

Interactivity in Visual Data Analysis

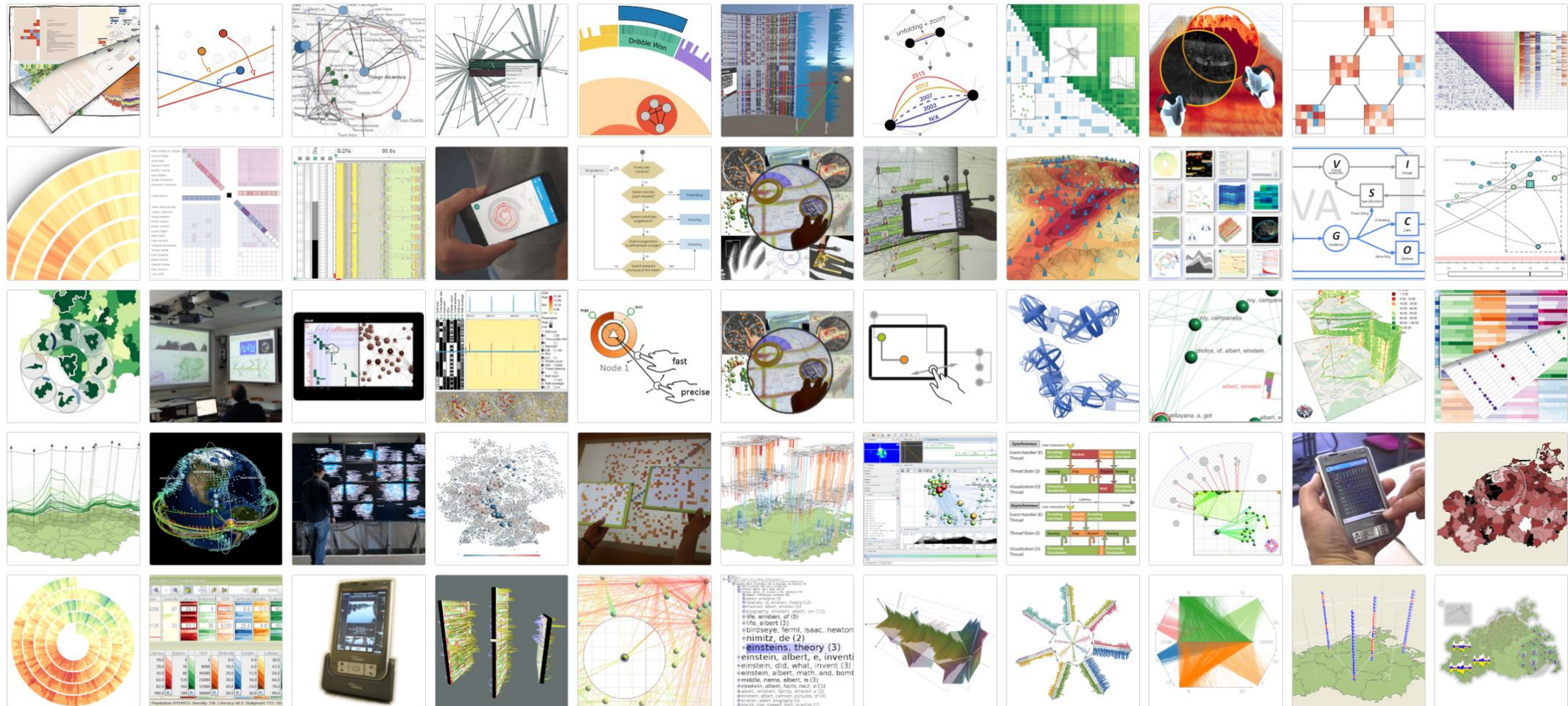
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University of Rostock

