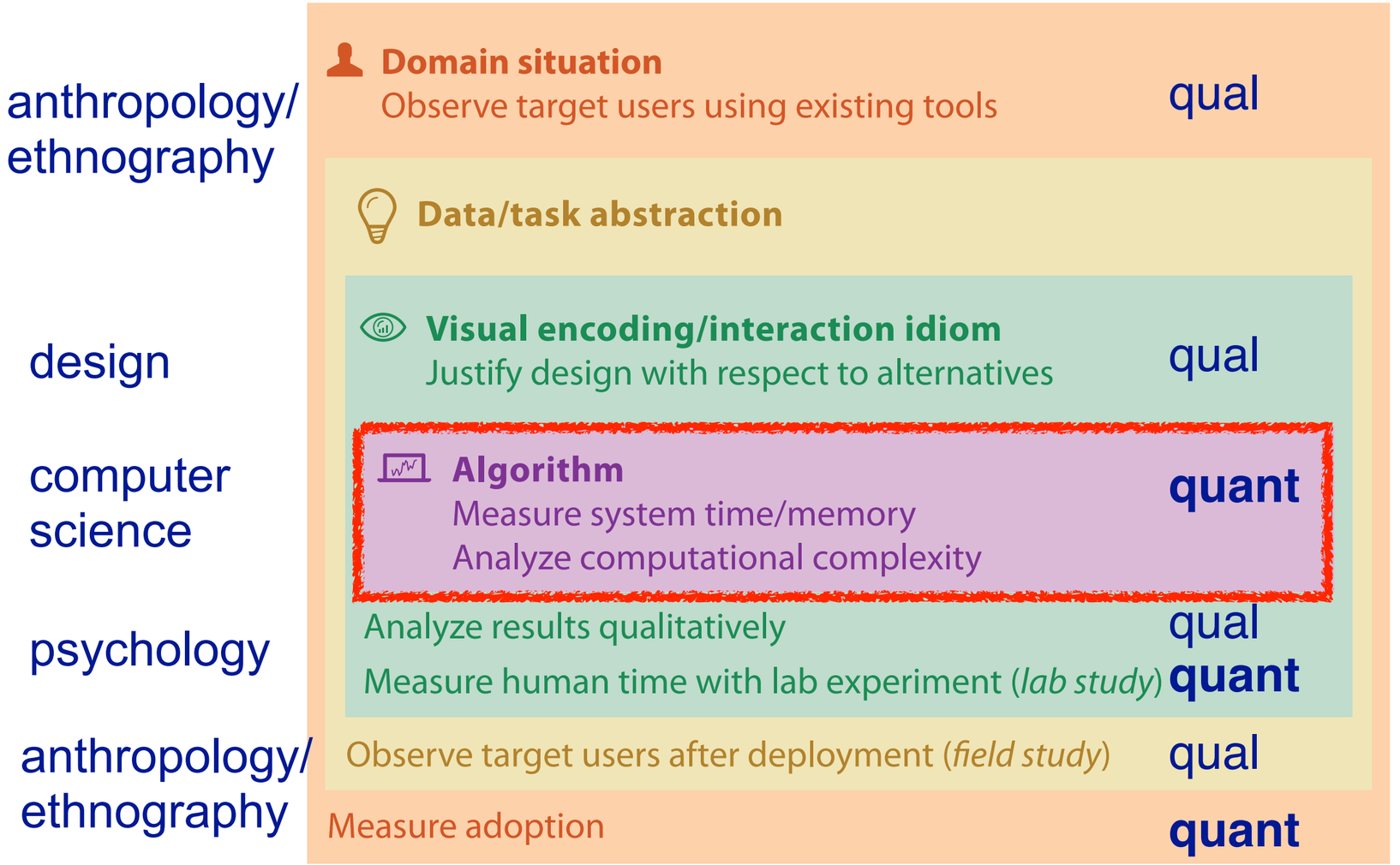
Different threats to validity at each level

- cascading effects downstream



Different methods for different problems, from different fields

- interdisciplinary, mix of qual and quant approaches (typically)

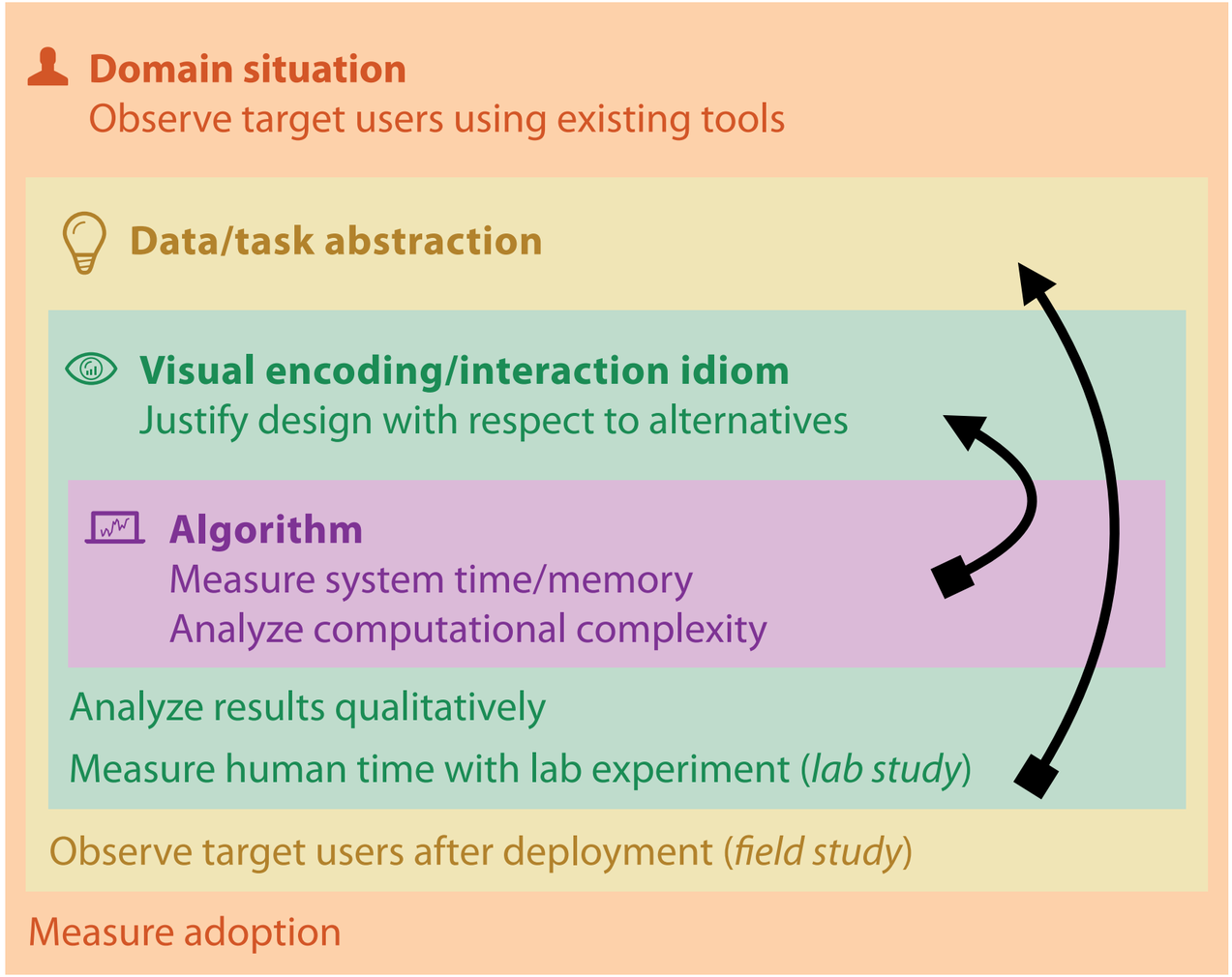


problem-driven work

technique-driven work

[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Method mismatches: Common problem



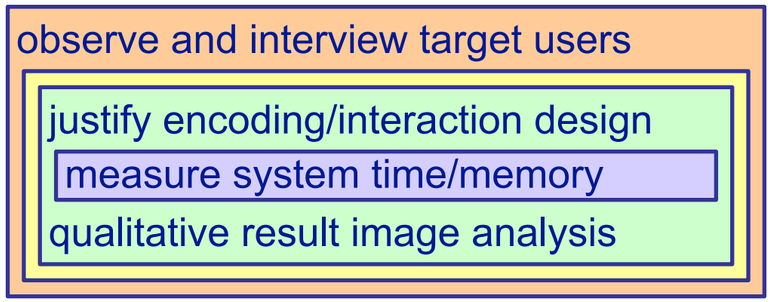
benchmarks can't confirm design

lab studies can't confirm task abstraction

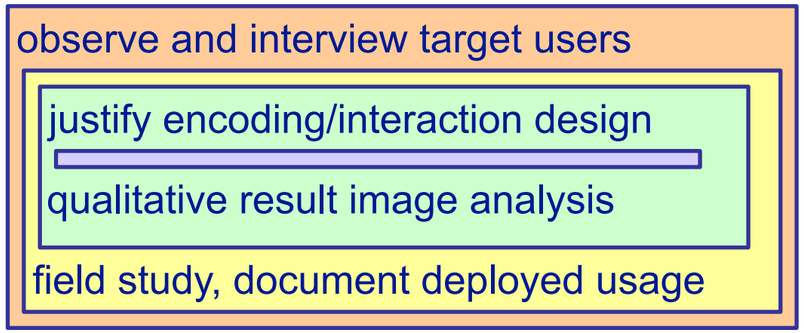
[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Analysis examples: Single paper includes only subset of methods

MatrixExplorer. Henry and Fekete. InfoVis 2006.

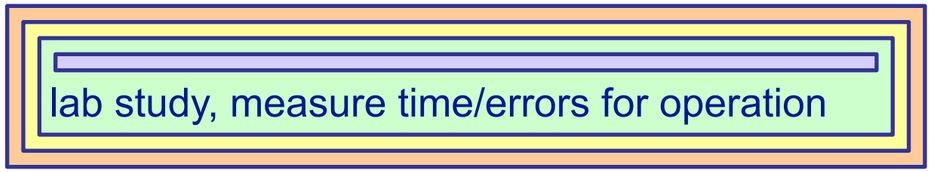


LiveRAC. McLachlan, Munzner, Koutsofios, and North. CHI 2008.

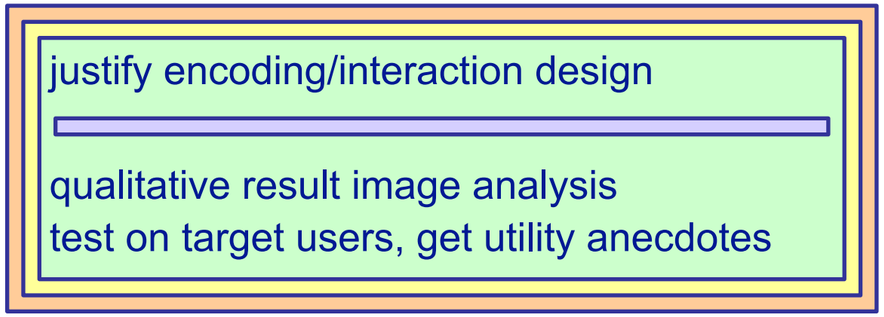


An energy model for visual graph clustering. (LinLog) Noack. Graph Drawing 2003

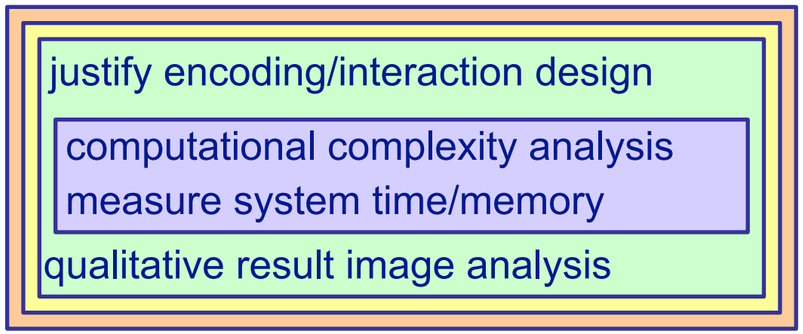
Effectiveness of animation in trend visualization. Robertson et al. InfoVis 2008.



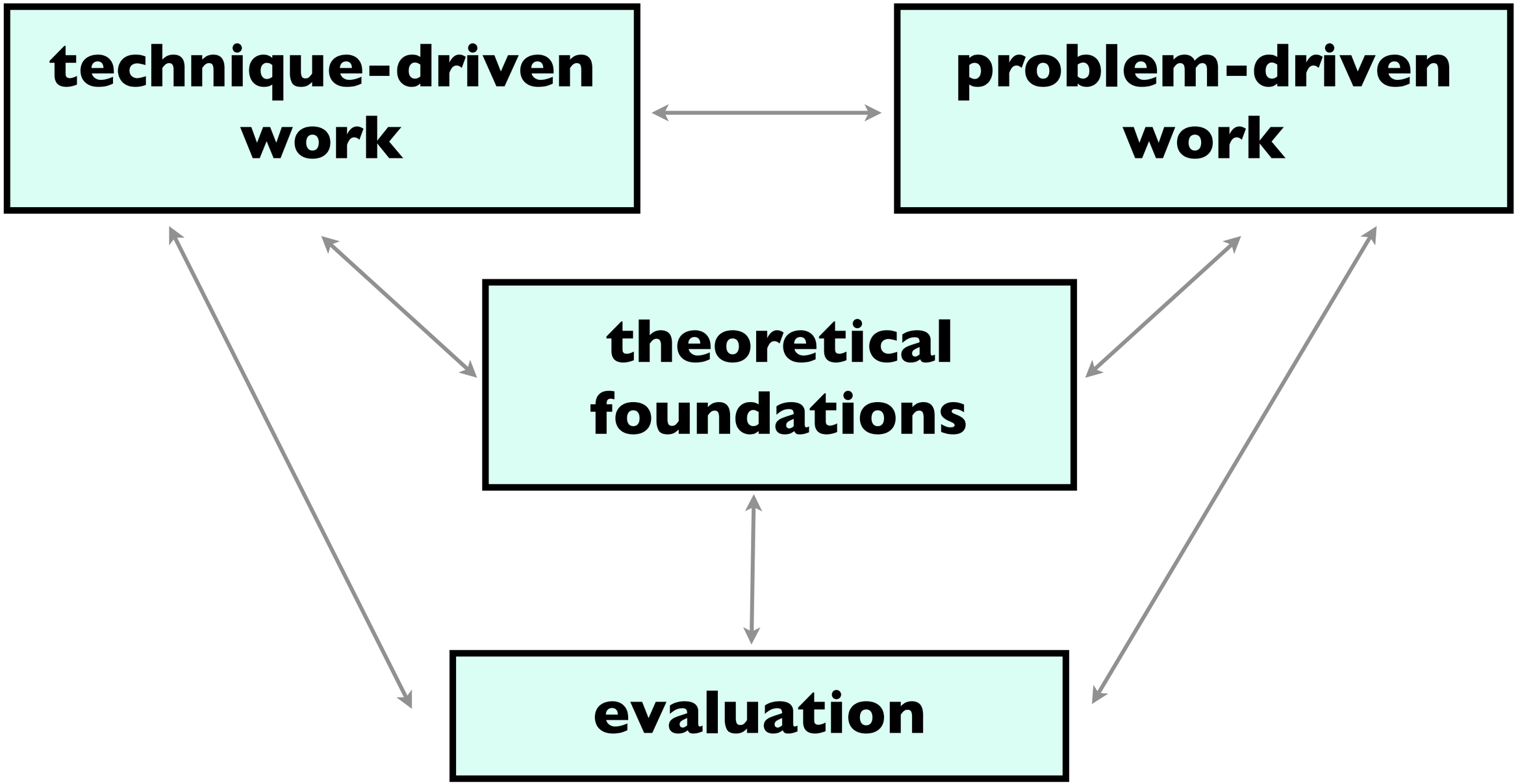
Interactive visualization of genealogical graphs. McGuffin and Balakrishnan. InfoVis 2005.



Flow map layout. Phan et al. InfoVis 2005.



