Visual Analytics
Empowering the Human in the Loop

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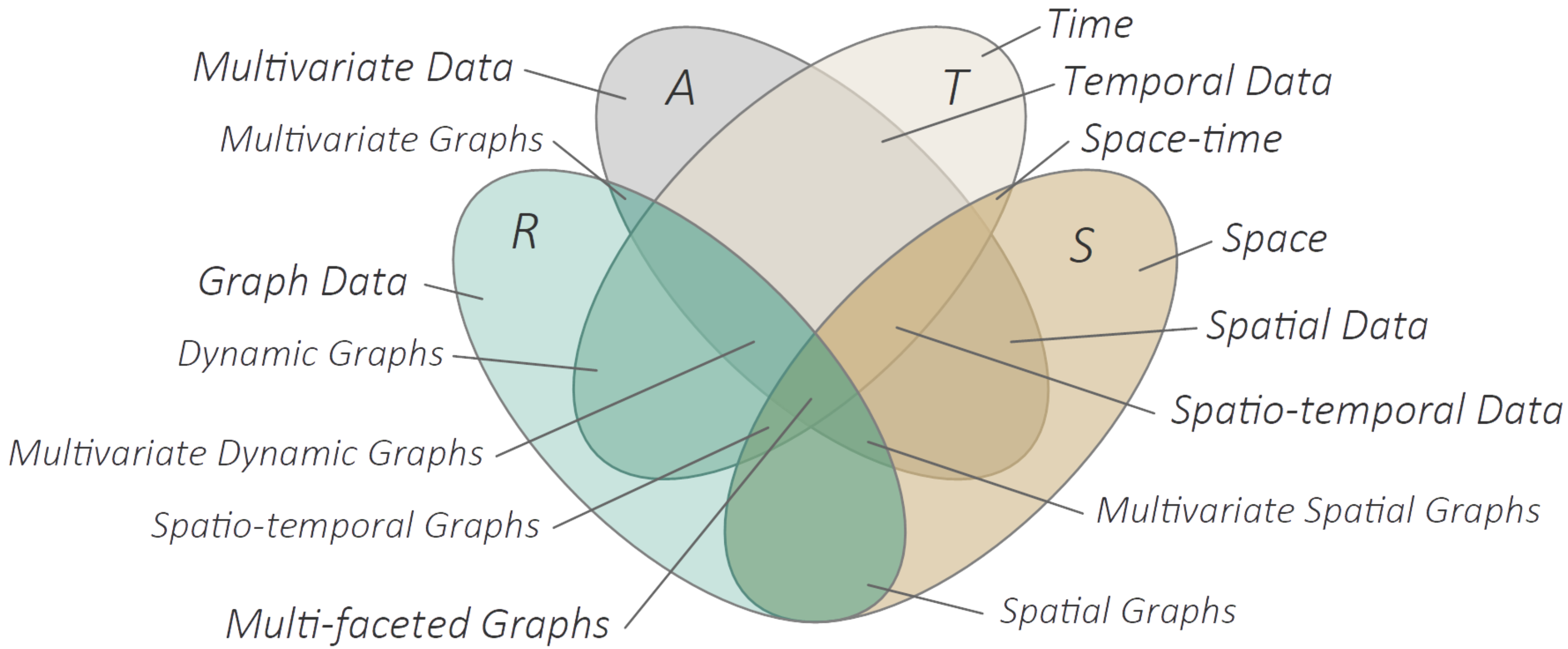
Visual Analytics



Gain **insight** into large **data** to **understand** complex **phenomena**

Visual Analytics

- Interplay of:

If answer can be computed, do:
Computation

If answer cannot be computed, add:
Visualization

If visual representations do not suffice, add:
Interaction

Many real-world problems are here!

Historic Roots

“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**.