About Me

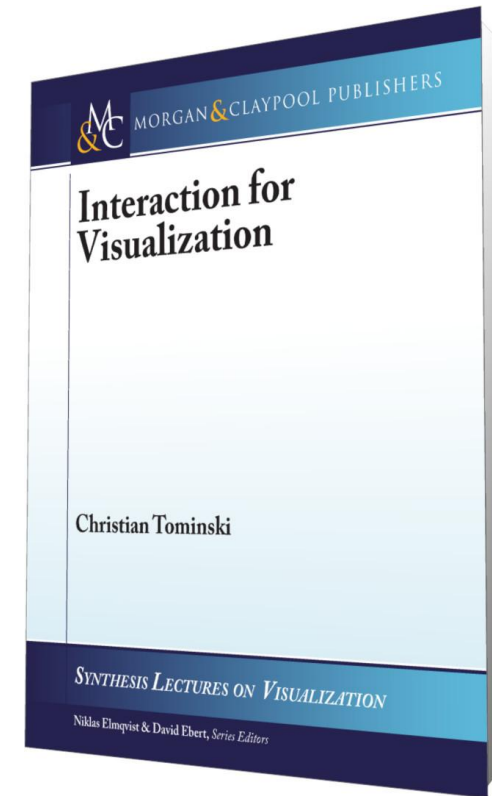
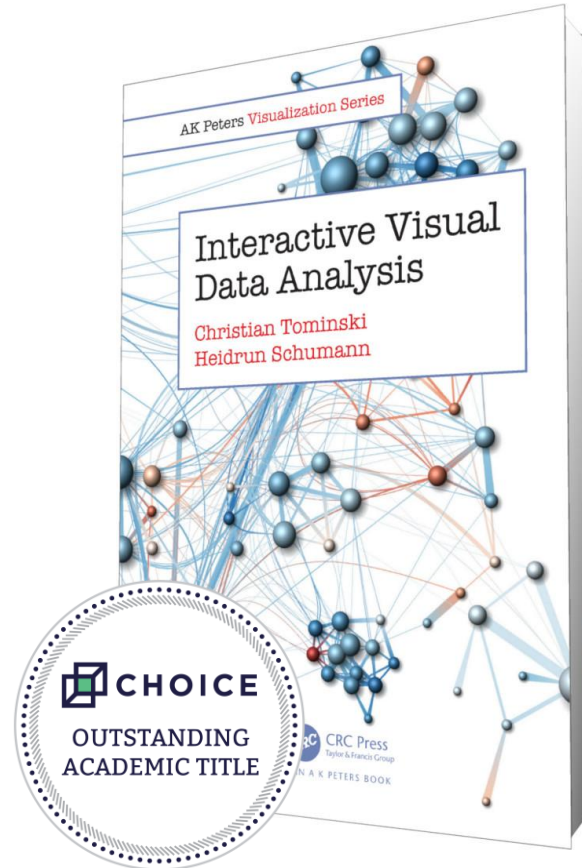
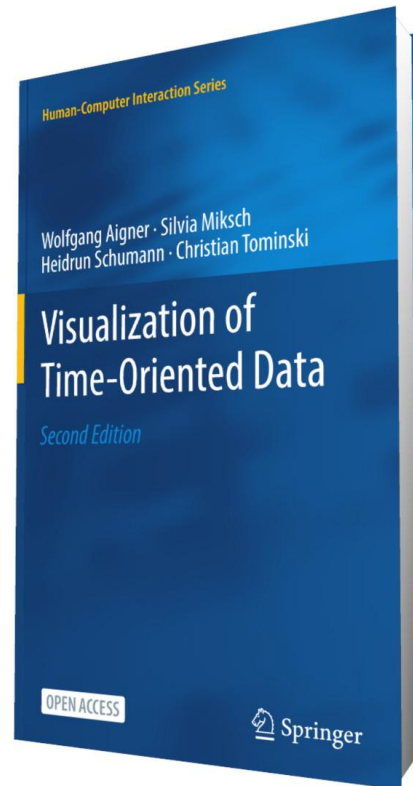
- **Location:** Hanseatic city of Rostock, Germany, located at shore of Baltic Sea
- **Affiliation:** Institute for Visual & Analytic Computing, University of Rostock
- **Interest:** Visual Analytics with a focus on interactivity and special interest in dynamic data graphics



About Me



About Me



Visual Data Analysis

“The purpose of **computing** is **insight**, not numbers.
— Richard Hamming, 1962

“**Visualization** offers a method for **seeing the unseen**. It enriches the process of **scientific discovery** and fosters **profound and unexpected insights**.
— McCormick et al., 1989

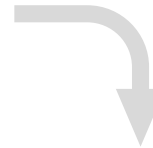
“**Interaction is the fuel** for analytic discourse.
— Thomas & Cook, 2005

Interactive Visual Data Analysis

Why is interactivity relevant?

Clear problem, answer can be computed, do:

Computation



If questions ill-defined or answers hardly computable, add:

Visualization

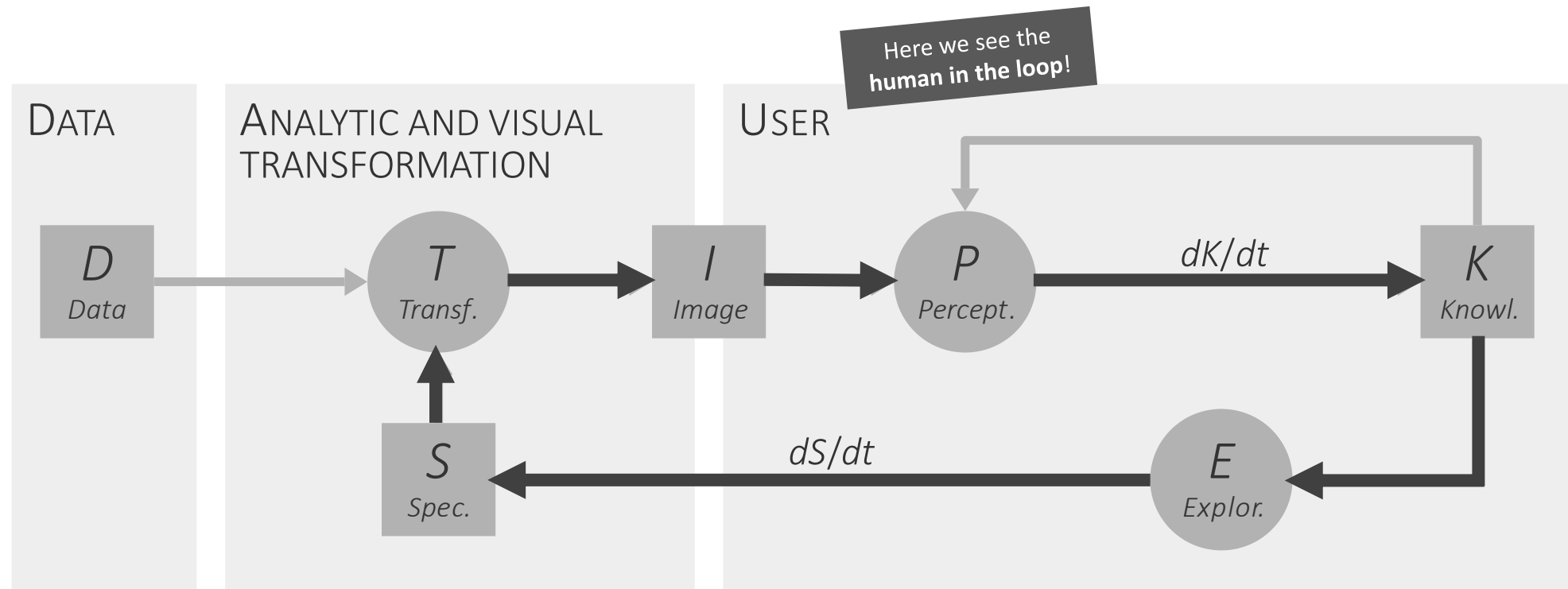


If single computation and visual representation do not suffice, add:

Interaction

Many real-world problems are here!