Different angles of attack for different problems



Technique-driven work

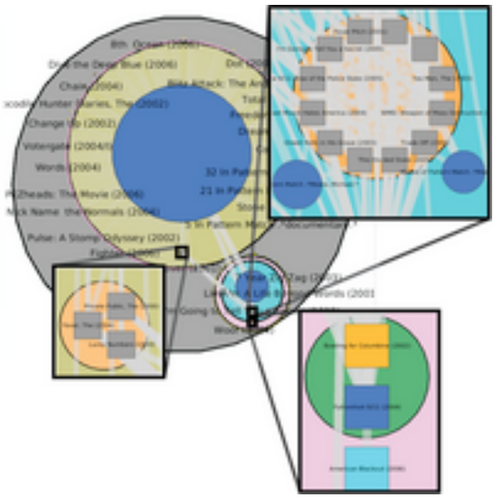
- scalable algorithms & systems
  - typical evaluation: computational benchmarks
- new layout & interaction techniques
  - typical evaluation: usage scenarios
  - typical evaluation/characterization: controlled experiments on human subjects

Technique-driven: Graph/network drawing

T P F E

Daniel Archambault

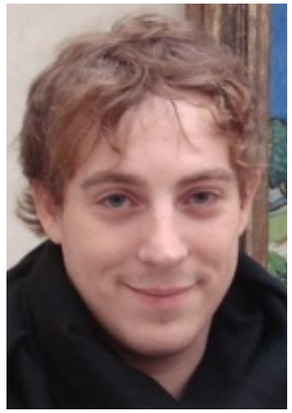
David Auber (Bordeaux)



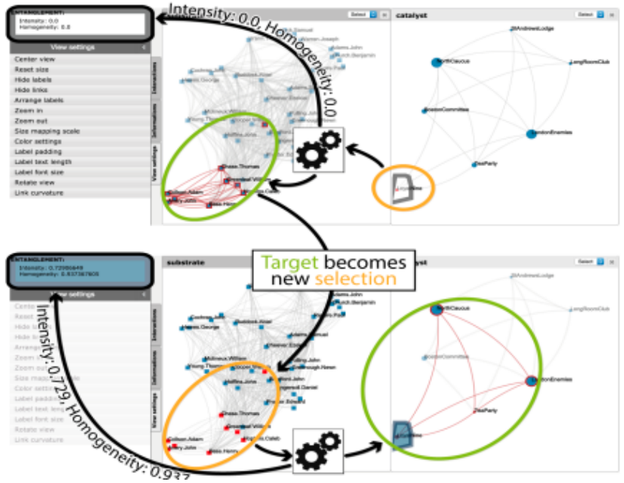
https://youtu.be/AWXAe8zvkt8

TopoLayout
SPF
Grouse
GrouseFlocks
TugGraph

Benjamin Renoust



Guy Melançon (Bordeaux)



Detangler

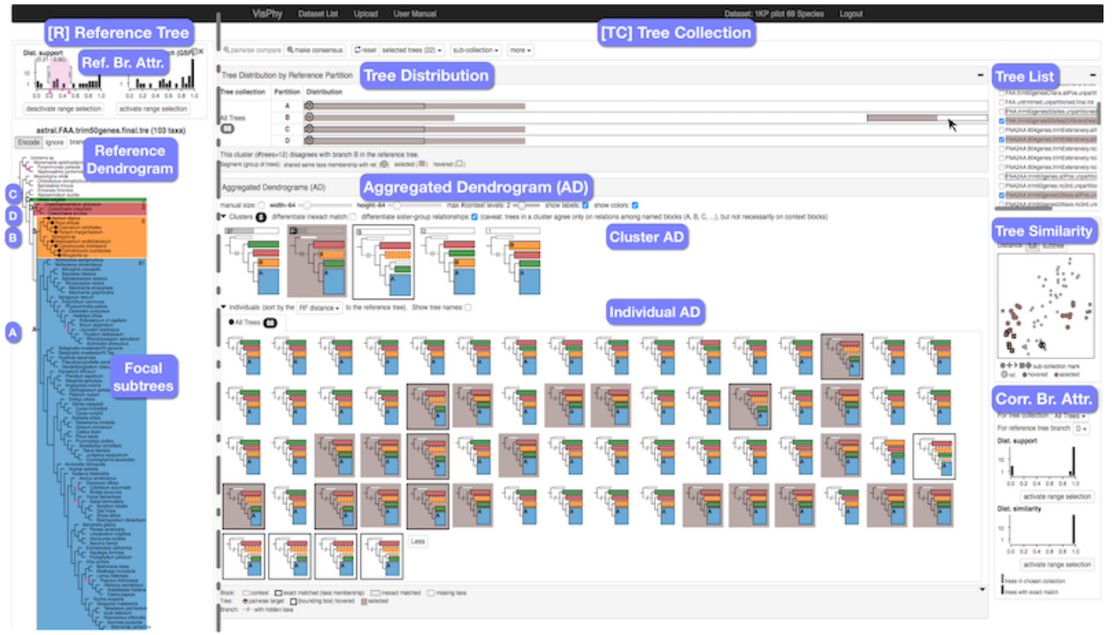
https://youtu.be/QOtnHSsUV6k

Technique-driven: Tree drawing

T P F E

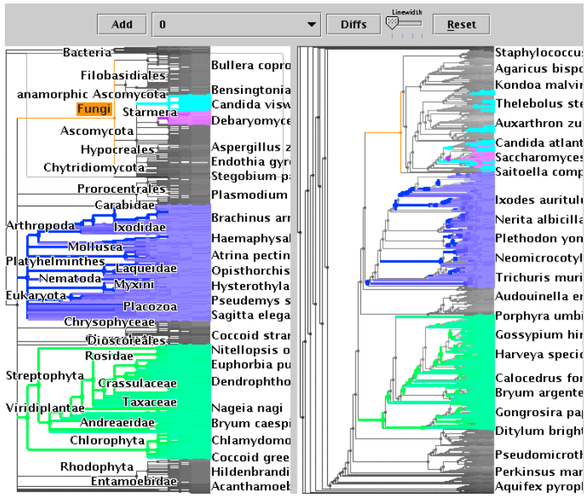
Zipeng Liu

Shing Hei Zhan



Aggregated Dendrograms

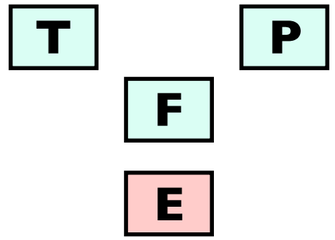
https://youtu.be/2SLcz7KNLJw



TreeJuxtaposer

https://youtu.be/GdaPj8a9QEo

Evaluation experiments: Graph/tree drawing



Dmitry Nekrasovski

Adam Bodnar

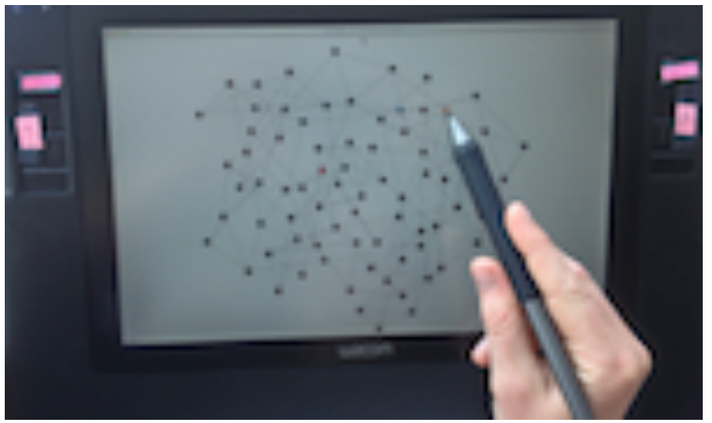
Joanna McGrenere

Stretch and squish navigation

lab study led to "focus+context" idiom disenchantment

Jessica Dawson

Joanna McGrenere



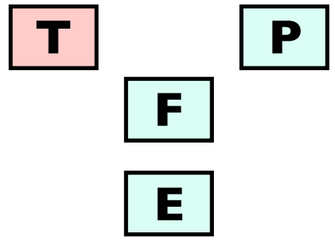
Search set model of path tracing

1 qualitative study: coding observational video

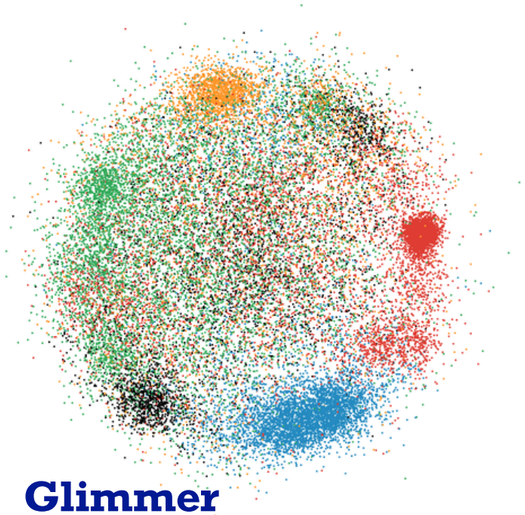
2 create & implement behavioral model

3 multiple regression to untangle factor relationships

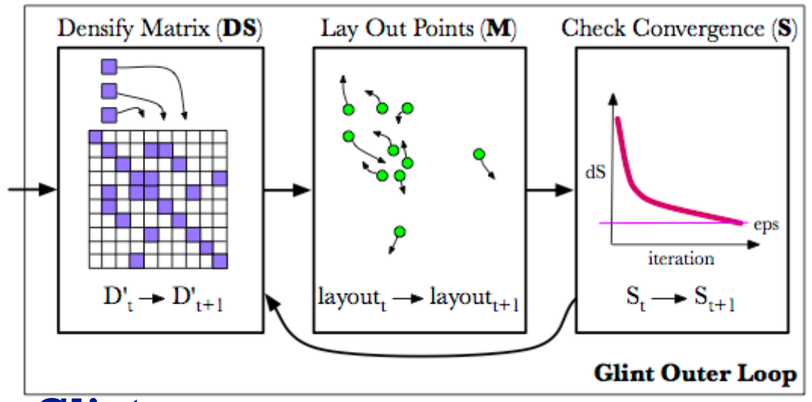
Technique-driven: Dimensionality reduction



Stephen Ingram

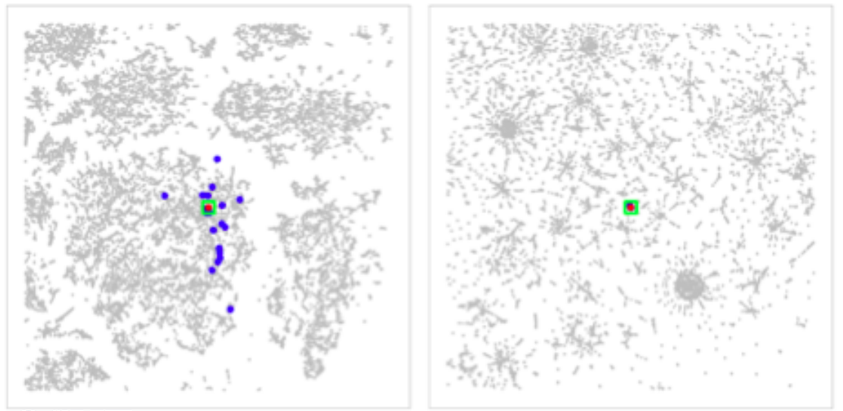


Glimmer



Glint

DimStiller



QSNE

Dimensionality reduction for documents

- derive low-dimensional target space from high-dimensional measured space

Task 1

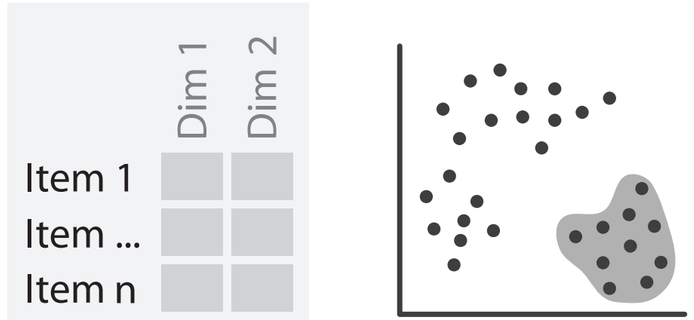
In
HD data

Out
2D data

What?
- In High-dimensional data
- Out 2D data

Why?
- Produce
- Derive

Task 2



In
2D data

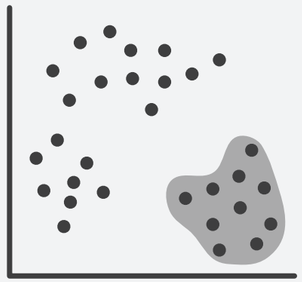
Out
Scatterplot
Clusters & points

What?
- In 2D data
- Out Scatterplot
- Out Clusters & points

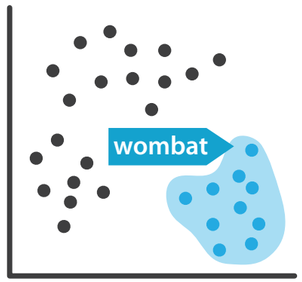
Why?
- Discover
- Explore
- Identify

How?
- Encode
- Navigate
- Select

Task 3



In
Scatterplot
Clusters & points



Out
Labels for clusters

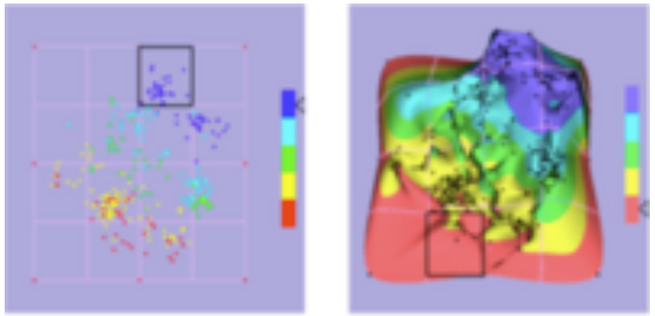
What?
- In Scatterplot
- In Clusters & points
- Out Labels for clusters

Why?
- Produce
- Annotate

Evaluation experiments: Dimensionality reduction

T P F E

Melanie Tory

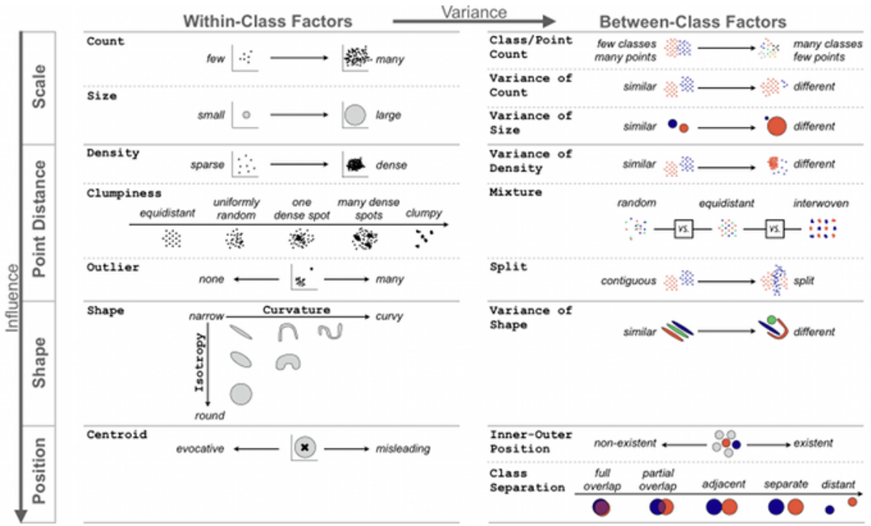


Points vs landscapes for dimensionally reduced data

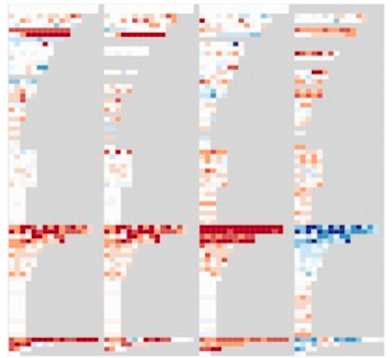
traditional user study:
many people for short time,
few datasets

data studies: many datasets, few people for long time (experts qual+quant coding)

Michael Sedlmair Melanie Tory

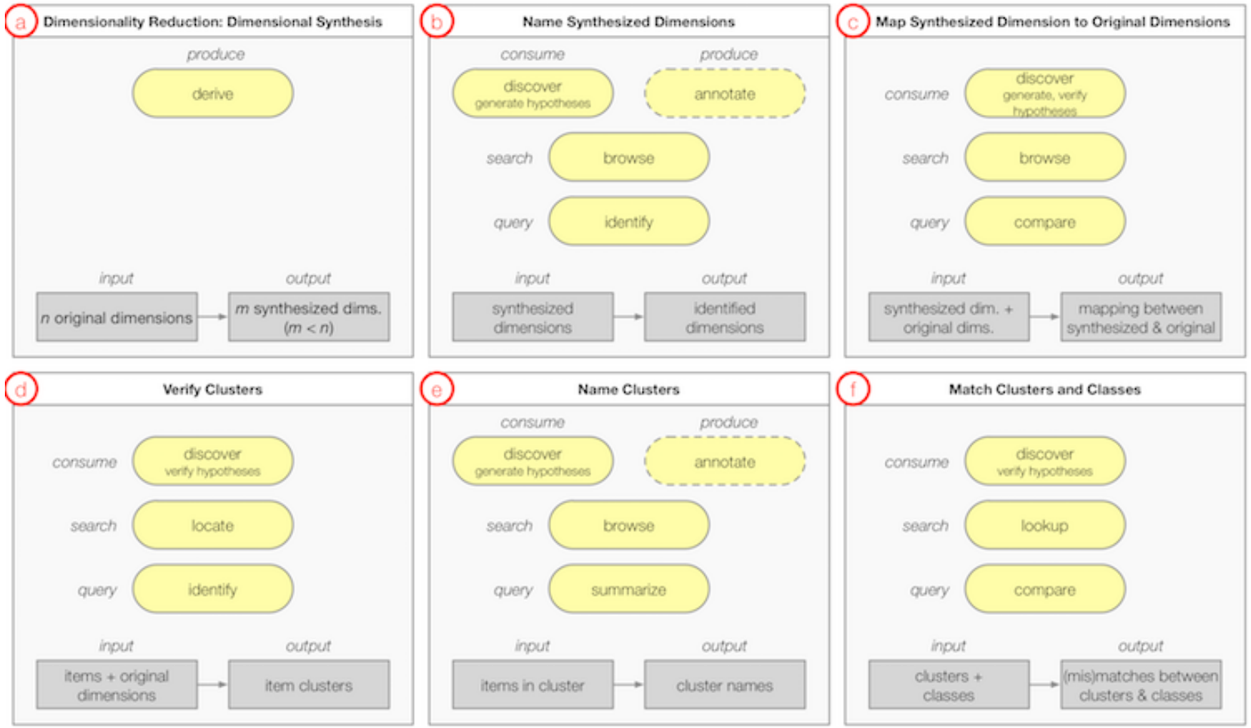


Taxonomy of cluster separation factors



Guidance on DR & scatterplot choices

Evaluation in the field: Dimensionality reduction



DR in the Wild

interview study & qualitative coding led to task abstractions:
specific to data type,
agnostic to domain