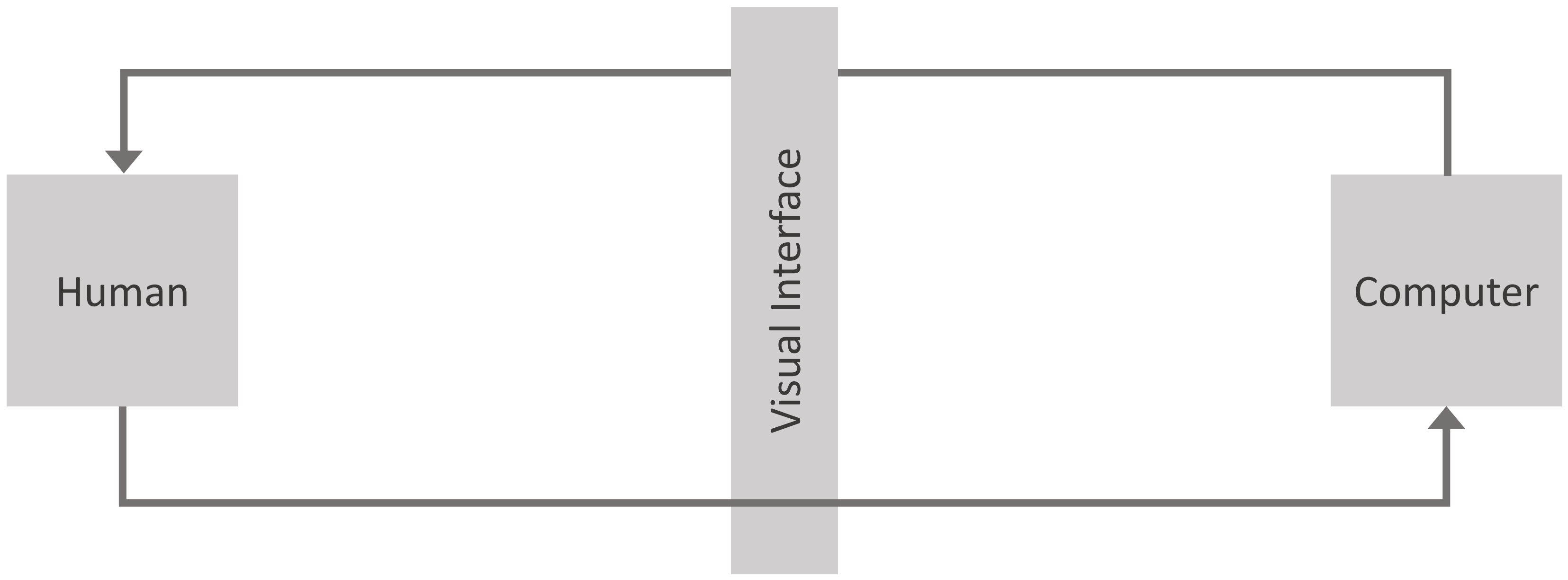
— McCormick et al., 1989

“Are we analyzing data? Then we should be **manipulating** the **data themselves**; or if we are designing an analysis of data, we should be **manipulating** the **analytic structures themselves**.