Abstract Model



Adapted from [van Wijk, 2006](#)

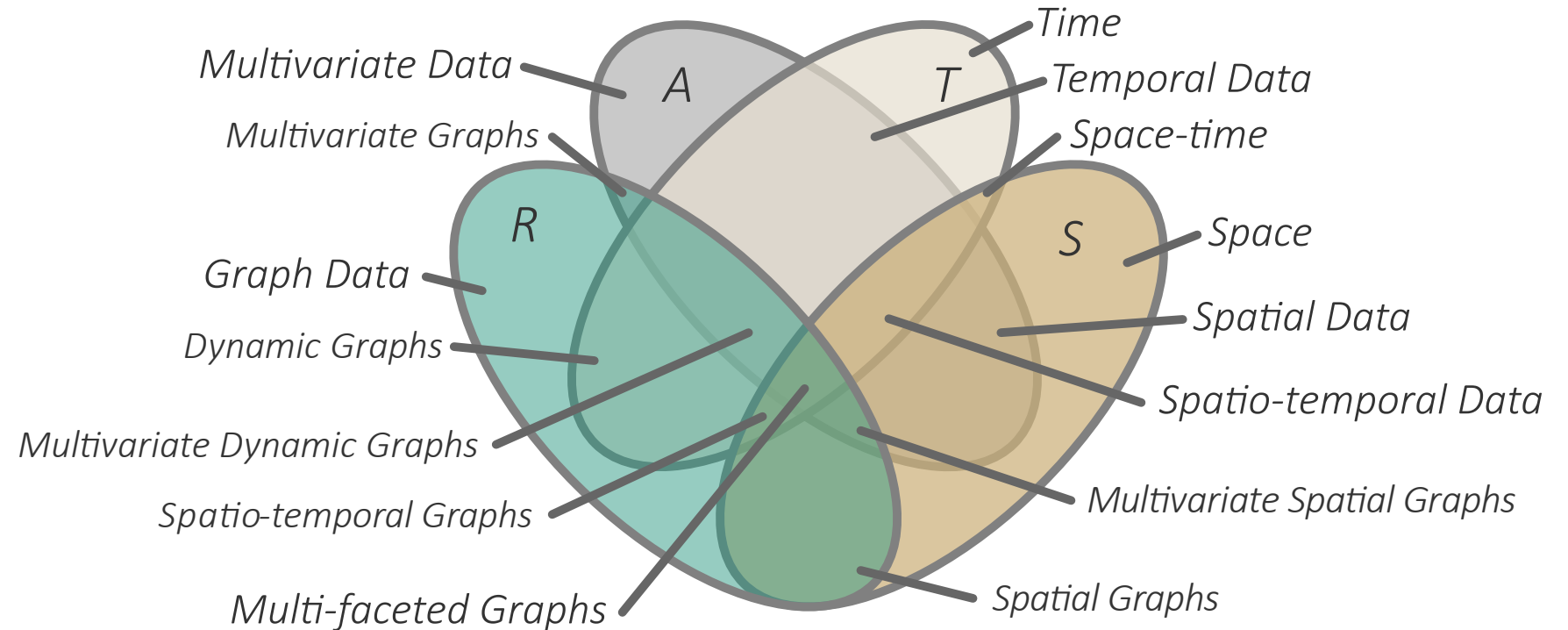
Challenges

- **Effective visual analysis** requires **loop** to run smoothly
- **Hindering factors**
 - **Processing costs** (system side)
 - Generate informative feedback
 - Re/computing visualizations
 - **Interaction costs** (user side)
 - Planning next data analysis steps
 - Executing interactions
 - Understanding visual feedback

Challenges

Costs increase for large and complex
multi-faceted data

- **S** – Space
- **T** – Time
- **A** – Attributes
- **R** – Relations



Goal

- **What: Interactive** visual analysis of large and complex data
 - Large data space to be explored
 - Multi-faceted questions to be asked
 - Many possible solutions

- **How: Fluid interaction** ([Elmqvist, 2011](#))
 - Promote “flow” (avoid disruptions, make interaction engaging and enjoyable)
 - Support direct manipulation (reduce UI, interact directly with visualization)
 - Minimize interaction costs (decrease effort, make easy to perform and understand)

Dynamic data graphics

- Often: Visualizations do not follow the fluid interaction principle
 - Static charts
 - Hard-wired arrangement of views
 - Standard UI controls for interaction

- I advocate: **Dynamic data graphics**
 - Visualizations are **adaptable** and **transformable**
 - Interactions are **lightweight** and **context-specific**
 - Feedback is **informative** and **in-situ**
 - Computations are guaranteed to be **non-blocking**

Dynamic data graphics

Examples and demos

- Progressiveness for non-blocking computation
- Graph exploration with interactive lenses
- From overview, to detail, to editing
- Natural interaction for visual comparison
- Smoothly bridging dimensional boundaries for movement exploration
- Fluid un/folding for details on demand