Matt Brehmer Michael Sedlmair Melanie Tory Stephen Ingram




Problem-driven work

- "design studies"
  - in collaboration with target users
    - real data, real tasks
    - intensive requirements analysis
  - iterative refinement
    - deploy tools/systems
  - typical evaluation: field studies

- my strategy: opportunistic collaboration
  - many domains
  - both industrial and academic partners

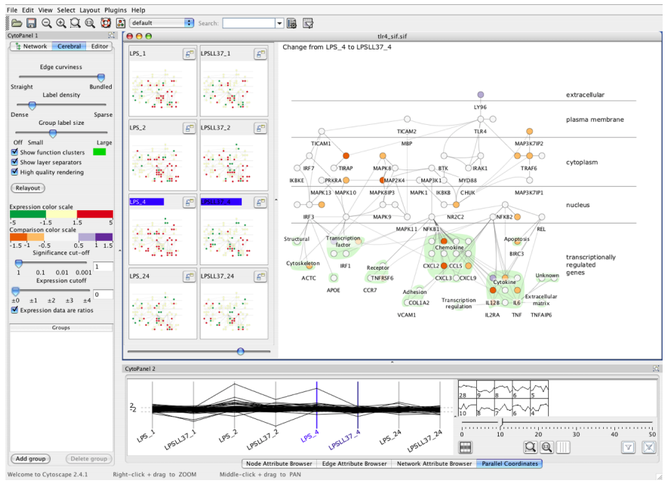
Problem-driven: Genomics

T F E P

Aaron Barsky

Jenn Gardy (Microbio)

Robert Kincaid (Agilent)

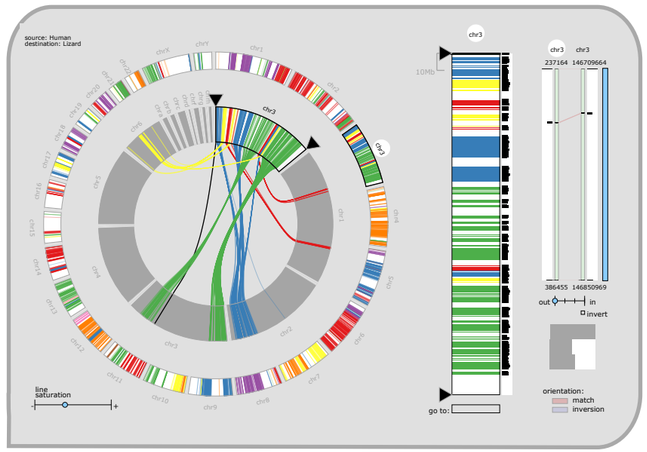


Cerebral

https://youtu.be/76HhG1FQngI

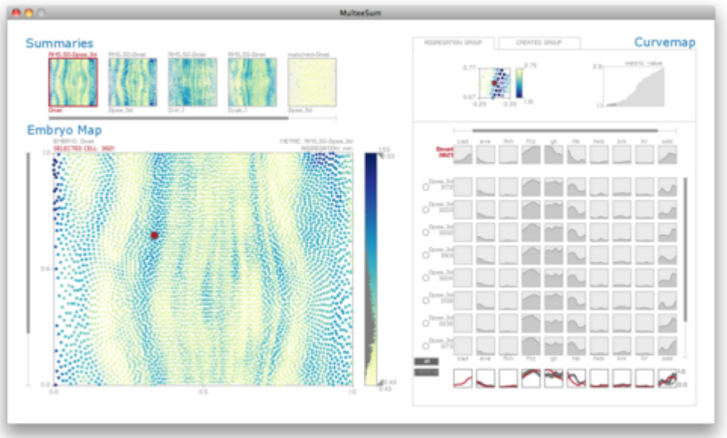
Miriah Meyer

Hanspeter Pfister (Harvard)



MizBee

https://youtu.be/86p7brwuz2g



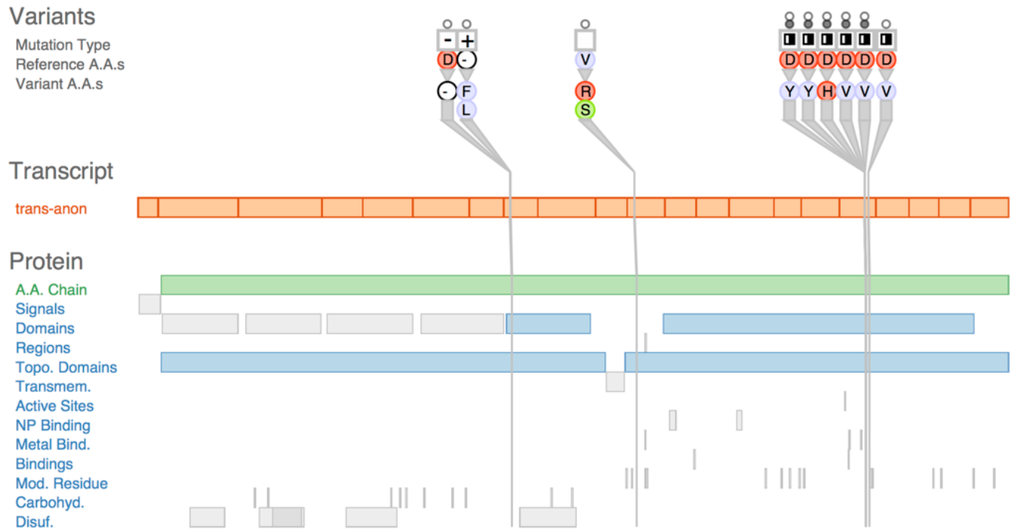
MulteeSum, Pathline

Problem-driven: Genomics, fisheries

T P F E

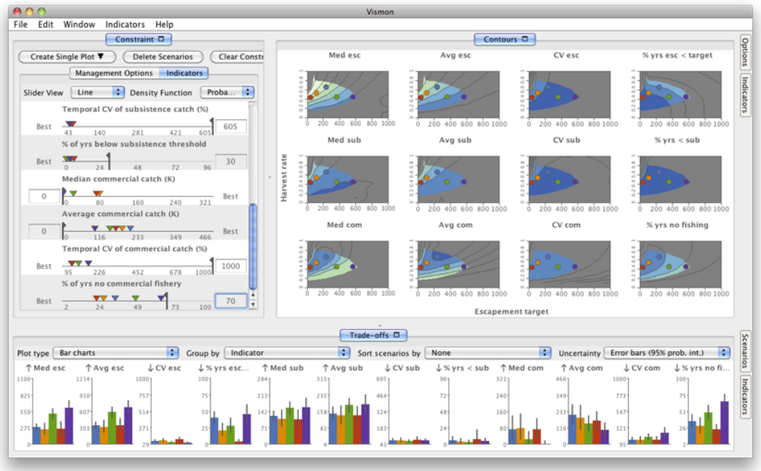
Joel Ferstay

Cydney Nielsen (BC Cancer)



Variant View

https://youtu.be/AHDnv_qMXxQ

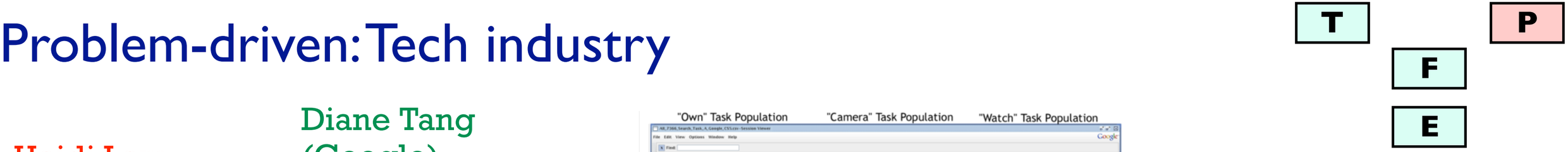


Vismon https://youtu.be/h0kHoS4VYmk

Maryam Booshehrian

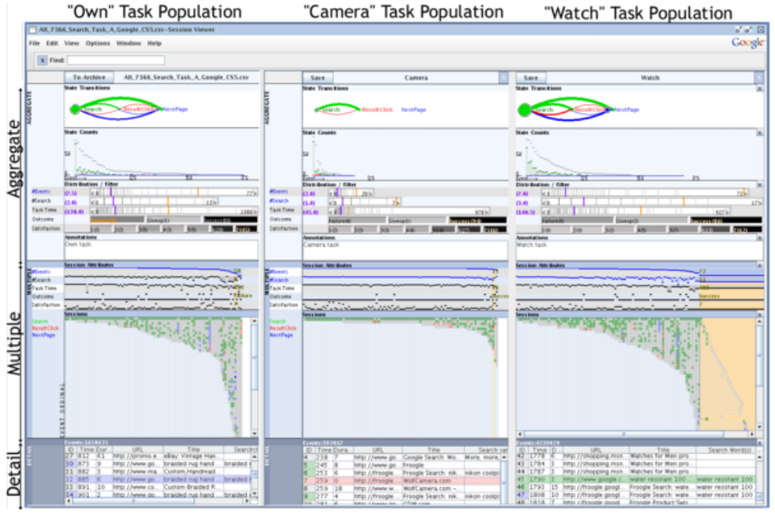
Torsten Moeller (SFU)

Problem-driven: Tech industry



Heidi Lam

Diane Tang (Google)

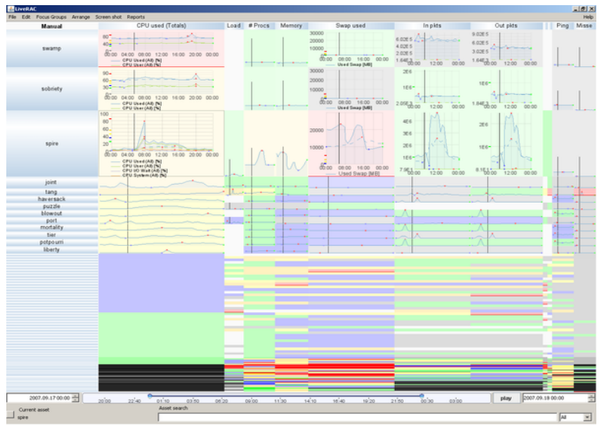


SessionViewer: web log analysis

https://youtu.be/T4MaTZd56G4

Peter McLachlan

Stephen North (AT&T Research)

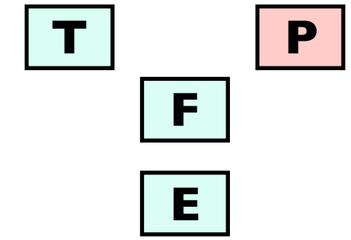


LiveRAC: systems time-series

https://youtu.be/Id0c3H0VSkw

methods reflection: staged model of access to target users

Problem-driven: Building energy mgmt, journalism



Matt Brehmer

Kevin Tate
(Pulse/EnerNOC)

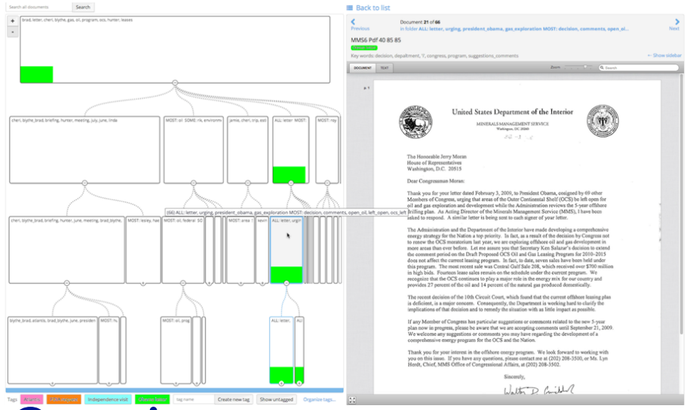
Energy Manager

redesign success:
industrial swdev
resources committed

Matt Brehmer

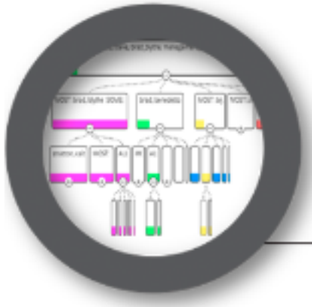
Stephen Ingram

Jonathan Stray
(Assoc Press)



Overview

https://vimeo.com/71483614



Overview

The Design, Adoption, and Analysis of a Visual Document Mining Tool For Investigative Journalists

http://www.cs.ubc.ca/labs/imager/tr/2014/Overview/

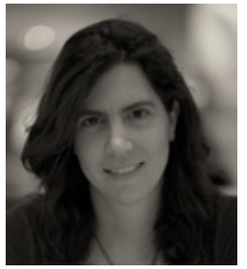
https://www.overviewdocs.com

Matthew Brehmer
@mattbrehmer

Stephen Ingram
@FroweFace

Jonathan Stray
@jonathanstray

Tamara Munzner
@tamaramunzner



Overview: The Design, Adoption, and Analysis of a Visual Document Mining Tool For Investigative Journalists.
Brehmer, Ingram, Stray, and, Munzner. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2014), 20(12):2271-2280, 2014.

From design

Case Study	#1
Document Collection	4,500 pages from FOIA
Question	*What did security contractors do during Iraq war?*

From design, to deploy, …

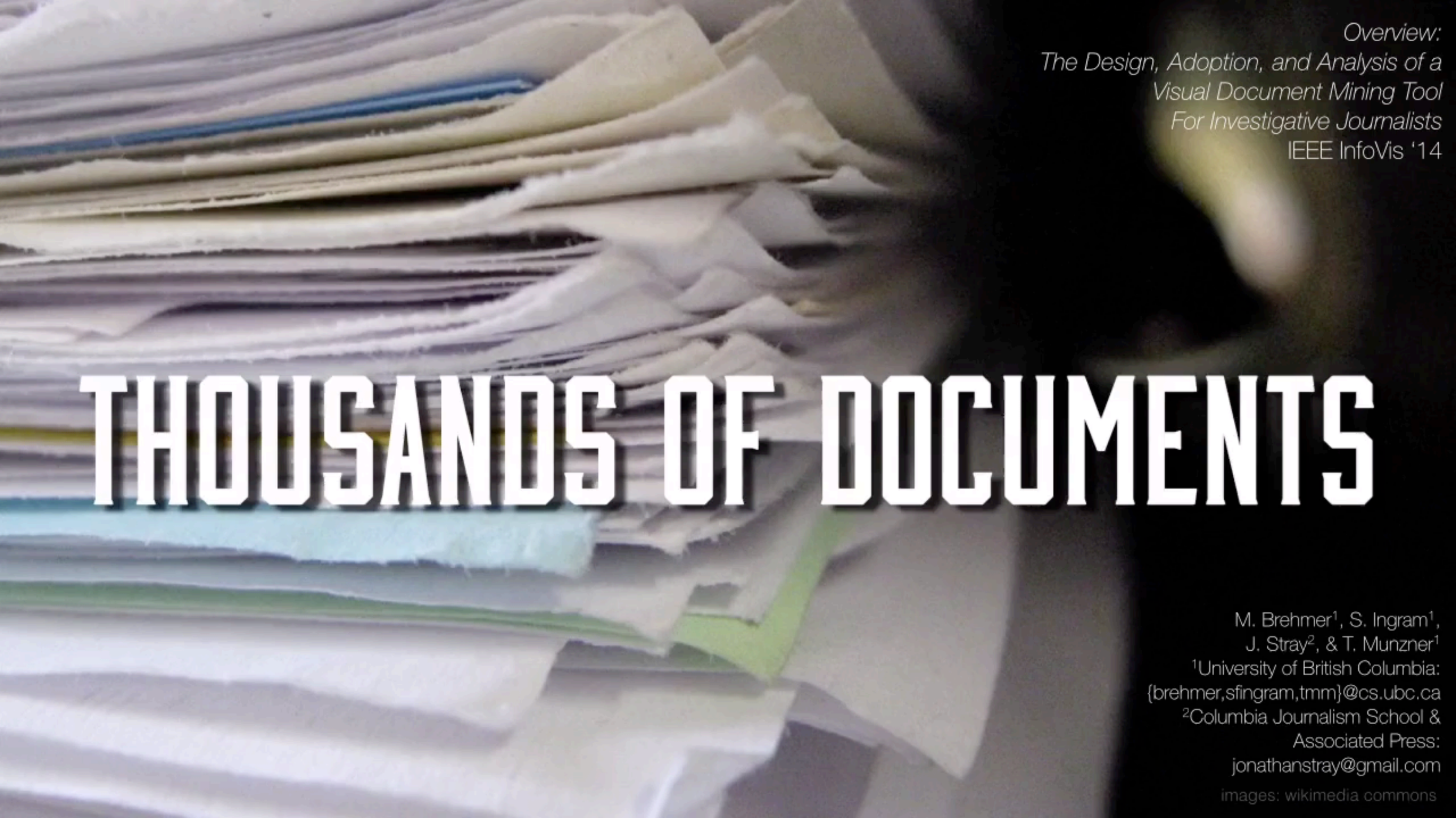
Case Study	#1	#2	#3	#4	#5	#6
Document Collection	4,500 pages from FOIA	5,996 emails from FOIA	8,680 pages from FOIA	1,278 survey comments	4,653 emails from FOIA	1,680 bills
Question	*What did security contractors do during Iraq war?*	*Were municipal police funds mismanaged?*	*Were Paul Ryan's campaign statements hypocritical?*	*What is the gun ownership debate about?*	*Was gov't response to emergency incident effective?*	*Did gov't fail to pass bills addressing police misconduct?*

… to redesign, to reflect on task abstractions…

Case Study	#1	#2	#3	#4	#5	#6
Document Collection	4,500 pages from FOIA	5,996 emails from FOIA	8,680 pages from FOIA	1,278 survey comments	4,653 emails from FOIA	1,680 bills
Question	*What did security contractors do during Iraq war?*	*Were municipal police funds mismanaged?*	*Were Paul Ryan's campaign statements hypocritical?*	*What is the gun ownership debate about?*	*Was gov't response to emergency incident effective?*	*Did gov't fail to pass bills addressing police misconduct?*

find the needle in the haystack

prove haystack contains no needles!