— Hutchins et al., 1985

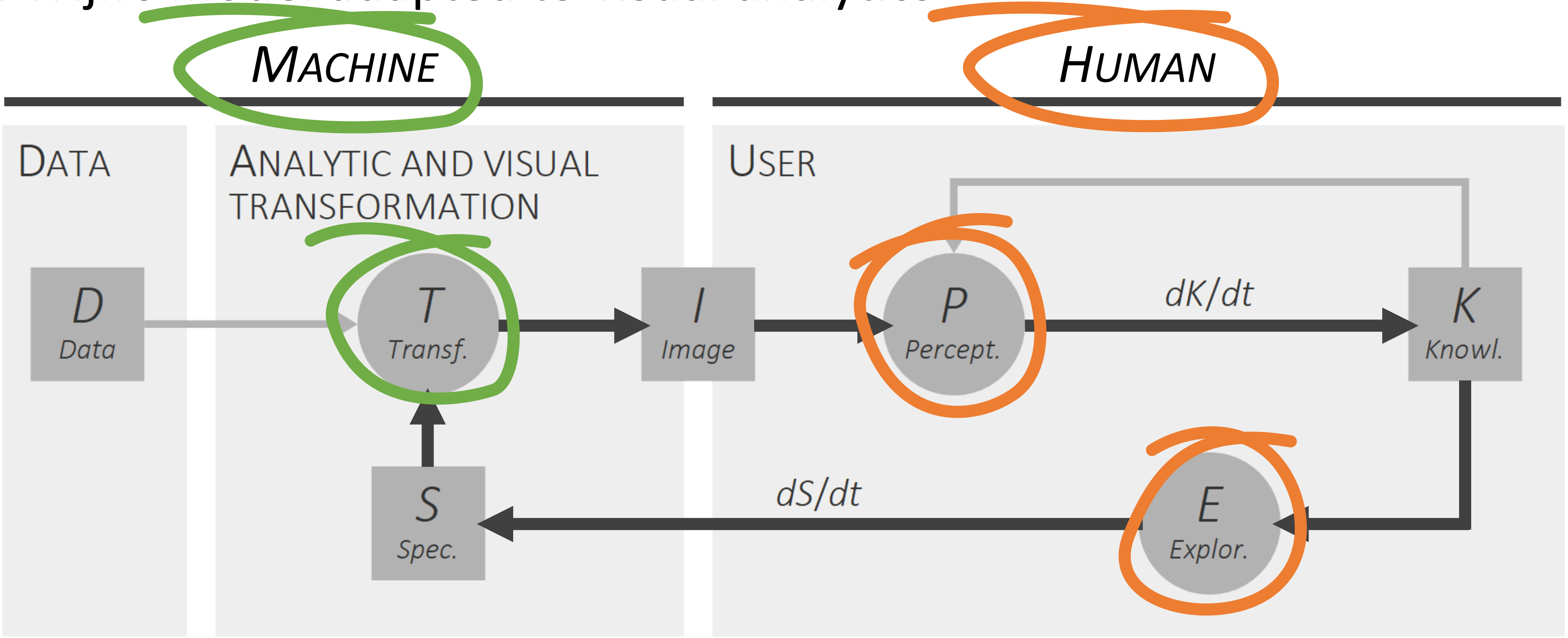
Interactive Visual Data Analysis as a Loop

> "**Visual analytics** is the science of **analytical reasoning** facilitated by **interactive visual interfaces**.
>
> — Thomas & Cook, 2005



Interactive Visual Data Analysis as a Loop

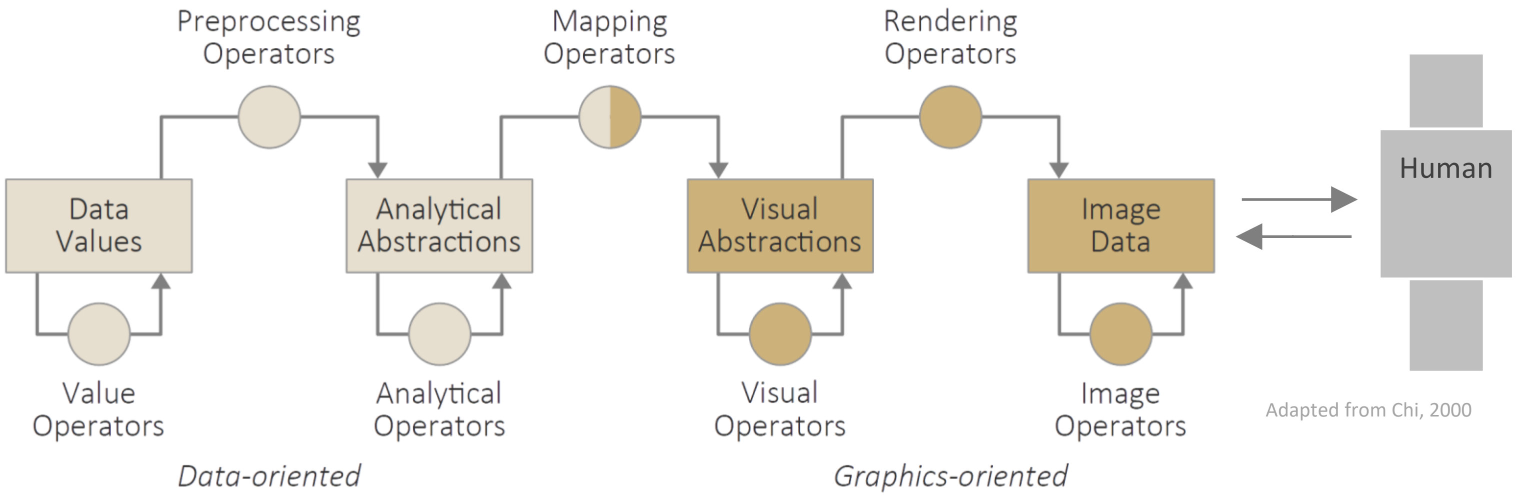
Van Wijk's model adapted to visual analytics