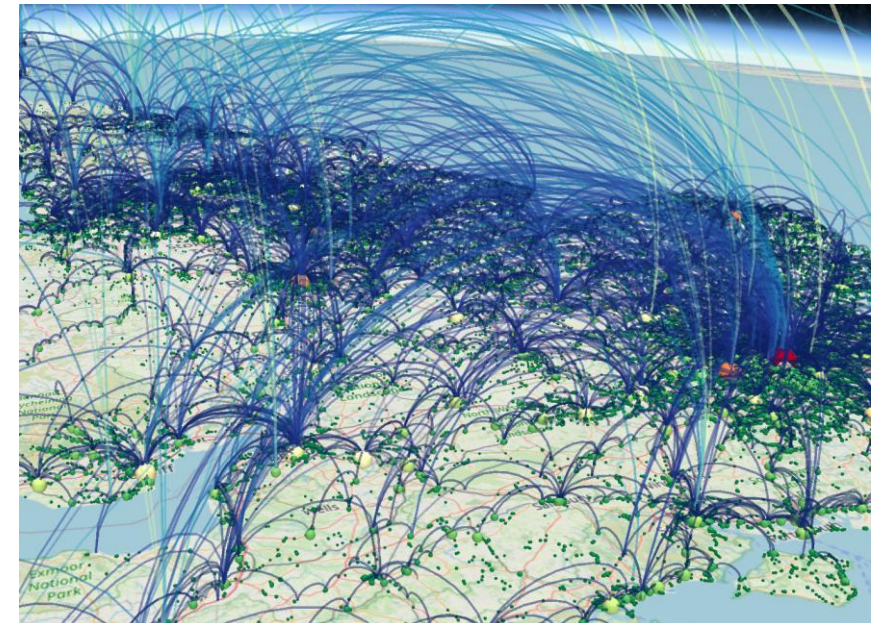
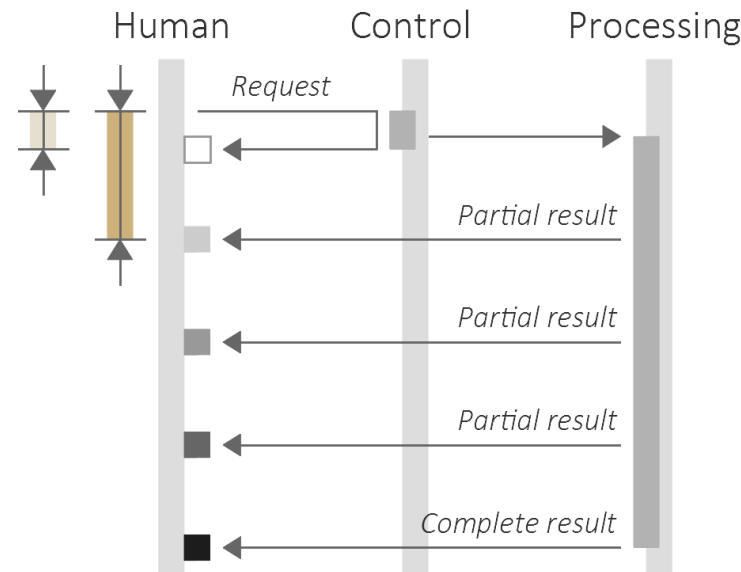
Progressiveness for non-blocking computation

Keep the system **responsive** even for large data

Example: Progressive multi-layer
spatial network visualization
(**267k** nodes, **475k** edges)

Progressive methods

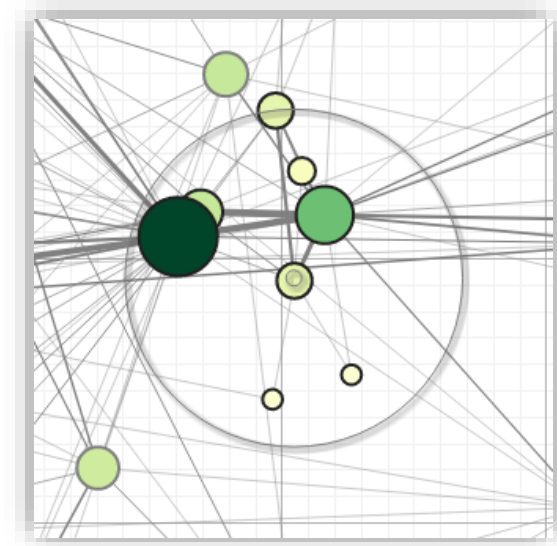
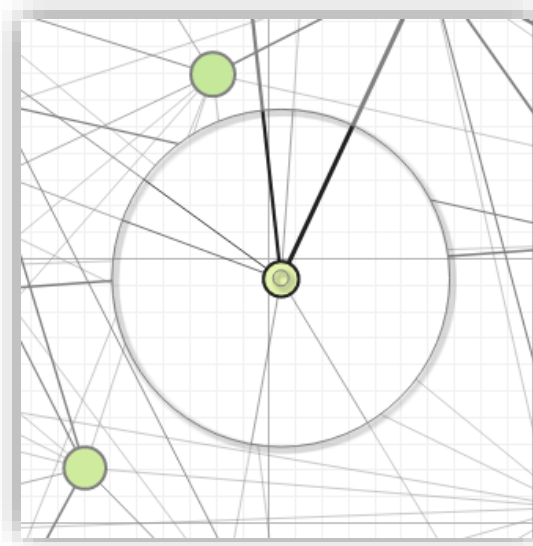
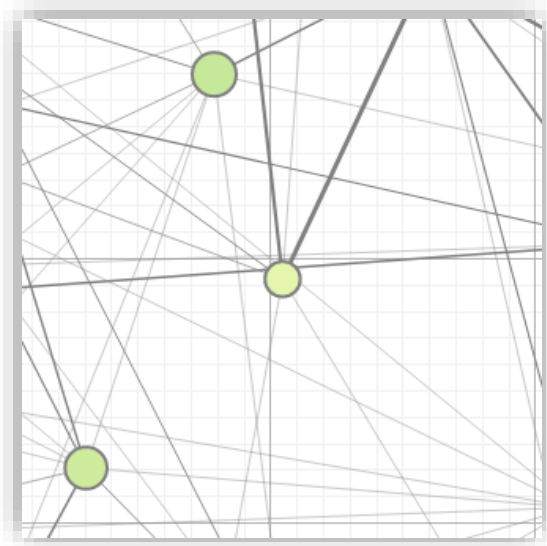
- Process large data progressively
- Quickly show first partial result
- Progress towards more and more mature results