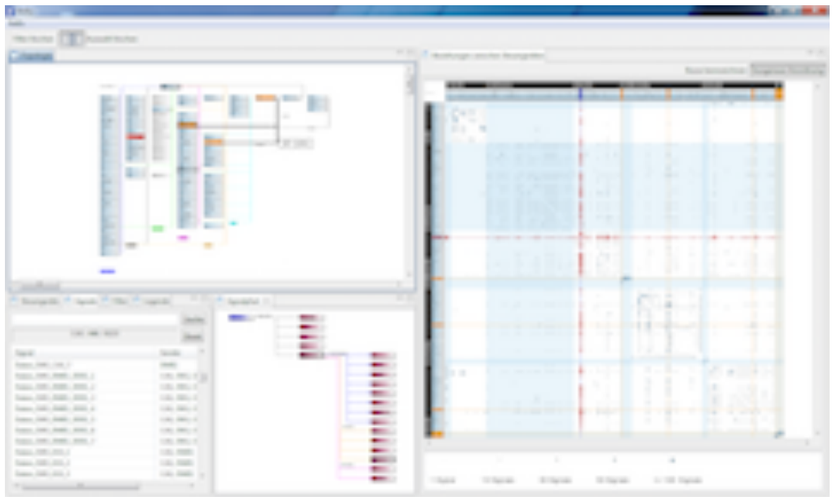
Overview:
The Design, Adoption, and Analysis of a Visual Document Mining Tool For Investigative Journalists
IEEE InfoVis '14

M. Brehmer[1], S. Ingram[1],
J. Stray[2], & T. Munzner[1]
[1]University of British Columbia:
{brehmer,sfingram,tmm}@cs.ubc.ca
[2]Columbia Journalism School &
Associated Press:
jonathanstray@gmail.com

images: wikimedia commons

Problem-driven: In-car networks, e-commerce

Michael Sedlmair



RelEx (BMW)

https://youtu.be/89lsQXc6Ao4

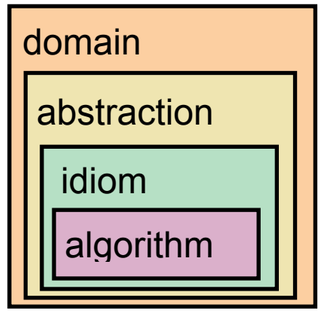
Kim Dextras-Romagnino

latest work: Segmentifier (Mobify): e-commerce clickstreams

sneak preview video

Segmentifier: Interactively Refining Clickstream Data into Actionable Segments

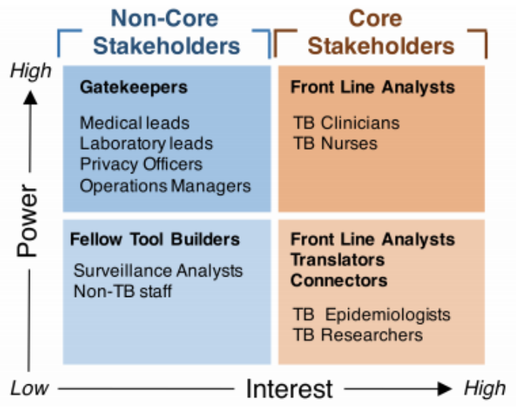
Theoretical foundations: Methodology



Nested Model

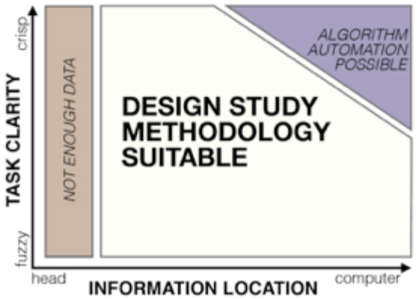
- Visual Encoding Pitfalls
  - Unjustified Visual Encoding
  - Hammer In Search Of Nail
  - 2D Good, 3D Better
  - Color Cacophony
  - Rainbows Just Like In The Sky
- Strategy Pitfalls
  - What I Did Over My Summer
  - Least Publishable Unit
  - Dense As Plutonium
  - Bad Slice and Dice

Papers Process & Pitfalls



Anamaria Crisan

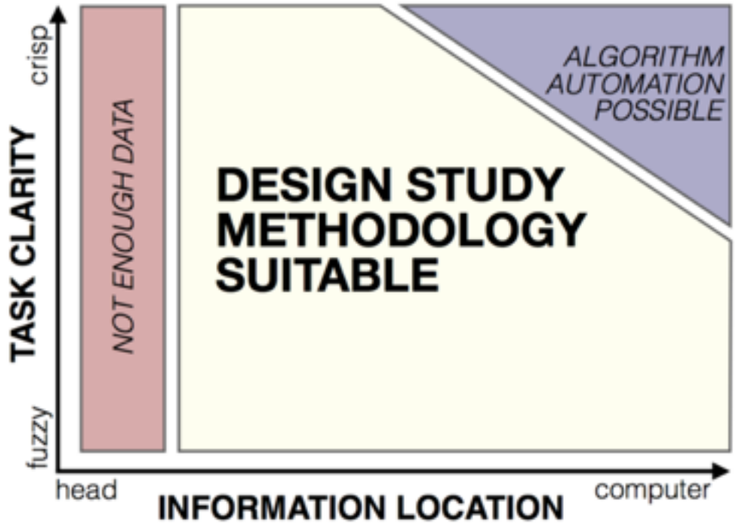
Regulatory & Organizational Constraints



Design Study Methodology

Michael Sedlmair

Miriah Meyer



Design Study Methodology

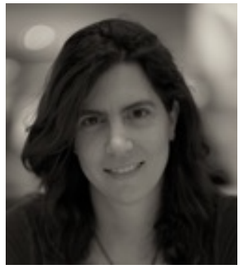
Reflections from the Trenches and from the Stacks

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

Michael Sedlmair

Miriah Meyer

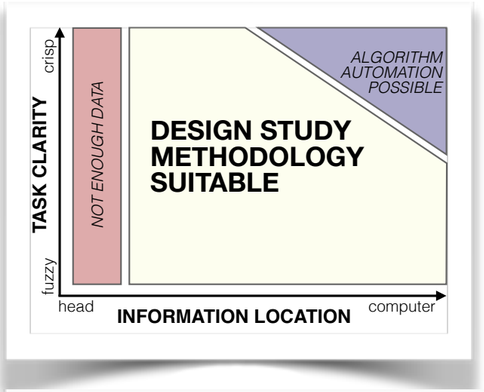
Tamara Munzner
@tamaramunzner

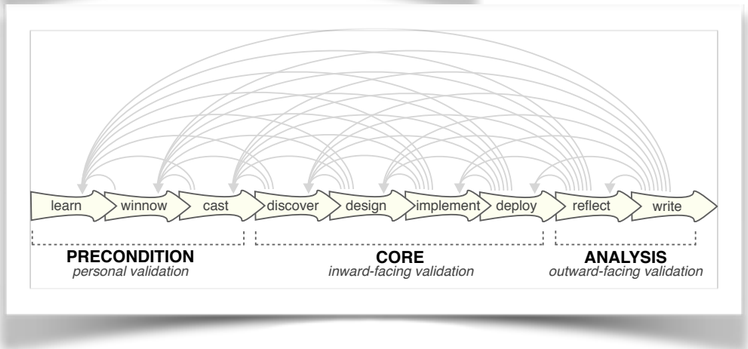


Design Study Methodology: Reflections from the Trenches and from the Stacks.
Sedlmair, Meyer, Munzner. IEEE Trans. Visualization and Computer Graphics 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).

Methodology for problem-driven work

- definitions
- 9-stage framework
- 32 pitfalls & how to avoid them
- comparison to related methodologies





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
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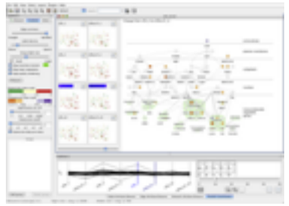
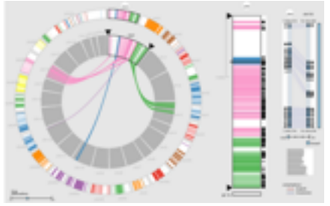
PF-7	researcher expertise does not match domain problem	winnow
PF-8	no need for research: engineering vs. research project	winnow
PF-9	no need for change: existing tools are good enough	winnow

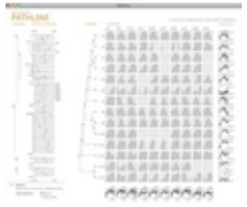
Lessons learned from the trenches: 21 between us