Adapted from van Wijk, 2006

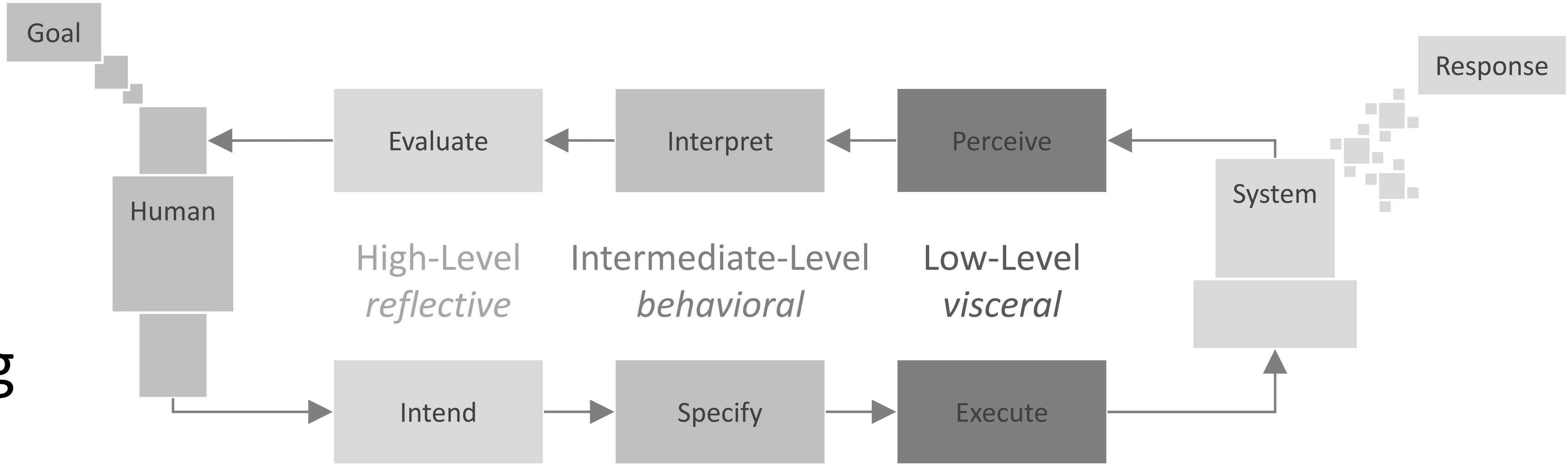
Interactive Visual Data Analysis as a Loop

- T explained in data state reference model (Chi, 2000)



Adapted from Chi, 2000

- P and E explained in Norman's stages of action and levels of processing (Norman, 1988)