<https://vca.informatik.uni-rostock.de/~ct/software/NetworkGlobe/>

Graph exploration with interactive lenses

- Interactive lenses for visualization ([Tominski et al., 2017](#))
- **Lightweight** tools for **local** visualization adjustment

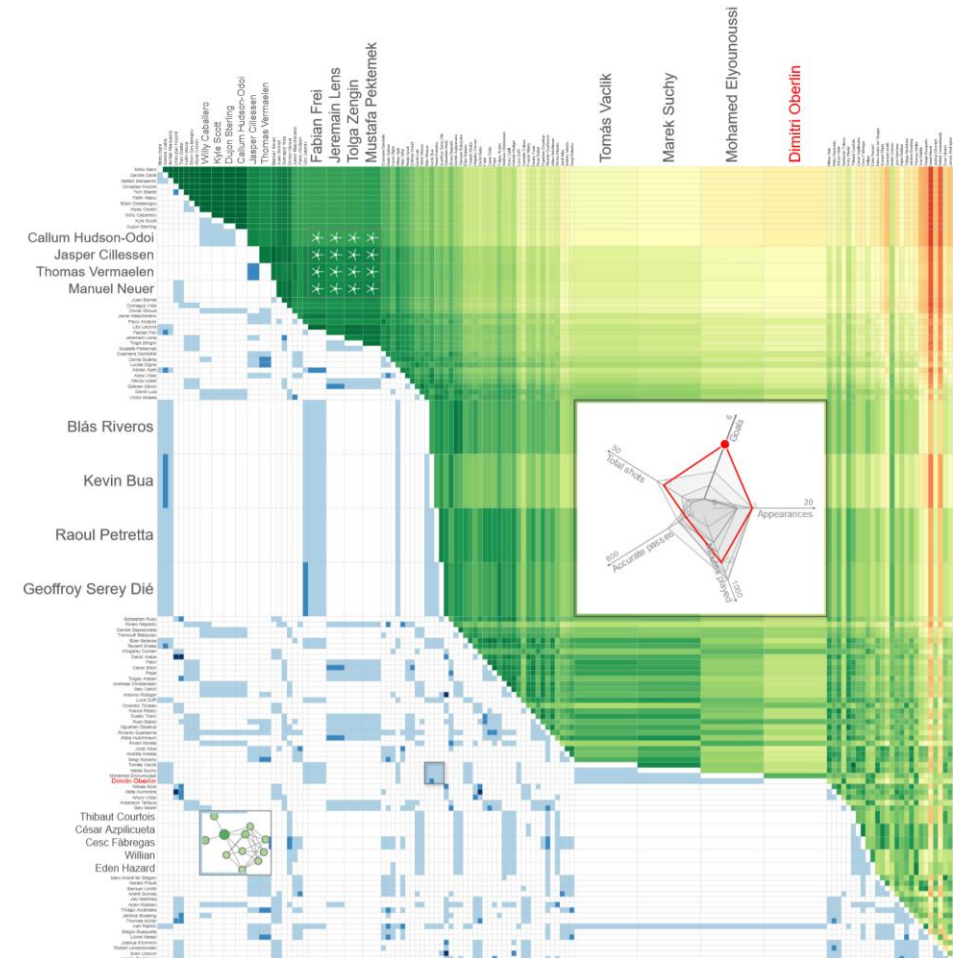


Lenses for Graph Exploration (Tominski et al., [2006](#), [2009](#), [2024](#))

<https://vca.informatik.uni-rostock.de/~ct/software/iGraph.js/iGraph.html>

From overview, to detail, to editing

- Overview: Two-sided matrix visualization
- Detail: **Integration of embedded views** showing different data aspects
- **Visual editing:** Attribute values can be edited directly in views
- Example: **Responsive Matrix Cells**
([Horak et al., 2021](https://horak.github.io/papers/2021/RMC/))



<https://vca.informatik.uni-rostock.de/~ct/software/RMC/>

Natural interaction for visual comparison

Draw inspiration from how people **naturally interact** in the real world

Example: Foldable views for visual comparison
([Tominski, 2012](#))