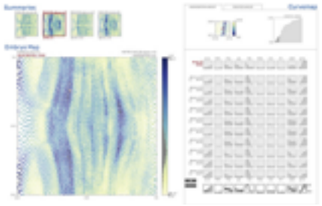
Cerebral
genomics



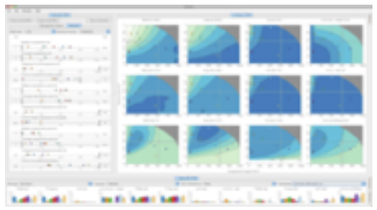
MizBee
genomics



Pathline
genomics



MulteeSum
genomics

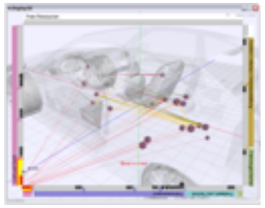


Vismon
fisheries management

QuestVis
sustainability

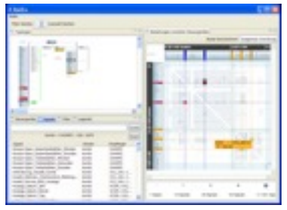
WiKeVis
in-car networks

MostVis
in-car networks



Car-X-Ray
in-car networks

ProgSpy2010
in-car networks



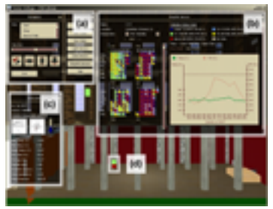
RelEx
in-car networks

Cardiogram
in-car networks

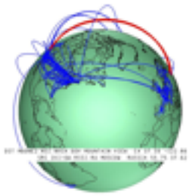
AutobahnVis
in-car networks

VisTra
in-car networks

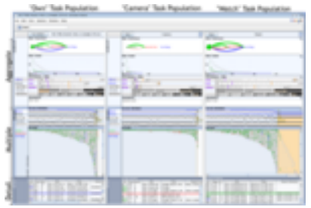
Constellation
linguistics



LibVis
cultural heritage

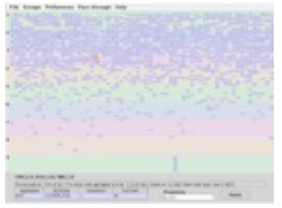


Caidants
multicast

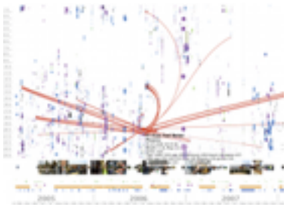


SessionViewer
web log analysis

LiveRAC
server hosting

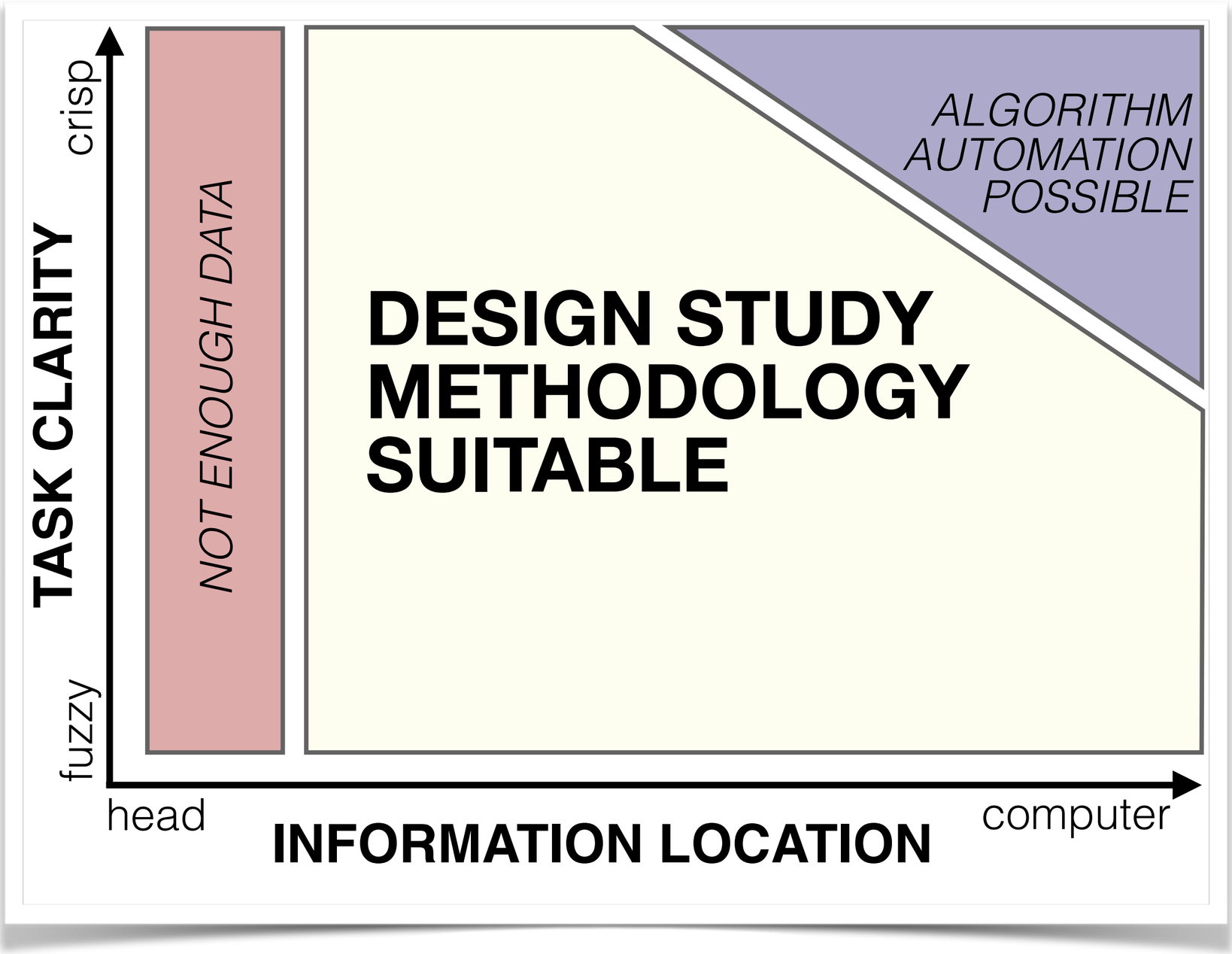


PowerSetViewer
data mining

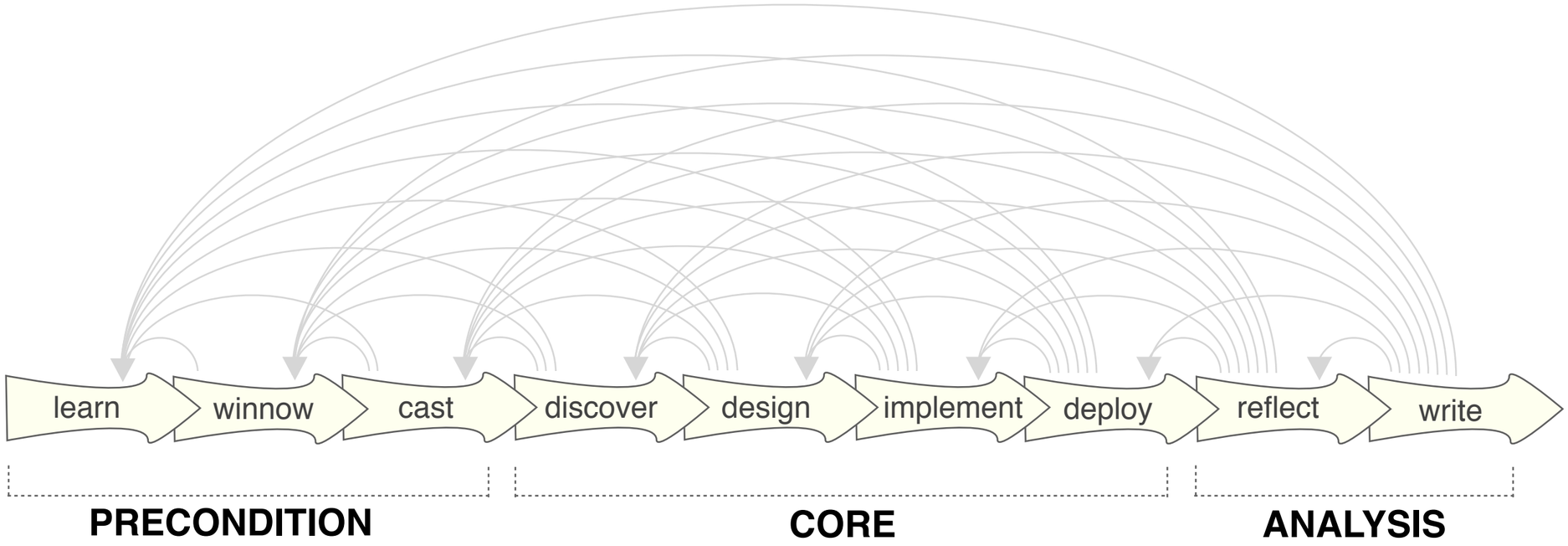


LastHistory
music listening

Design study methodology: definitions

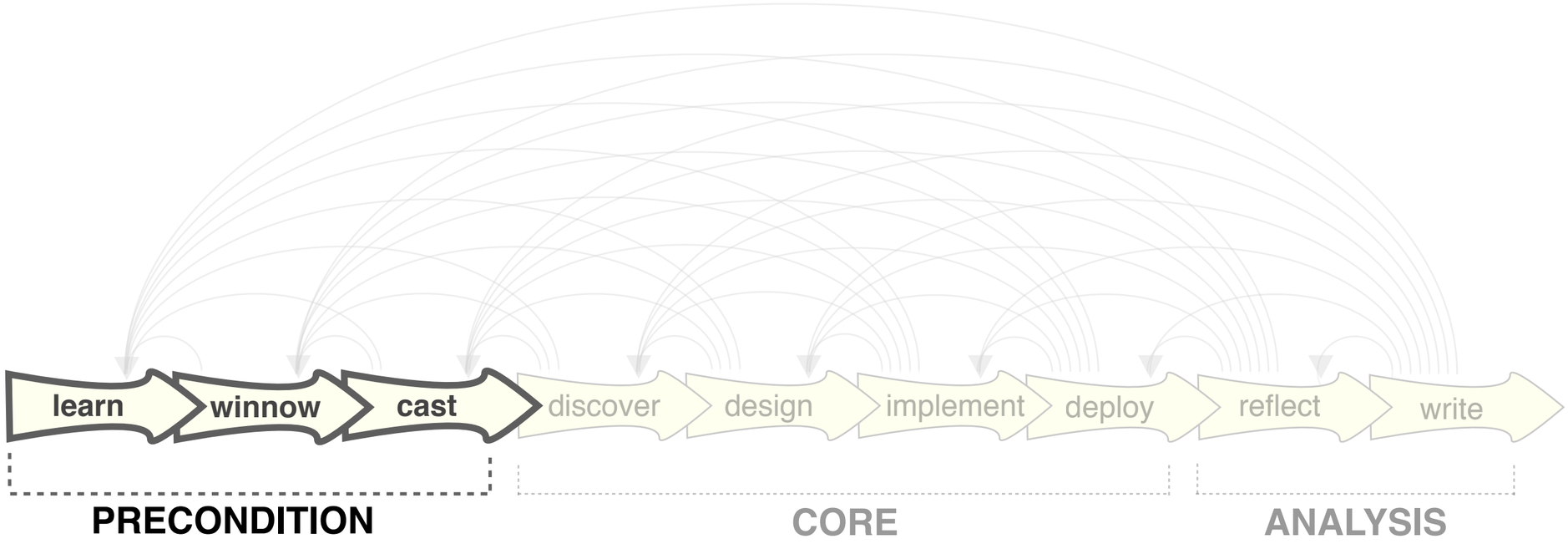


9 stage framework



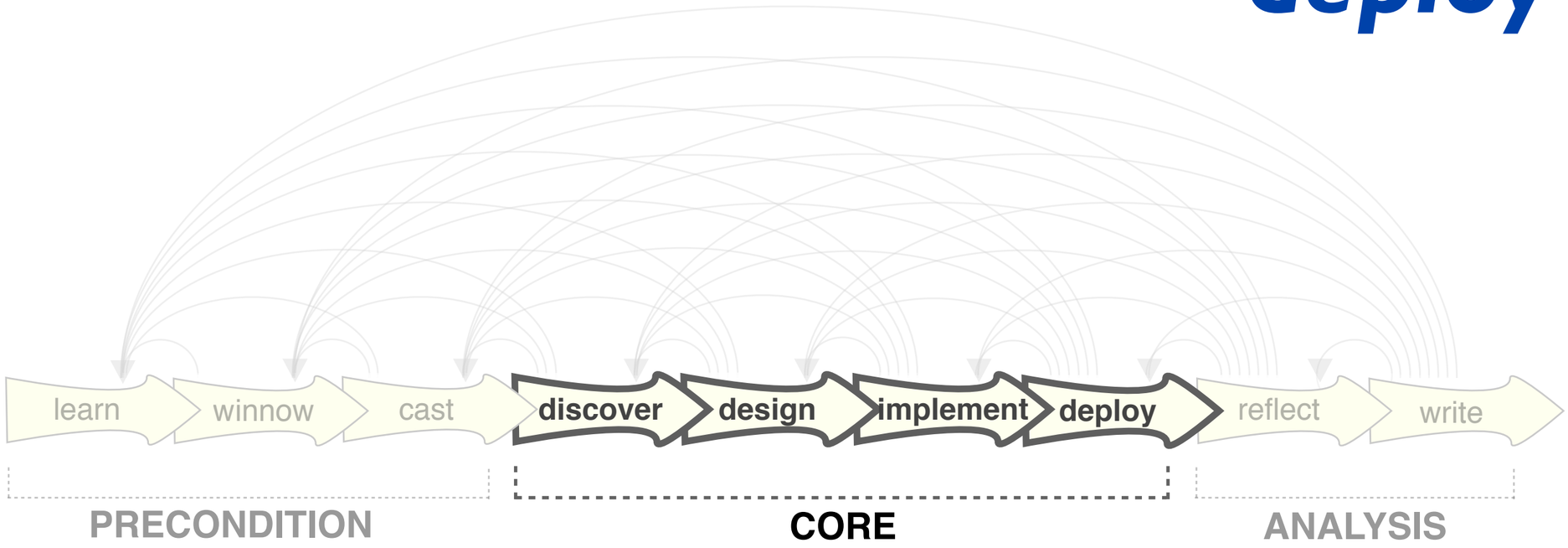
9-stage framework

learn
winnow
cast



9-stage framework

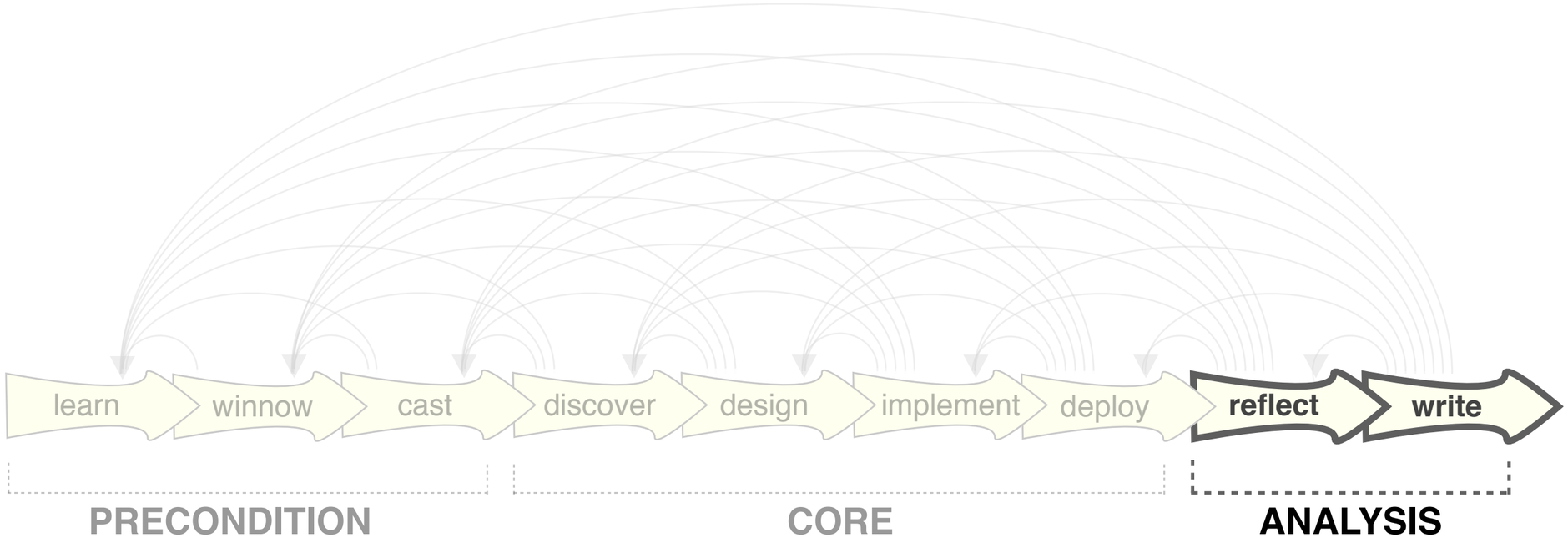
discover
design
implement
deploy



9-stage framework

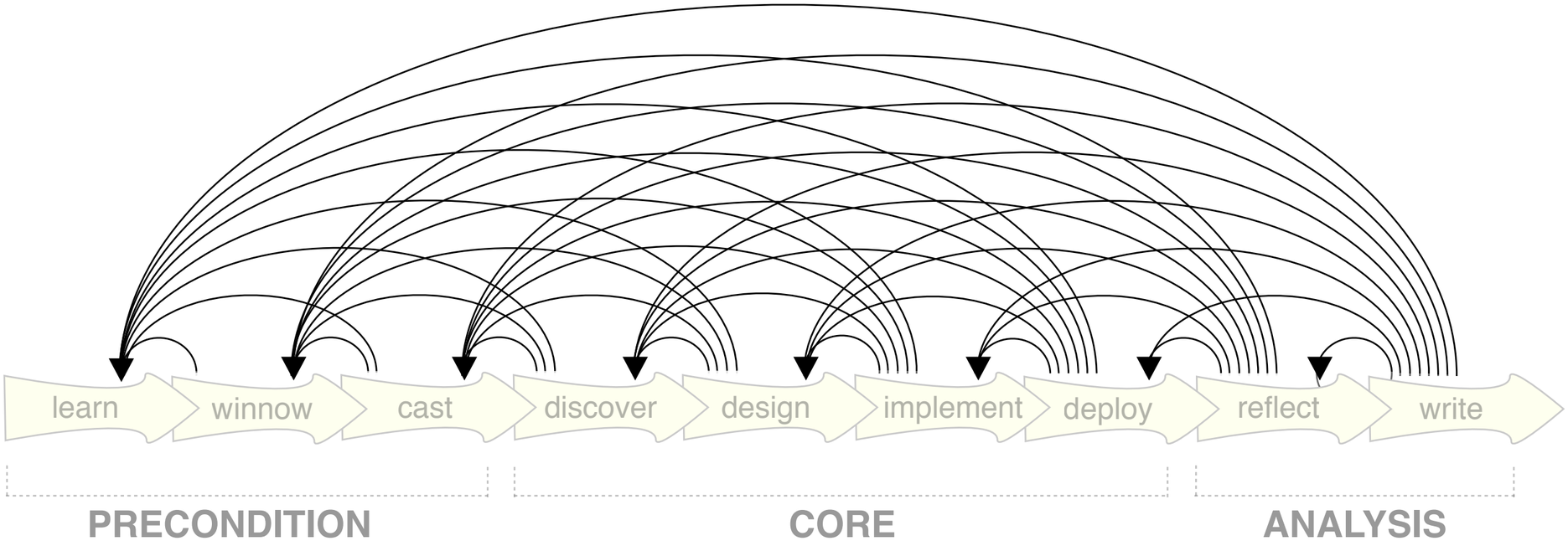
- guidelines: confirm, refine, reject, propose

reflect
write



9-stage framework

iterative



Design study methodology: 32 pitfalls

- and 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
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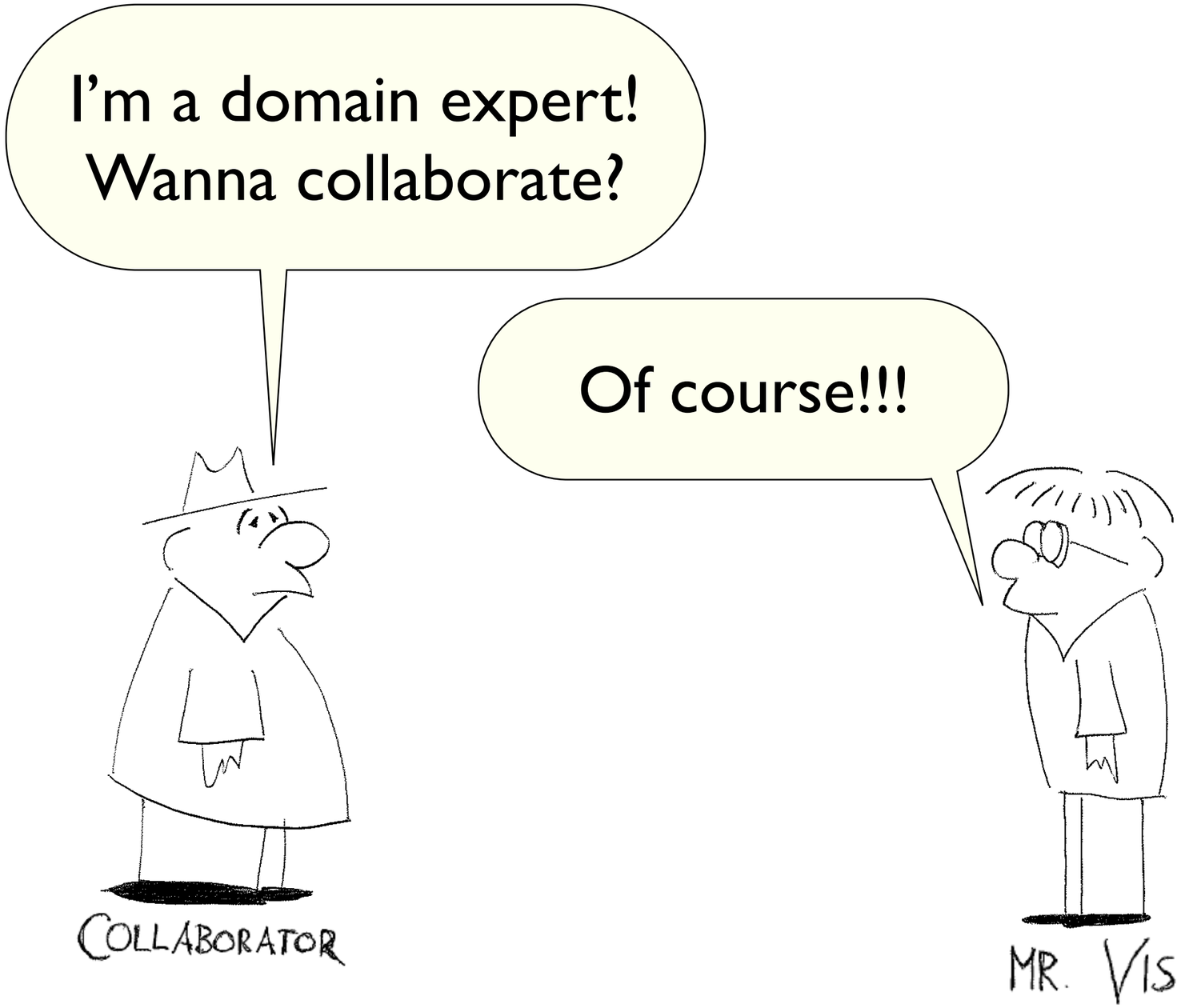
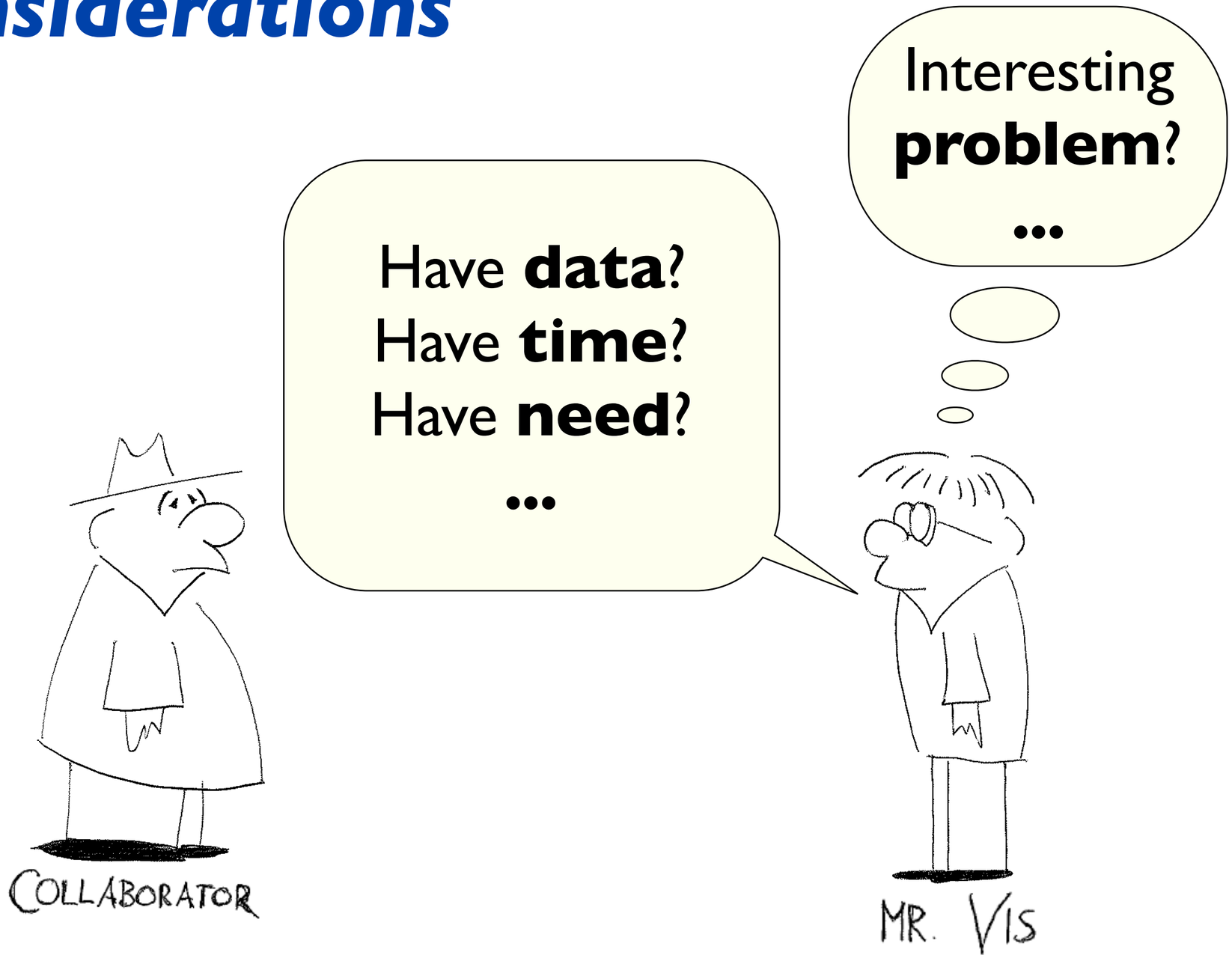