Adapted from Norman, 2013

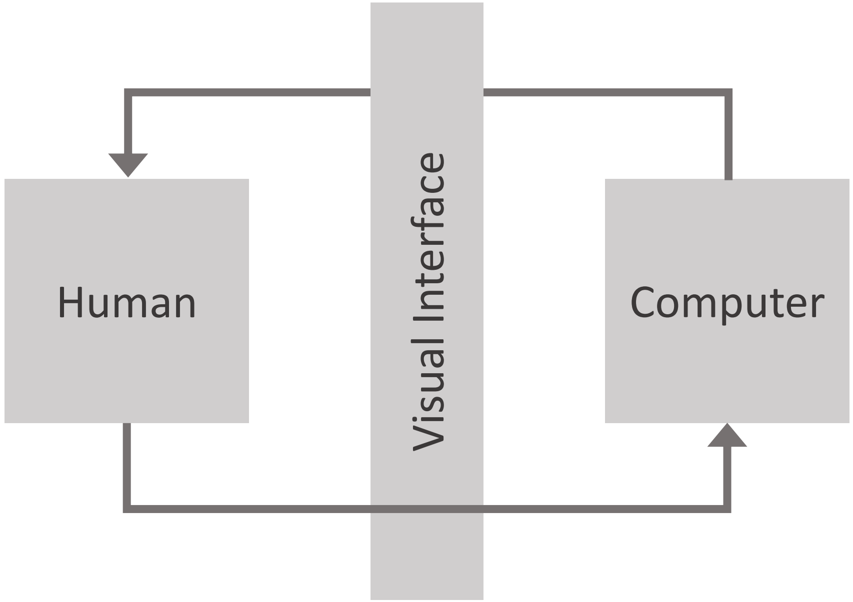
Directness of Human Control

Visual analytics loop requires **high degree of directness**

- Direct manipulation (Hutchins et al., 1985)
- Fluid interaction (Elmqvist et al., 2011)