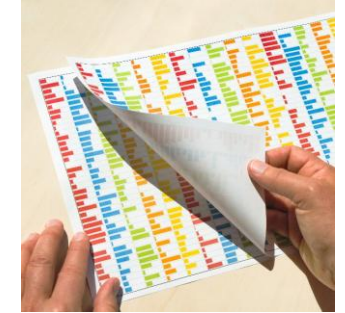
Side-by-side



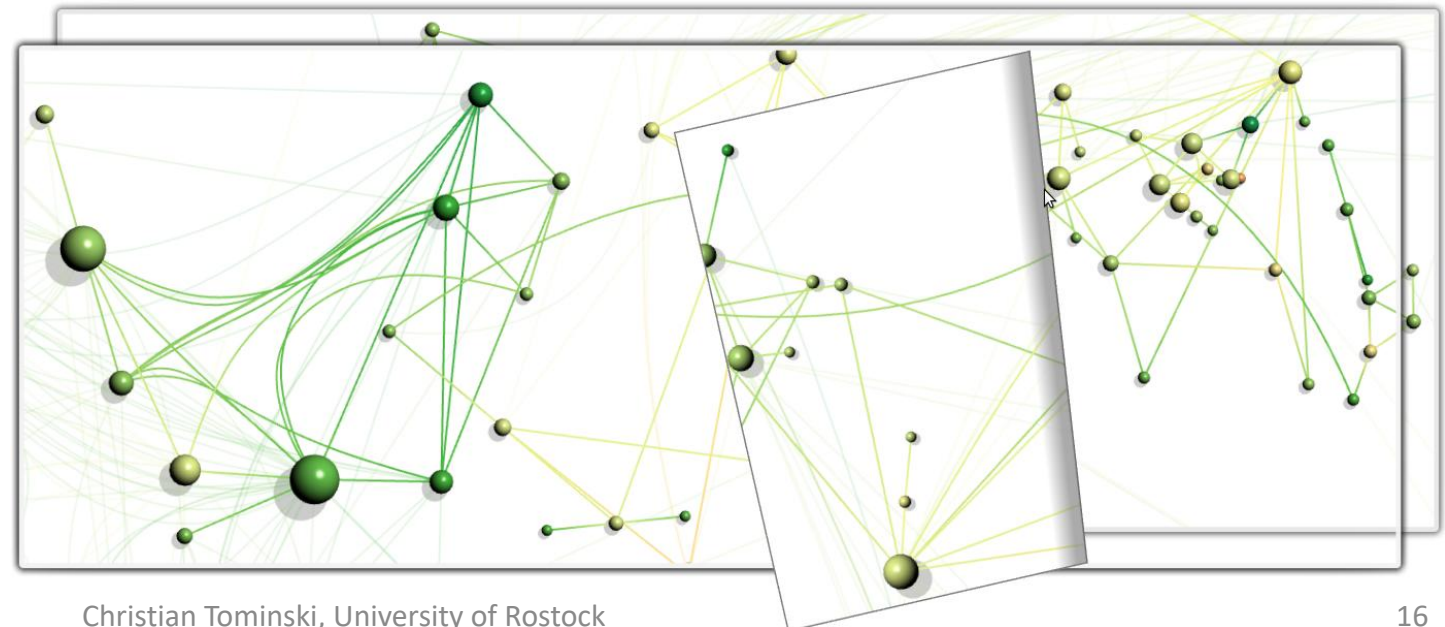
Shine-through



Folding

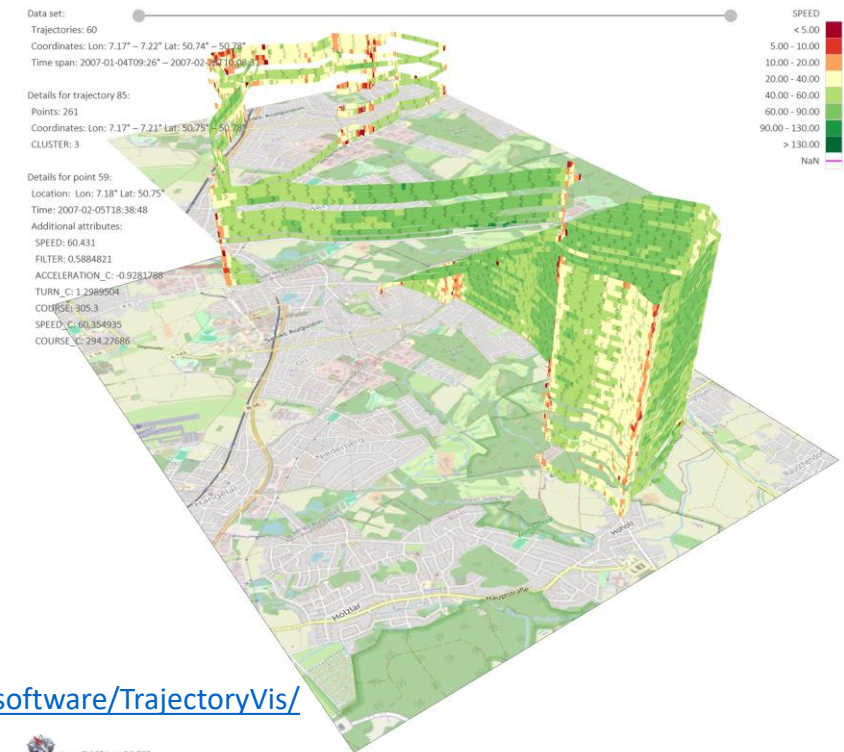


<https://vca.informatik.uni-rostock.de/~ct/software/FoldableVis/>



Smoothly bridging dimensional boundaries

- Different representations serve different purposes
- Avoid disruptive switch and **smoothly bridge**
 - **2D** map with trajectory lines
 - **3D** map with stacked trajectory bands
- Example: Hybrid 2D/3D trajectory visualization ([Tominski, 2012](https://vca.informatik.uni-rostock.de/~ct/software/TrajectoryVis/))