I'm a domain expert!
Wanna collaborate?
Of course!!!
COLLABORATOR
MR. VIS

considerations



Design study methodology: 32 pitfalls

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
PF-27	failing to improve guidelines: confirm, refine, reject, propose	reflect
PF-28	insufficient writing time built into schedule	write
PF-29	no technique contribution $\neq$ good design study	write
PF-30	too much domain background in paper	write
PF-31	story told chronologically vs. focus on final results	write
PF-32	premature end: win race vs. practice music for debut	write

METAPHOR
Horse Race vs. Music Debut

Must be first!

http://www.alaineknipes.com/interests/violin_concert.jpg

technique-driven

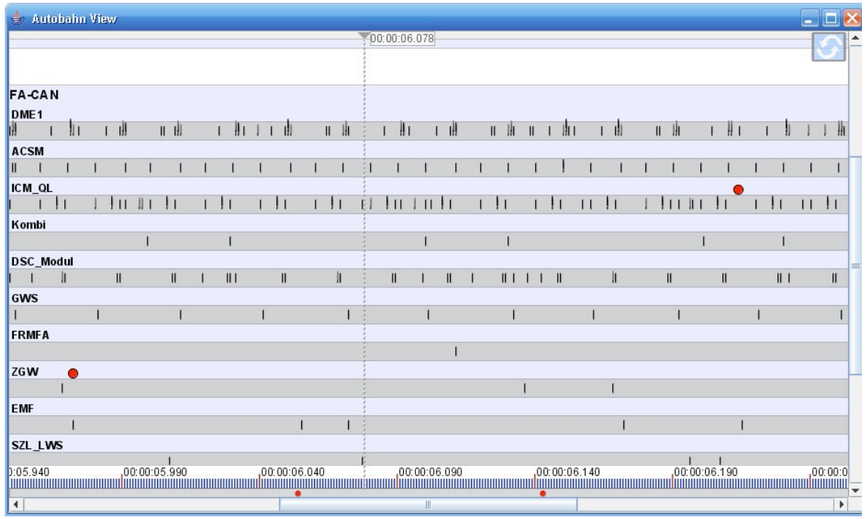
Am I ready?

http://www.prlog.org/10480334-wolverhampton-horse-racing-live-streaming-wolverhampton-handicap-8-jan-2010.html

problem-driven

EXAMPLE FROM THE TRENCHES
Don’t step on your own toes!

First design round published



AutobahnVis 1.0

[Sedlmair et al., Smart Graphics, 2009]

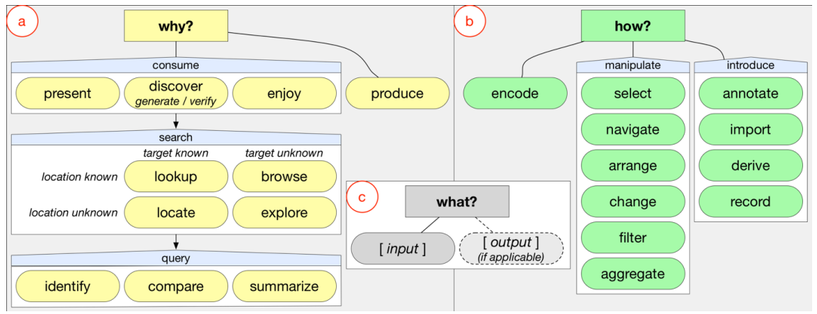
Subsequent work not stand-alone paper

AutobahnVis 2.0

[Sedlmair et al., Information Visualization 10(3), 2011]

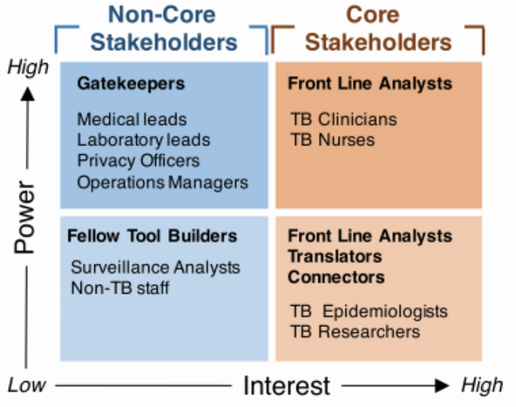
Theoretical foundations: Typologies

Matt Brehmer

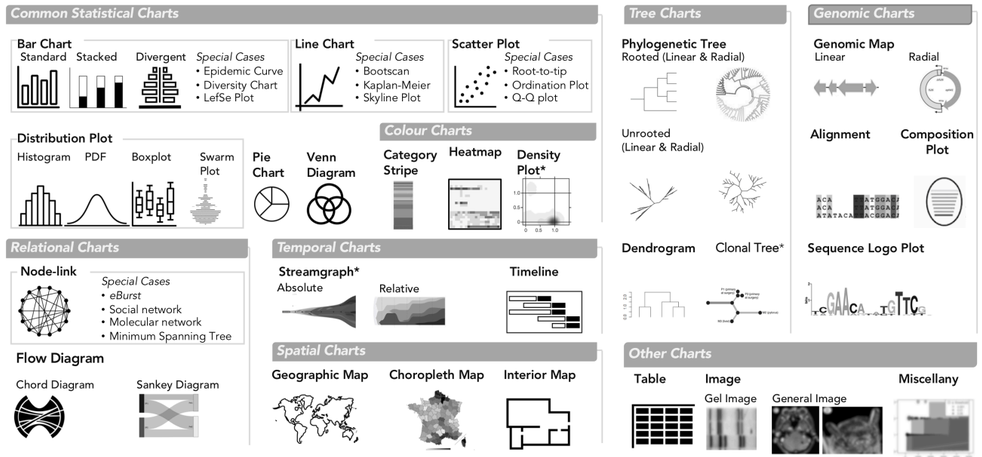


Abstract Tasks

Anamaria Crisan

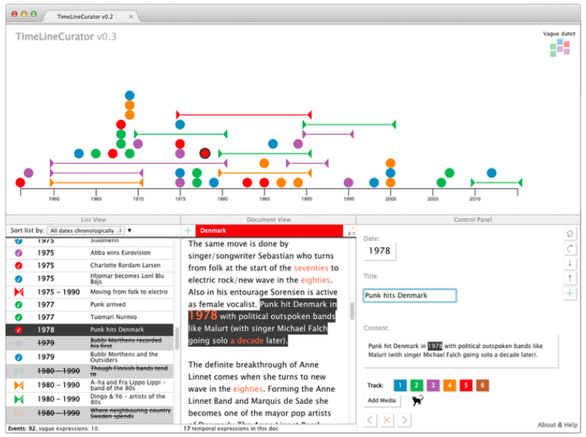


Regulatory & Organizational Constraints



GEViT: Genomic Epidemiology Visualization Typology

Curation & Presentation: Timelines

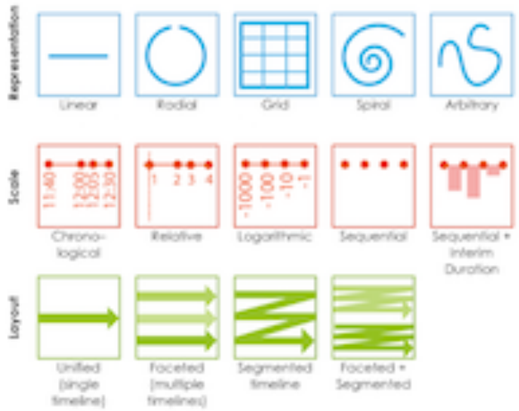


TimeLineCurator

https://vimeo.com/123246662

Matt Brehmer

Johanna Fulda
(Sud. Zeitung)



Timelines Revisited

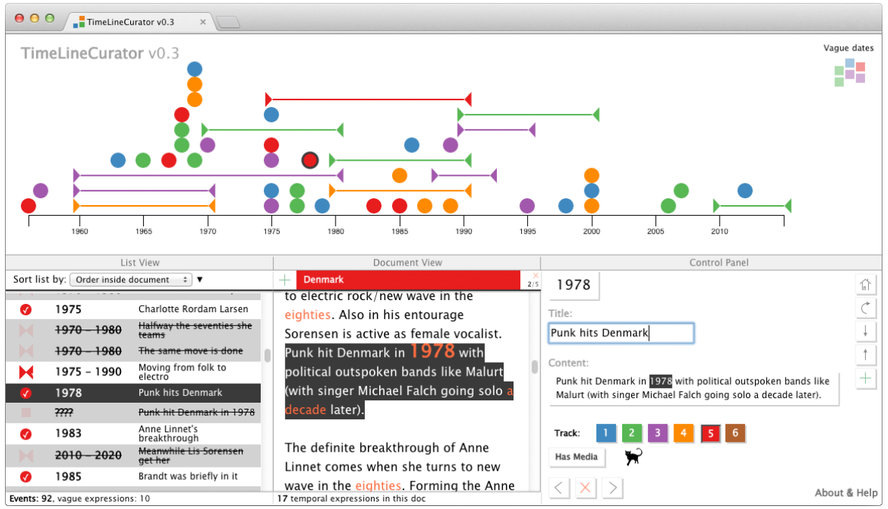
timelinesrevisited.github.io/

Matt Brehmer

Bongshin Lee
(Microsoft)

Benjamin Bach
(Microsoft)

Nathalie Henry-Riche



TimeLineCurator

Interactive Authoring of Visual Timelines from Unstructured Text

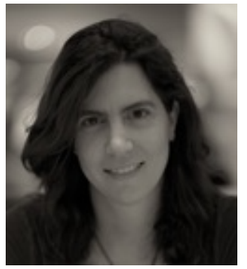
http://about.timelinecurator.org

http://timelinecurator.org

Johanna Fulda
@jofu_

Matthew Brehmer
@mattbrehmer

Tamara Munzner
@tamaramunzner



TimeLineCurator: Interactive Authoring of Visual Timelines from Unstructured Text.
Fulda, Brehmer, Munzner. IEEE Trans. Visualization and Computer Graphics (Proc IEEE VAST 2015) 22(1):300-309, 2015.