Threats to directness

- Spatial separation
- Temporal separation
- Conceptual separation



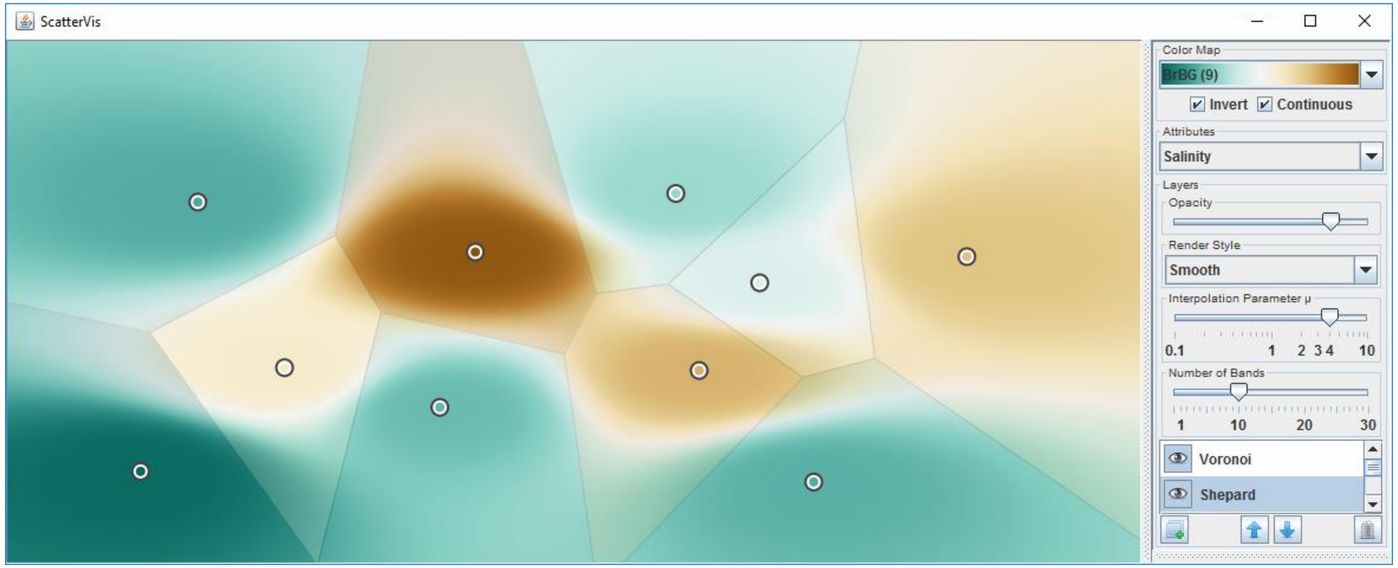
Threats to Directness

Spatial separation

- Control and effect in different places

Temporal separation

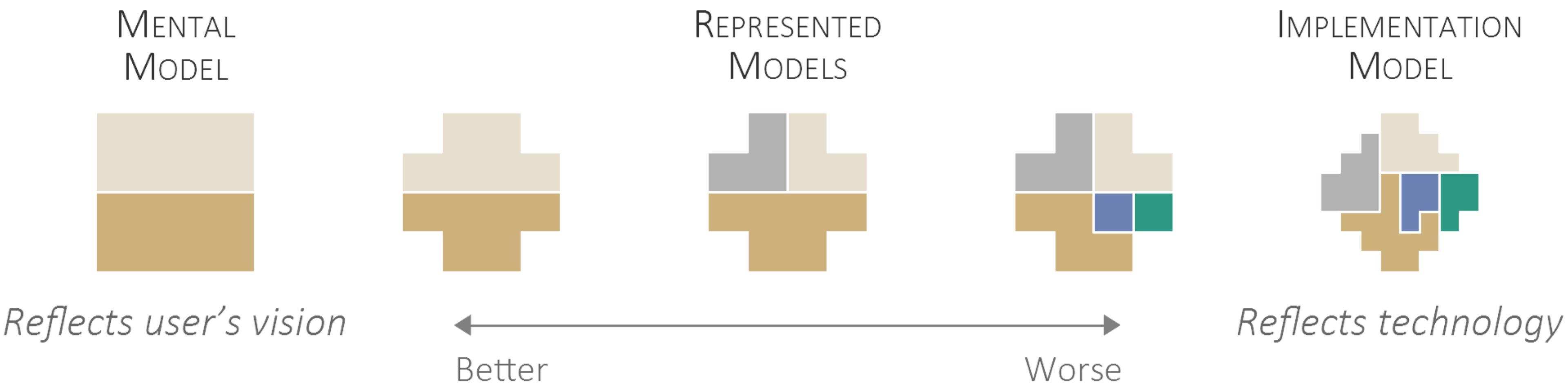
- Latency between action and effect



Threats to Directness

Conceptual separation

- Discrepancy between user's vision and technology (Cooper et al., 2007)

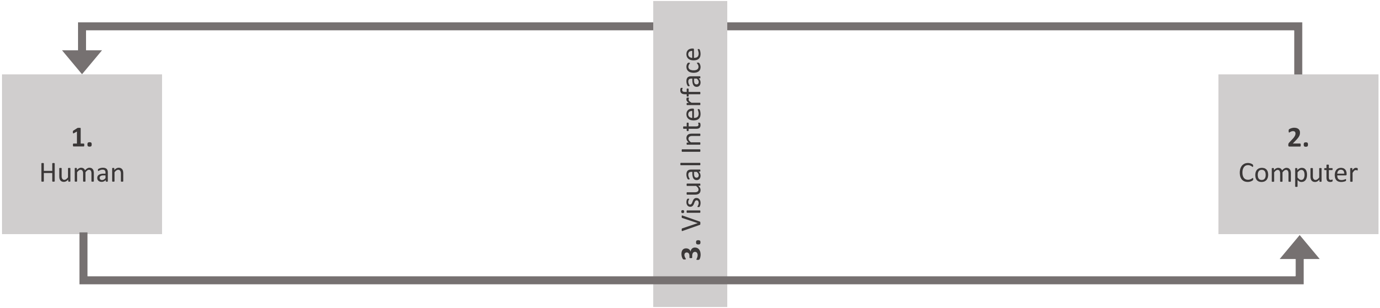


Adapted from Cooper et al., 2007

Outline

Goal: Reduce spatial, temporal, and conceptual separation to **empower the human in the loop**