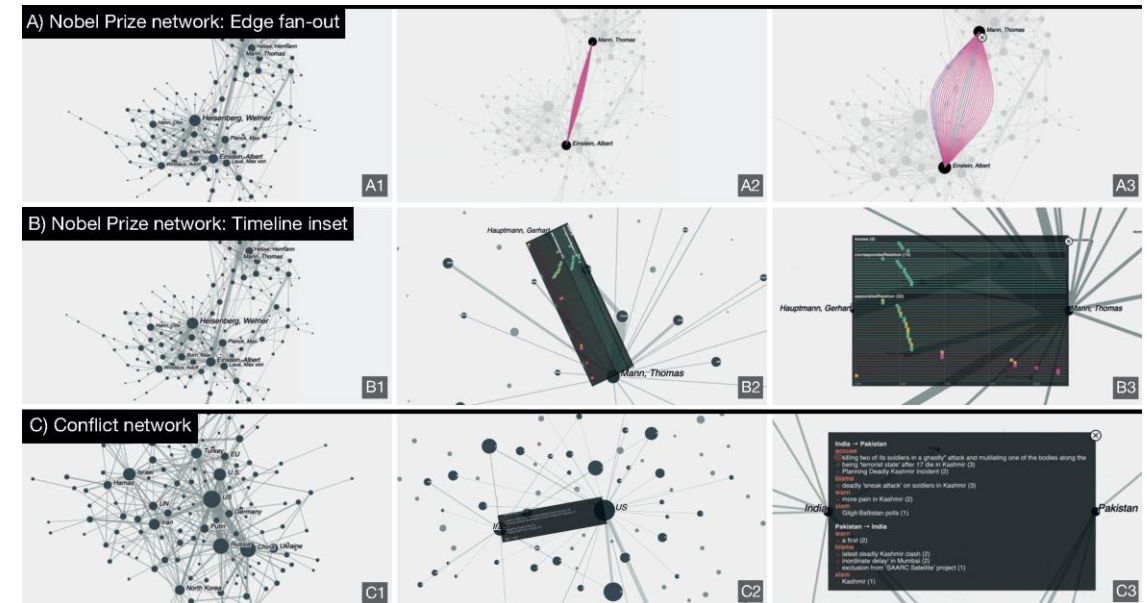


<https://vca.informatik.uni-rostock.de/~ct/software/TrajectoryVis/>

Fluid un/folding for details on demand

Fluid in-situ interaction triggers smooth animations that reveal the necessary information to make analytical progress

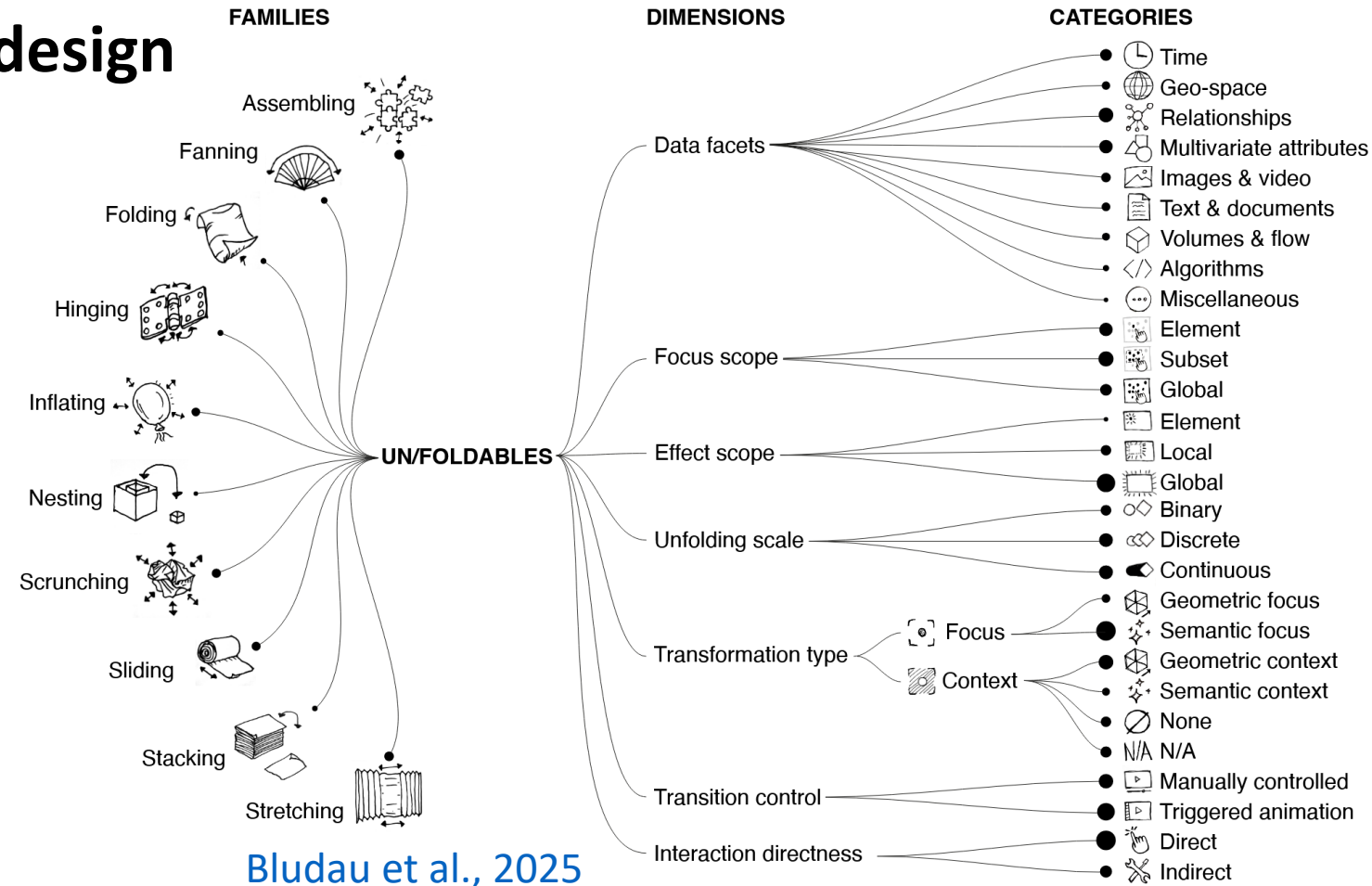
Example: Dynamic *edge unfolding* for multi-variate graph exploration ([Bludau et al., 2023](https://doi.org/10.1016/j.chaos.2023.111111))