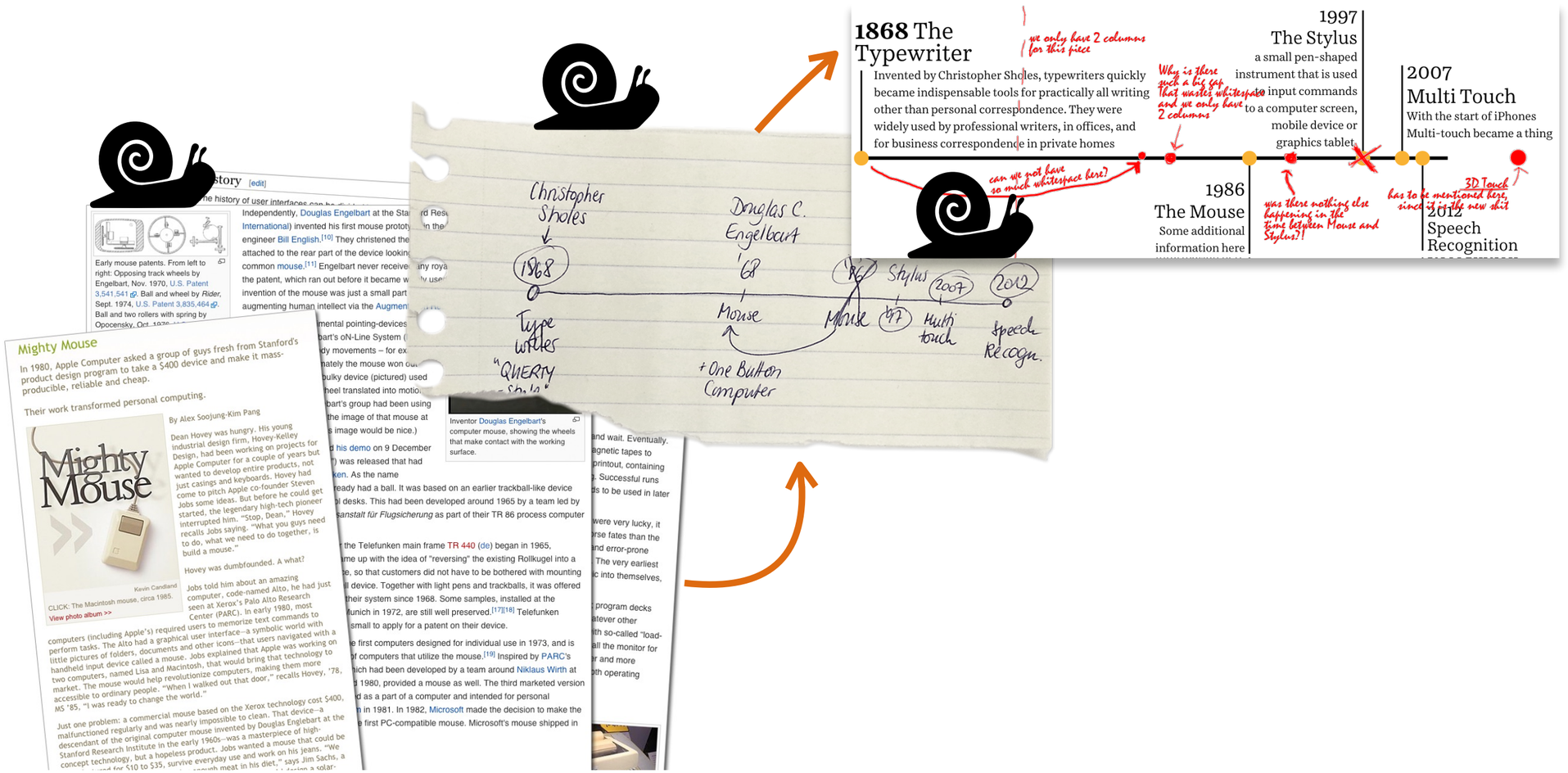
TimeLineCurator

visual & browser-based

https://vimeo.com/jofu/tlc

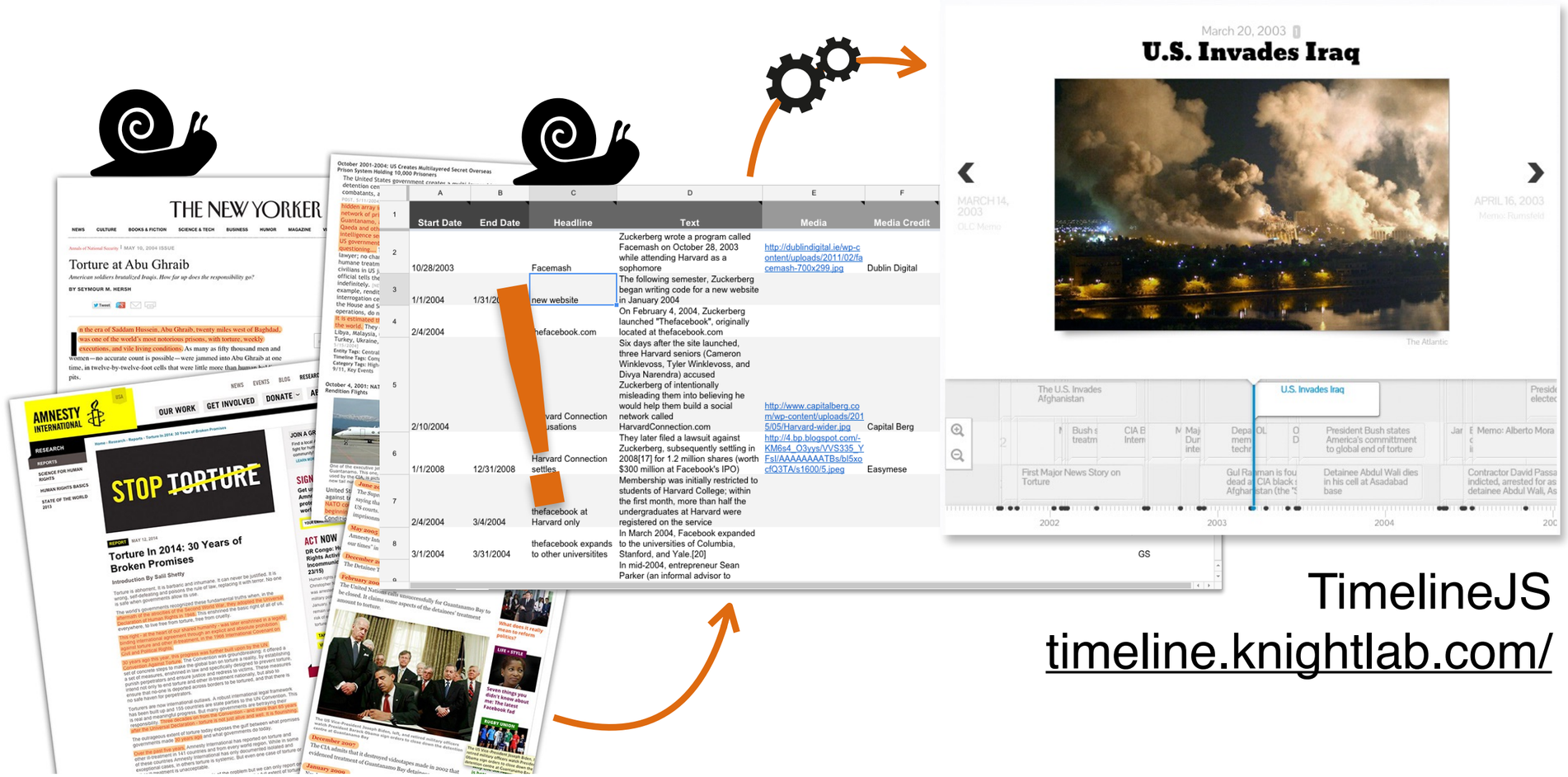
Manual creation process

Browse → Extract → Format → Show → Update



Structured creation process

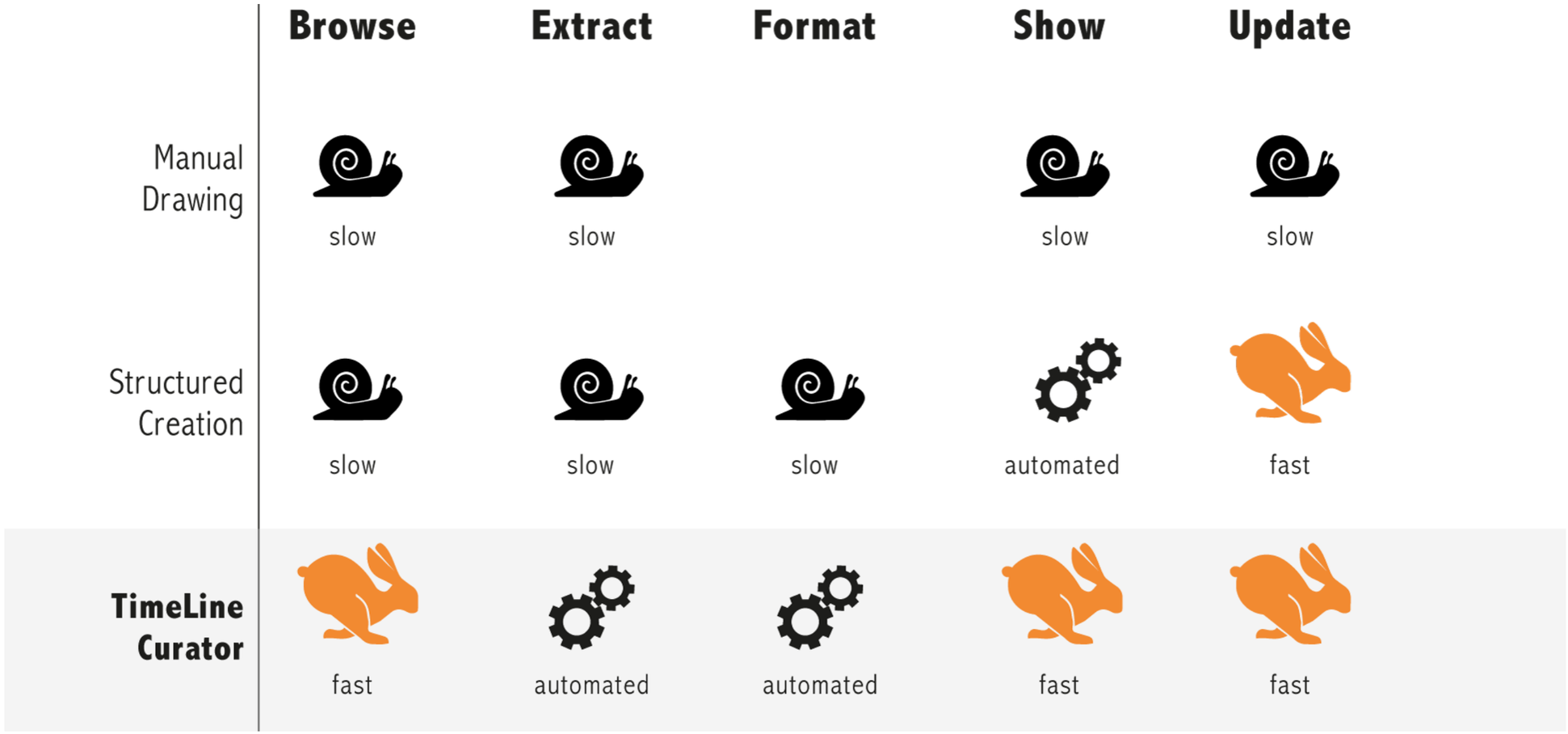
Browse → Extract → Format → Show → Update



TimelineJS
timeline.knightlab.com/

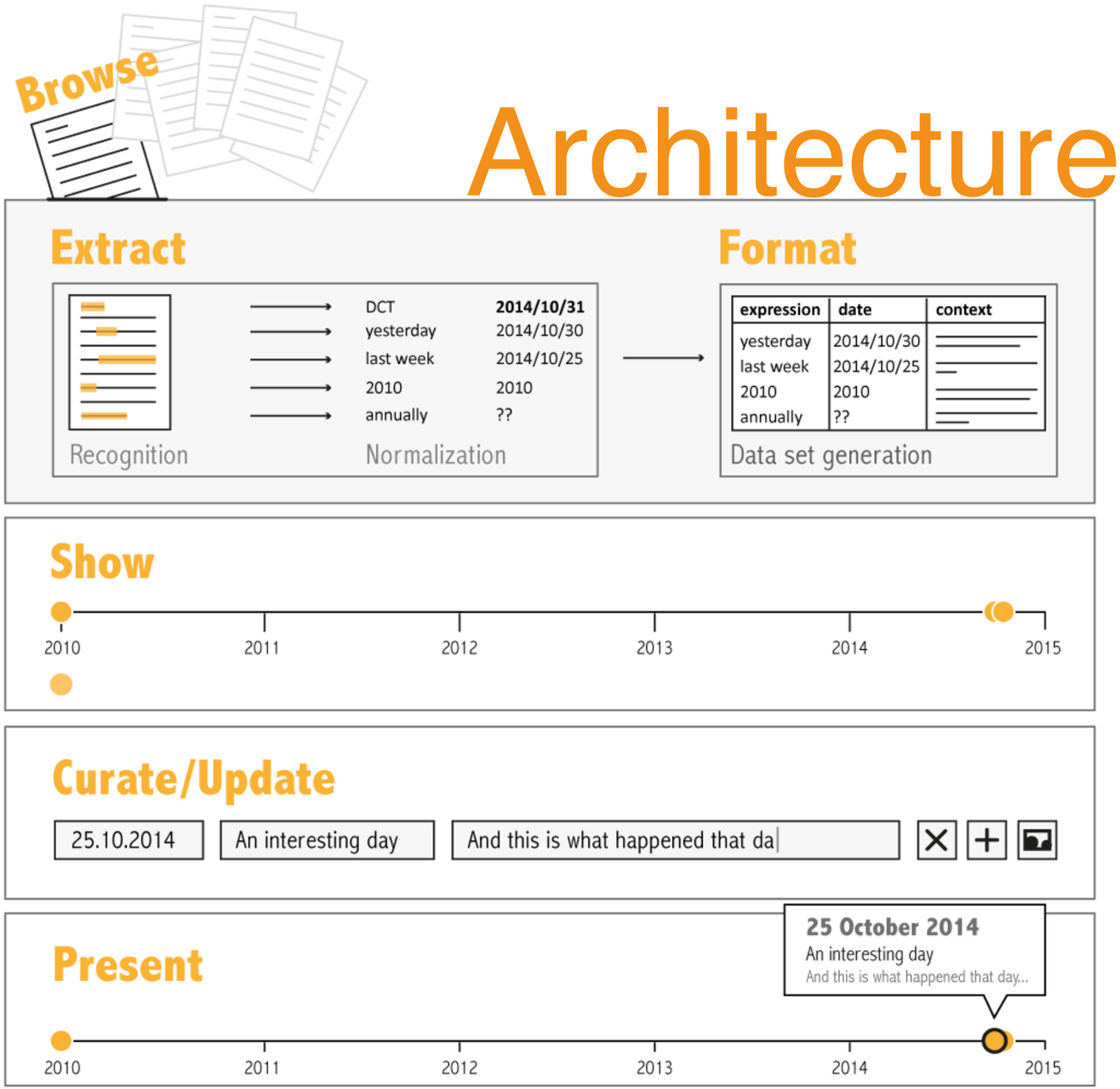
Timeline authoring model

- time required for each task



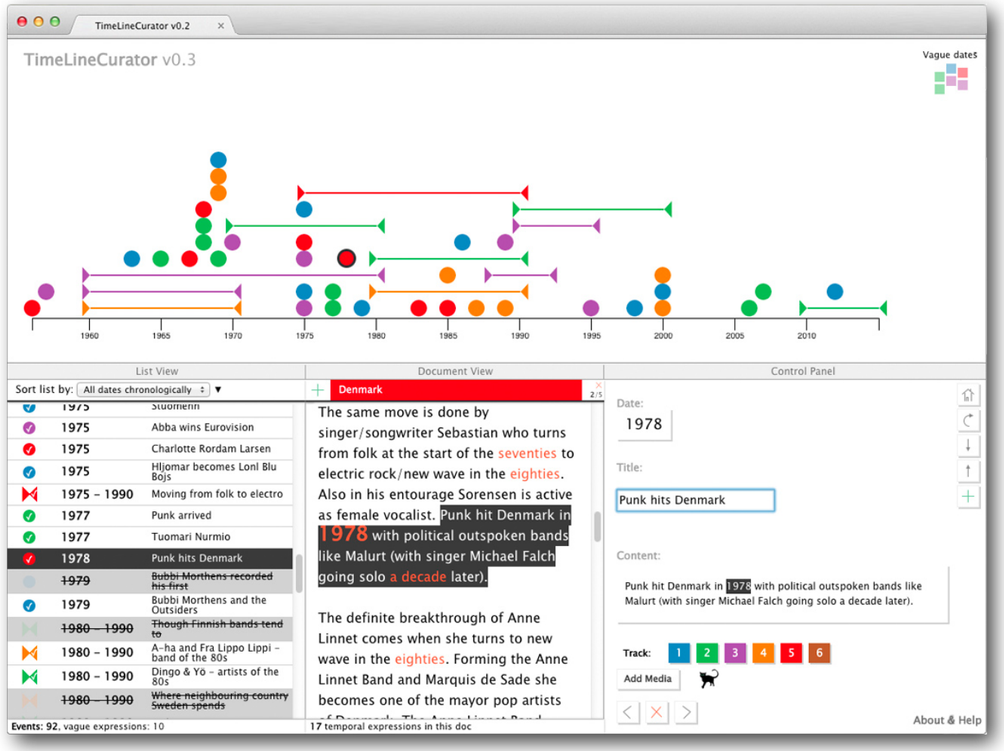
The general case for curation

- build for human in the loop as continuing need
  - automatic processing to accelerate not replace
  - assume computational results good but not perfect
    - for the indefinite future!
  - visual feedback to accelerate



The importance of being brisk

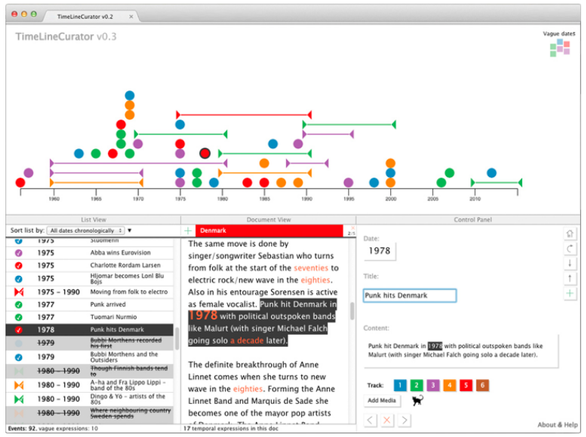
- sexy use case: eureka moment
  - success: enable what was impossible before
  - vis tools for new insights & discoveries
- workhorse use case: workflow speedup
  - success: vis tools accelerate your prior workflow
    - sometimes enables the previously infeasible
- TLC use cases
  - started with speedup use case, for presentation
    - make this doc into a timeline now!
  - two other use cases nudge towards exploration
    - comparison between multiple timelines
    - speculative browsing



TimeLineCurator: Speculative Browsing

https://vimeo.com/jofu/tlc

Curation & Presentation: Timelines



TimeLineCurator

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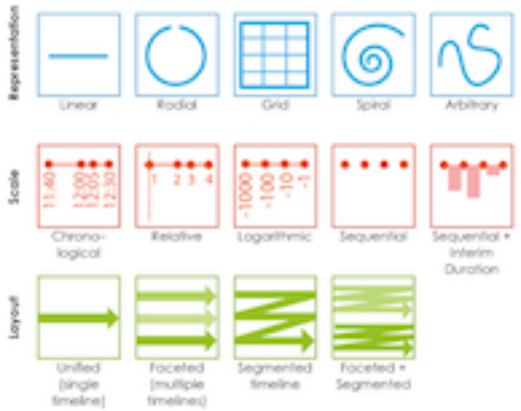
Matt Brehmer