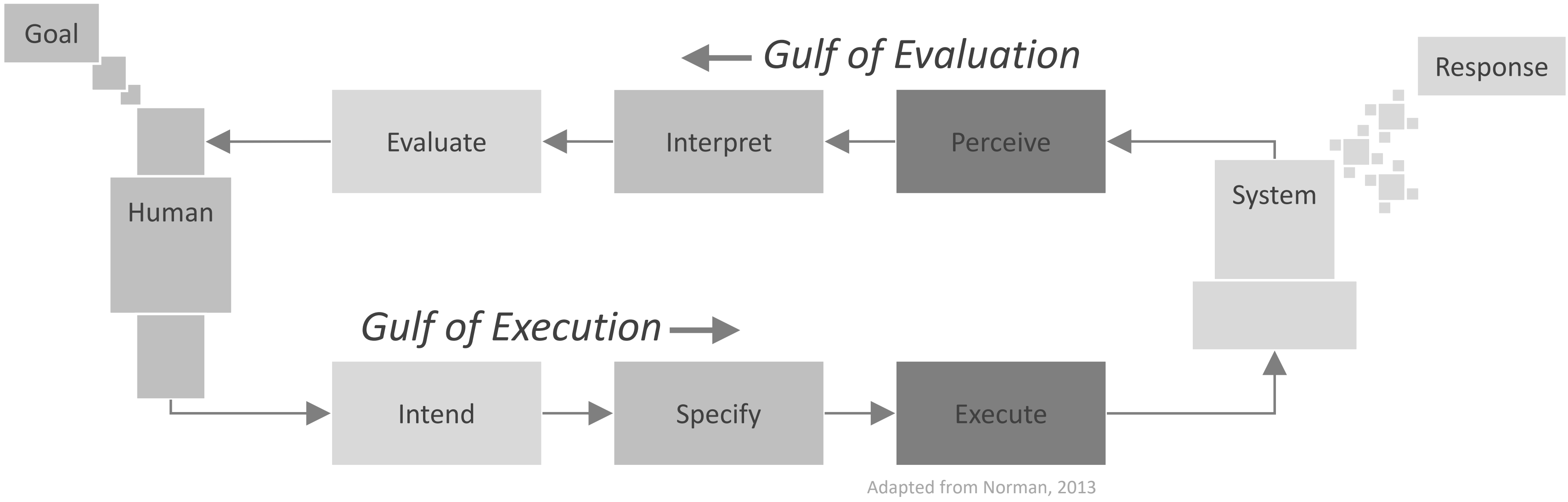
1. **In-situ interaction:** Shorten distances for flexible information access
2. **Progressive computation:** Reduce latency and improve control
3. **Guidance:** Overcome conceptual hurdles to keep analysis going



Interaction for Visual Analytics

Why consider reducing spatial separation?

- Interaction costs due to **Gulfs of Execution and Evaluation** (Lam, 2008)



Interaction for Visual Analytics

Standard approach: Basic VA graphical user interface

- **Usually spatially separated, often heavyweight, sometimes costly**
    - Interaction and effect not in same place
    - Global and permanent effect
    - Difficult to perform and understand

In-situ Interaction for Visual Analytics

In-situ approach inspired by direct manipulation (Hutchins et al., 1985) and fluid interaction (Elmqvist et al., 2011)

- **Integrated, lightweight, efficient**
  - Interaction and effect in same place
  - Local and transient effect
  - Interaction costs reduced

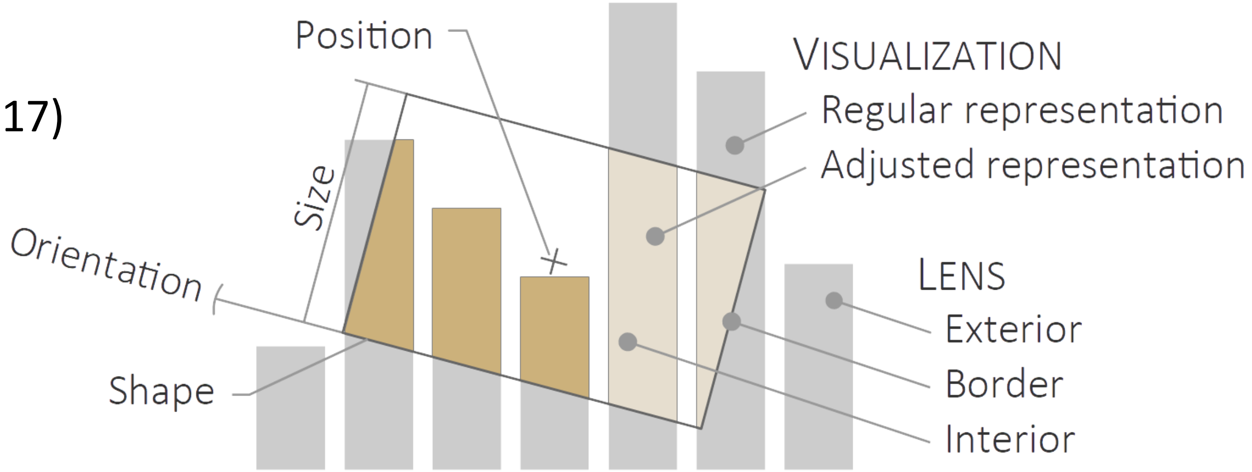
Examples

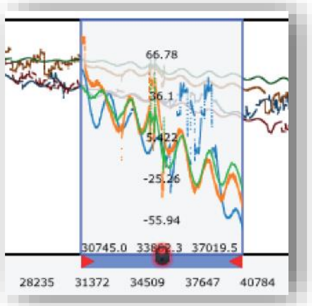
- Lenses for graph exploration
- Interaction for visual comparison