<https://uclab.fh-potsdam.de/unfoldingedges>

Un/foldables as a general design pattern

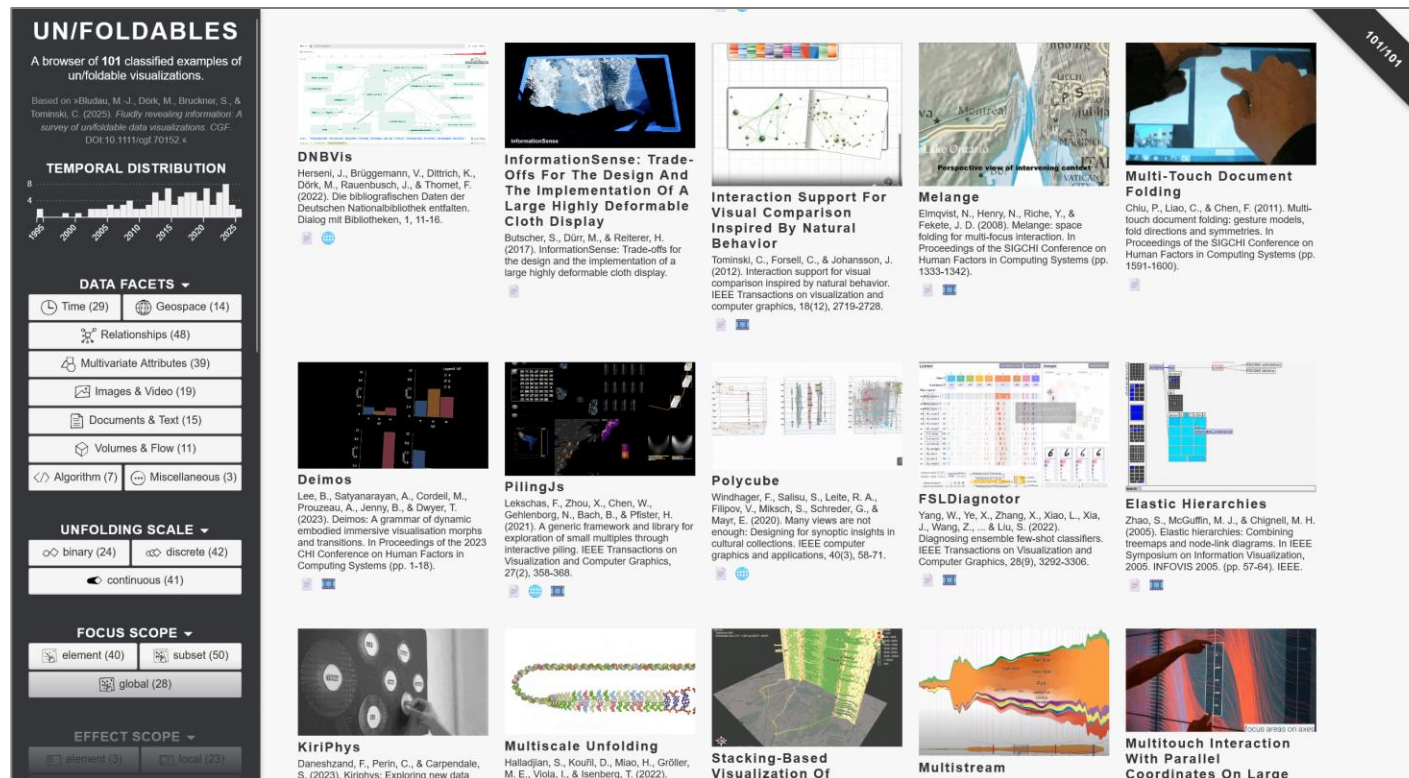
- Inspiration from **industrial design**
- **Design space** dimensions
 - What gets un/folded?
 - How many un/folding states?
 - What is the scope of the un/folding effect?
 - How can the un/folding be controlled?
 - ...



[Bludau et al., 2025](#)

Un/foldables as a general design pattern

- Survey of **un/foldables** in visualization ([Bludau et al., 2025](https://uclab.fh-potsdam.de/unfoldables/))



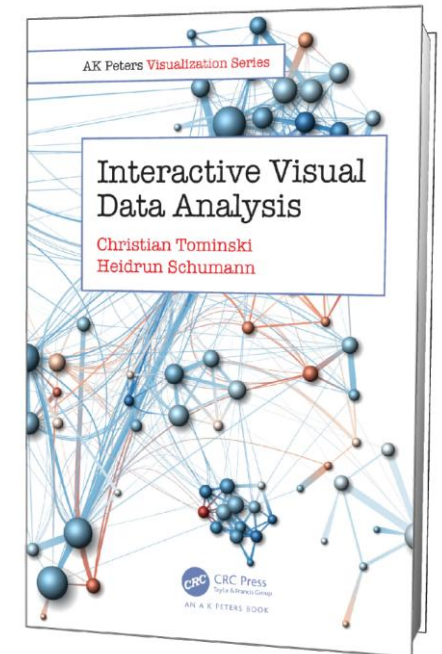
<https://uclab.fh-potsdam.de/unfoldables/>

Thank you!

Summary

- **Interactivity** is key ingredient of visual data analysis
- **Dynamic data graphics** transform visual representations in various ways to satisfy human information needs

Go for dynamic data graphics!
Keep the human in the loop!



<https://ivda-book.de>

Thank you!

Special thank you to TU Eindhoven's visualization researchers for so many influential works and for being a great source of inspiration!