Johanna Fulda



Timelines Revisited

timelinesrevisited.github.io/

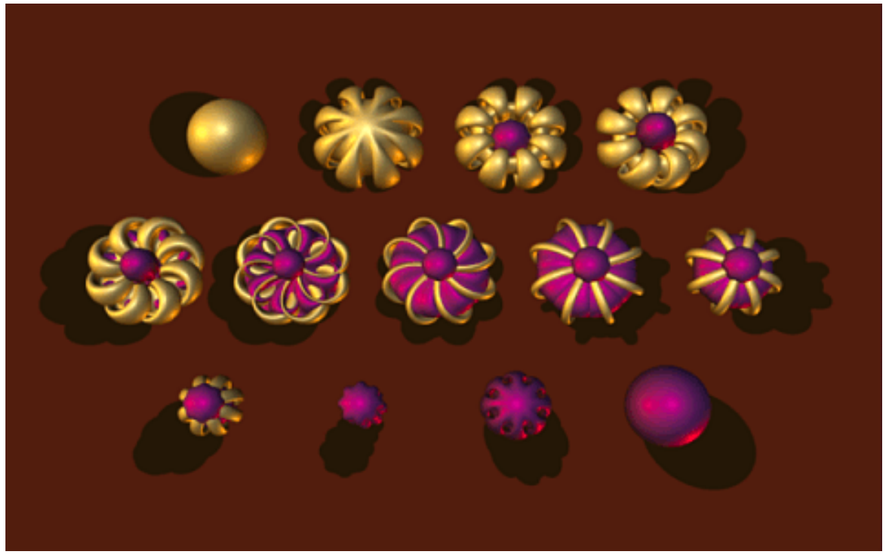
Matt Brehmer

Bongshin Lee **(Microsoft)**

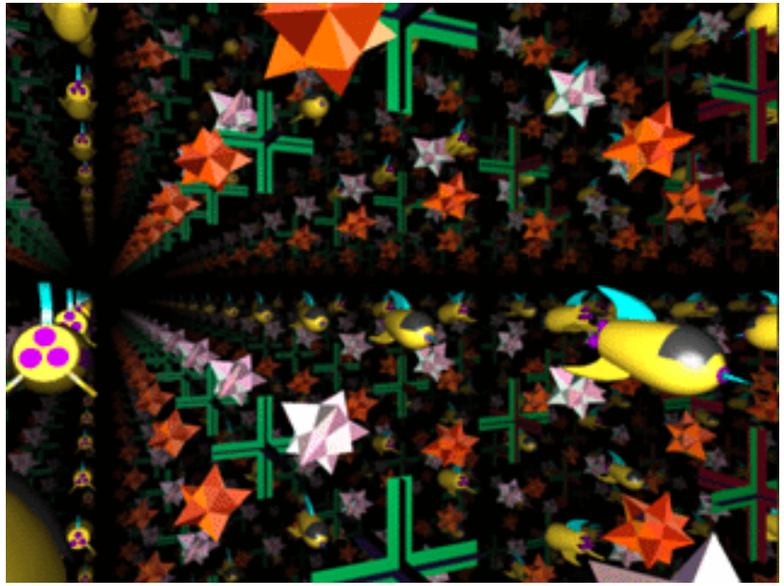
Benjamin Bach **(Microsoft)**

Nathalie Henry-Riche

Presentation: Geometry Center math vis videos



Outside In

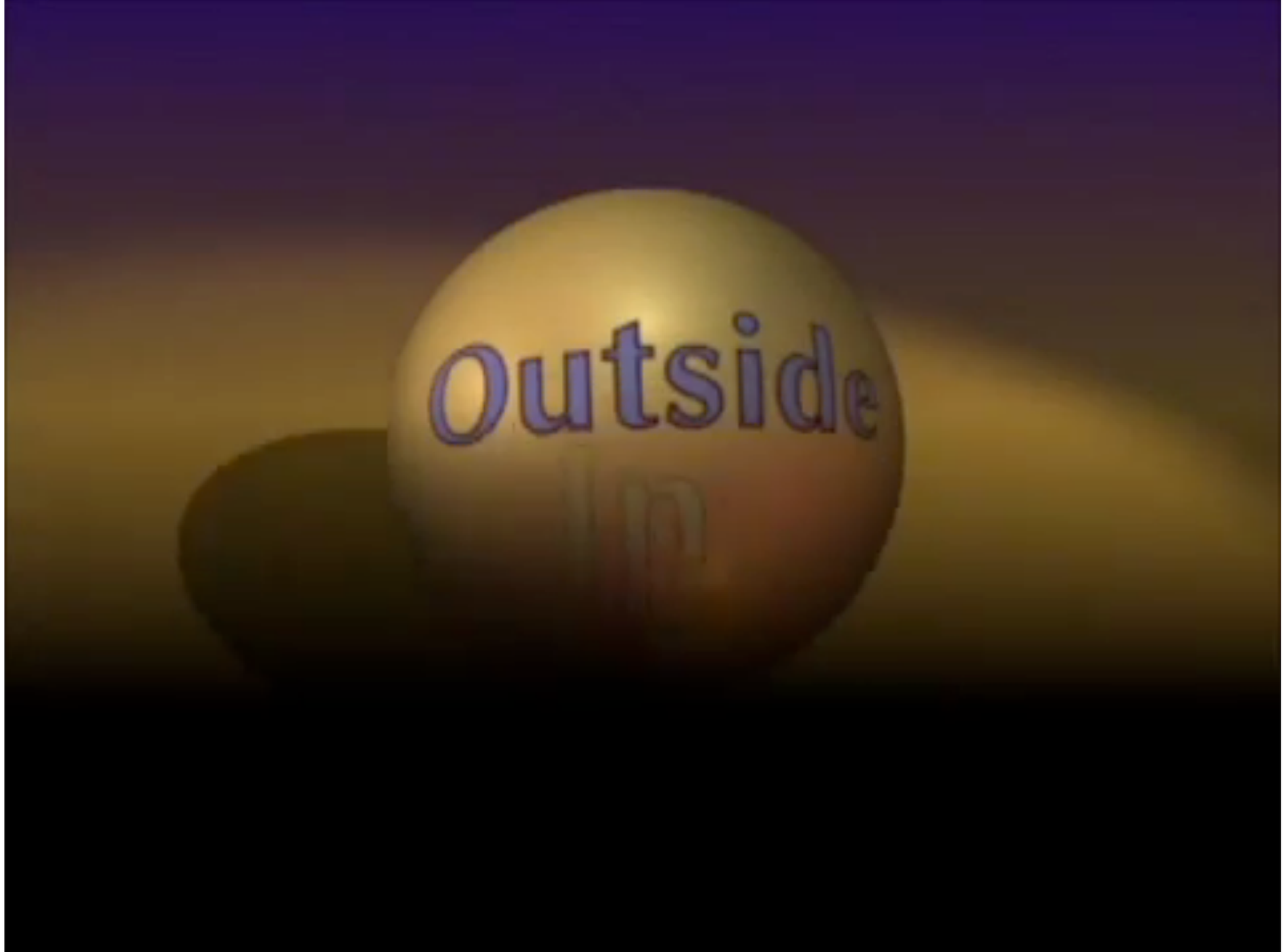


The Shape of Space

Stuart Levy

Mark Phillips

Delle Maxwell


Outside

Visualization entry points

- goals
  - exploratory data analysis
  - presentation
  - curation / authoring
- methods
  - algorithm development
  - system building & software development
  - lab studies with human subjects
  - field studies with human subjects

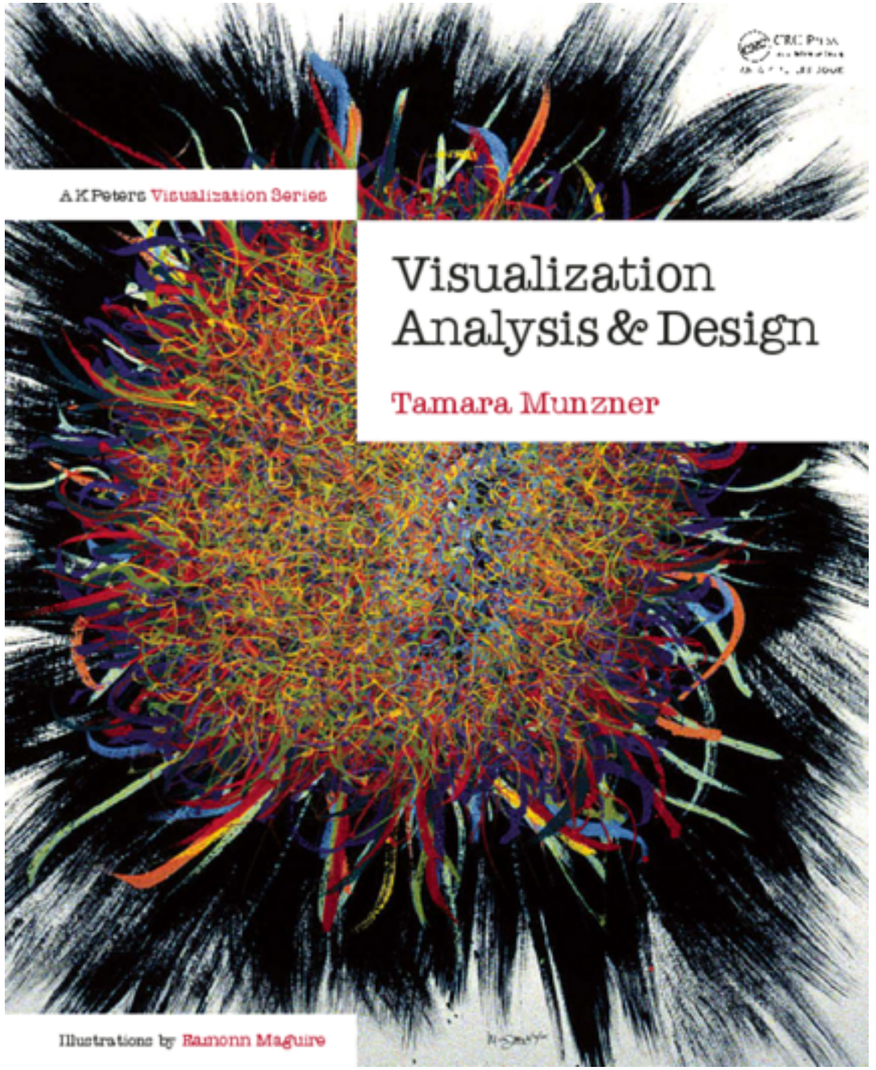
Teaching

Visualization Analysis and Design

@tamaramunzner

- book page
  http://www.cs.ubc.ca/~tmm/vadbook
  - 20% promo code for book+ebook combo: HVN17
  - http://www.crcpress.com/product/isbn/9781466508910
  - free to read online within UBC
    http://resolve.library.ubc.ca/cgi-bin/catsearch?bid=7678980

- slide decks at many talk lengths (1, 2, 3, 6, 8+ hrs), some w/ videos
  http://www.cs.ubc.ca/~tmm/talks.html#vadallslides



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

Visualization Analysis & Design

IEEE VIS 2014 Tutorial
Video Preview

Tamara Munzner
Department of Computer Science
University of British Columbia

What?

Why?

How?

Data Types

→ Items → Attribu

Data and Dataset Ty

Tables

Items

Attributes

Netw
Trees

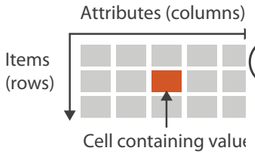
Items (

Links

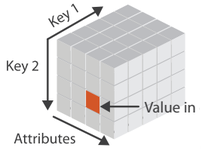
Attribu

Dataset Types

→ Tables



→ *Multidimensional Tab*



→ Geometry (Spatial)

Analyze

→ Consume

→ *Discover*

→ *Present*

→ Produce

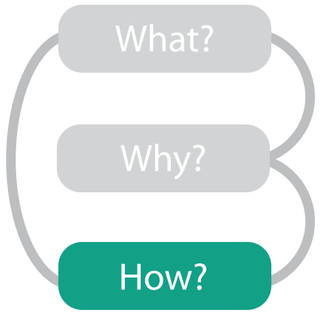
→ *Annotate*

→ *Record*

→ Use

Search

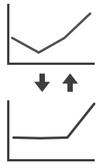
	Target kn
Location known	L
Location unknown	L



Query

→ Identify

→ Compare



→ Summarize

Encode

Arrange

→ Express

→ Separate

→ Order

→ Align

Map

from categorical and ordered attributes

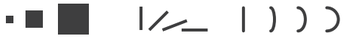
→ Color

→ *Hue*

→ *Saturation*

→ *Luminance*

→ Size, Angle, Curvature, ...



→ Shape

→ Motion

Direction, Rate, Frequency, ...

→ Paths

Spatial Data

→ Shape

Manipulate

Change

Select

Navigate

Facet

Juxtapose

Partition

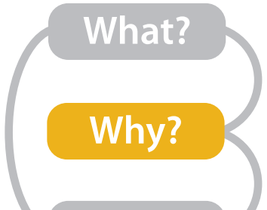
Superimpose

Reduce

Filter

Aggregate

Embed



How to handle complexity: 4 families of strategies

→ *Derive*

- derive new data to show within view
- change view over time
- facet across multiple views
- reduce items/attributes within single view

Manipulate	Facet	Reduce
→ Change	→ Juxtapose	→ Filter
→ Select	→ Partition	→ Aggregate
→ Navigate	→ Superimpose	→ Embed

Visualization Teaching at UBC: Me

- Computer Science grad
  - open to all students, no CS prereqs, non-programming project options available
  - tooling not taught (most use D3 or R)
- Computer Science ugrad
  - coming in January 2020, 4th year CS majors
  - tooling: D3
- Data Science
  - tooling: R
- Journalism
  - tooling: Tableau

- Ed Psych, Forestry, Geography, iSchool, Psychology
  https://dfp.ubc.ca/initiatives/viz-ubc/visualization-courses

Visualization Teaching Across UBC

- many other visualization-focused courses
  - Ed Psych
  - Forestry
  - Geography
  - iSchool
  - Psychology
- initial list compiled
  https://dfp.ubc.ca/initiatives/viz-ubc/visualization-courses
  - please contact vizatubc-info@cs.ubc.ca with additions/corrections!

- still todo: compile list of courses with significant visualization content

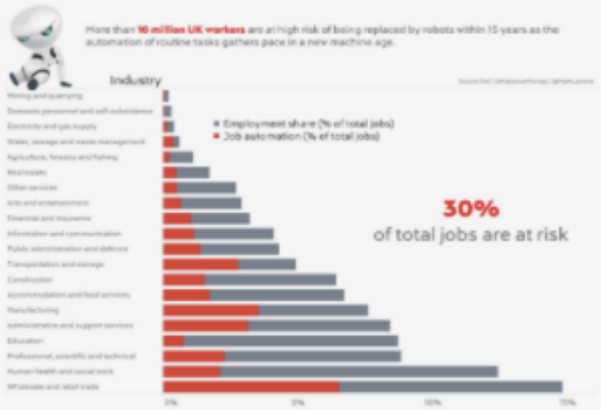
Engaging with visualization teaching

- teach/take a visualization-focused course
- teach/take domain-oriented course where visualization plays a role
  - presentation
  - exploratory data analysis
- offer your domain problem as project topic
  - research or administrative data

Engaging: Possible Next Steps

Redesign En Masse: **Makeover Mondays**

- easy entry point, Tableau focus



Week 14 – Millions of UK workers at risk of being replaced by robots

Apr 7, 2017

During week 14 we looked at job automation and the potential impact of robots and AI on the UK employment market.

Week 13 – The Secret of Success

Mar 31, 2017

Week 13 took a look at a Russian survey about the secret of success. Dot plot, bump charts, bar charts, radar charts. This week had it all! Plus seven lessons to take on board.

Week 12 – March Madness

Mar 24, 2017

We looked at March Madness data for week 12, highlighting the phenomenon that is US college basketball. Quite a few vizzes showed the passion that

http://www.makeovermonday.co.uk/blog/

Visual Design Process In Depth: **Dear Data**

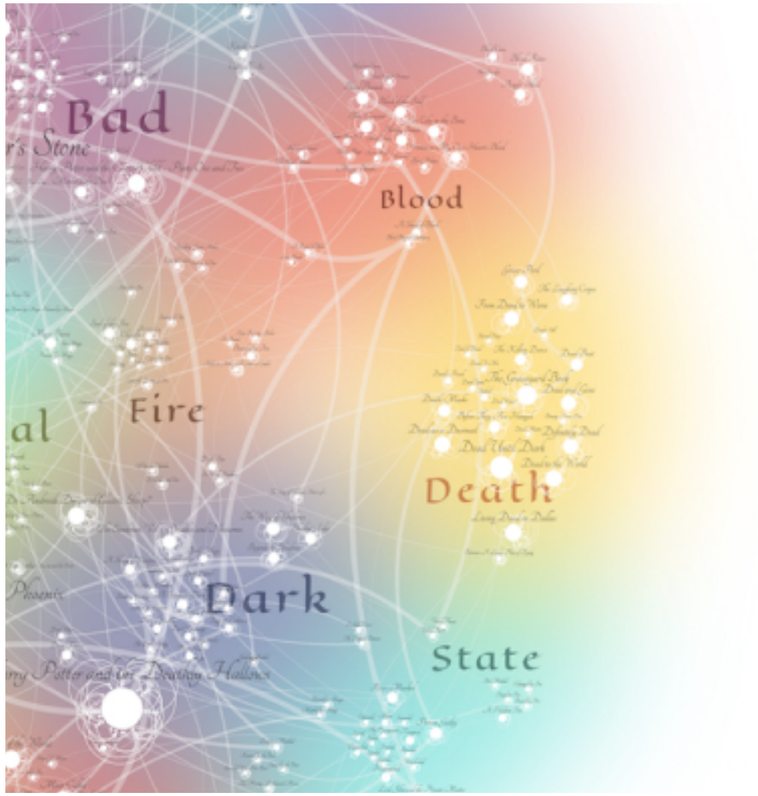
- inspiring celebration of data humanism

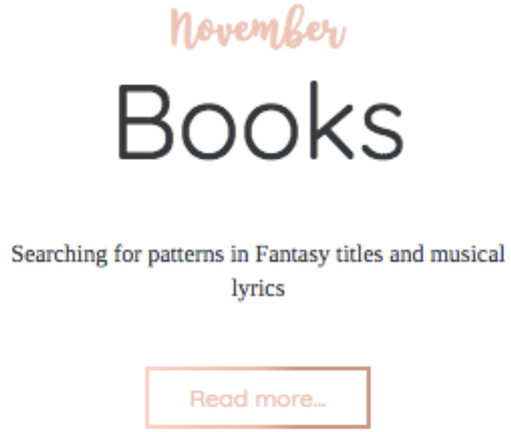
http://www.dear-data.com/by-week/

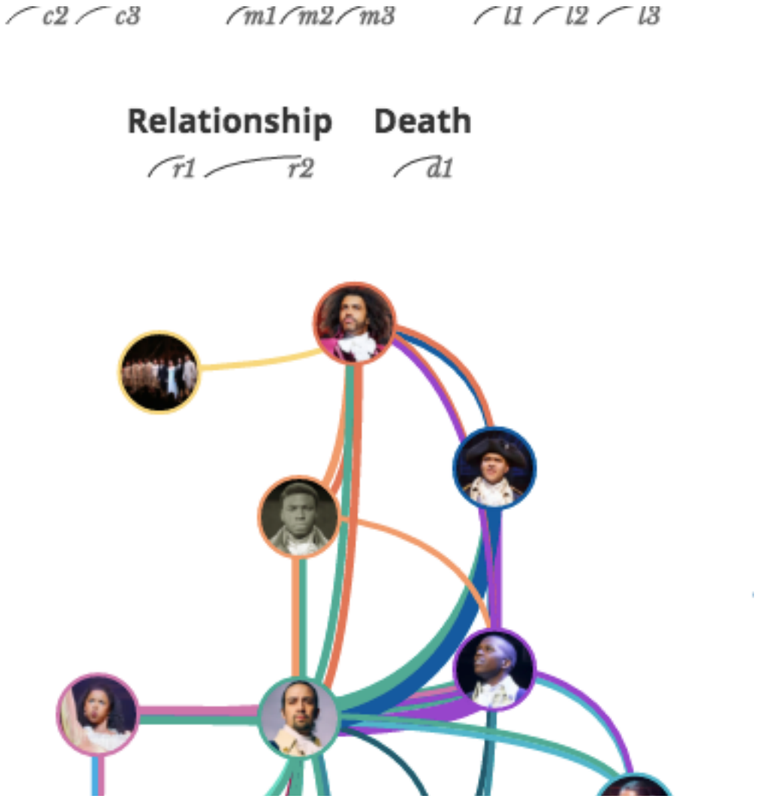
Giorgia Lupi and Stefanie Posavec

Visual Design Process In Depth: **Data Sketches**

- detailed process notes, from sketching through coding







http://www.datasketch.es/

Shirley Wu and Nadieh Brehmer

Pathways to participate

- join Viz@UBC
  - https://dfp.ubc.ca/initiatives/viz-ubc
  - get on visatubc-announce email list (send mail to vizatubc-info@cs.ubc.ca)
  - upcoming kickoff events: 2 more talks + 1 mixer
  - join as core, so you're findable in people index
  - join as organizer, help us decide what to do next
- join Data Visualization Society
  - https://www.datavisualizationsociety.com/
  - brand new! resources, jobs board,...

Pathways to participate

- participate in IEEE VIS 2019 in Vancouver, Oct 20-25
  - http://ieeevis.org
  - big 3 research tracks: VA, InfoVis, SciVis
  - many associated events
    - Vis in Data Science
    - Vis In Practice
    - Large Data Analysis & Visualization
    - Application Spotlights
    - many workshops including bio, security, ...
  - job fair (asynchronous)

More Information

- this talk
  https://www.cs.ubc.ca/~tmm/talks.html#vizatubc19-entry

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

@tamaramunzner

Q&A References

- entry points for practitioners?
  - D3 resources for advanced programmers:
    https://github.com/d3/d3/wiki/Gallery
    https://bl.ocks.org/
  - R resources for range of programming experience:
    https://www.tidyverse.org/
    https://ggplot2.tidyverse.org/
  - Tableau resources, for non-programmers:
    https://www.tableau.com/
  - Andy Kirk's continuously updated resources list
    http://www.visualisingdata.com/resources/
    - many of these do not require programming!