In-situ Interaction with Lenses

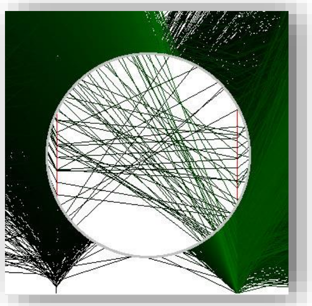
Interactive lenses (Tominski et al., 2017)

- Model
  - Select
  - Lens function
  - Join
- Effects
  - Alteration
  - Suppression
  - Enrichment

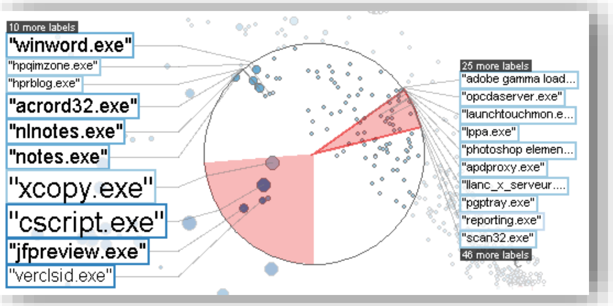




ChronoLenses, Zhao et al., 2011 (alteration)



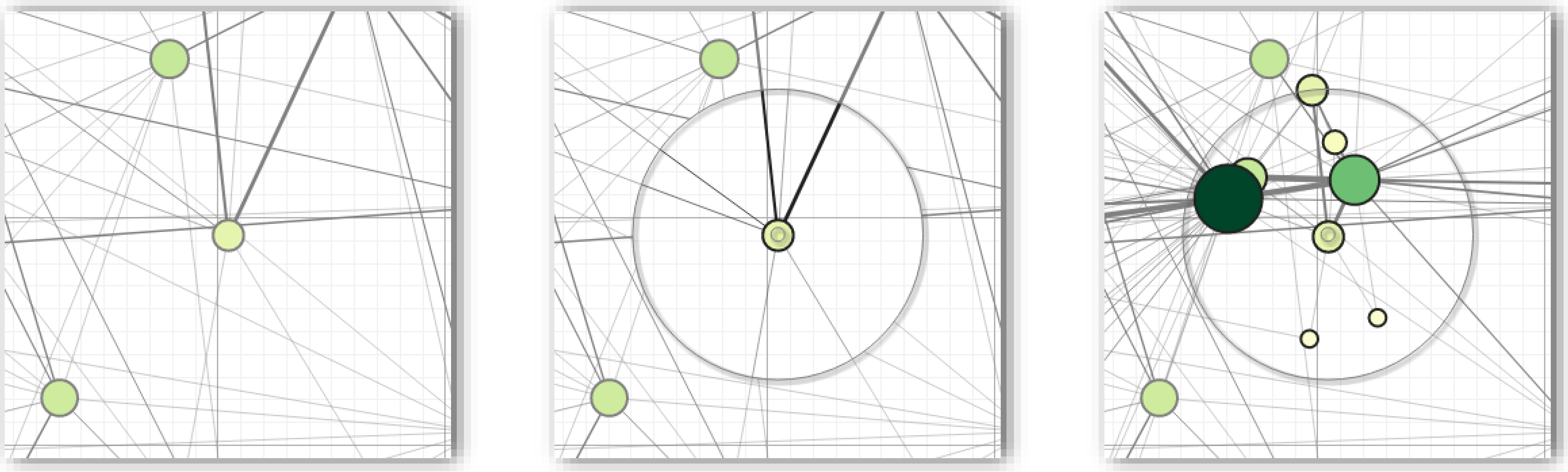
Sampling Lens, Ellis & Dix, 2006 (suppression)



Extended Excentric Labeling, Bertini et al., 2009 (enrichment)

In-situ Interaction with Lenses

Graph Lenses (Tominski et al., 2009)



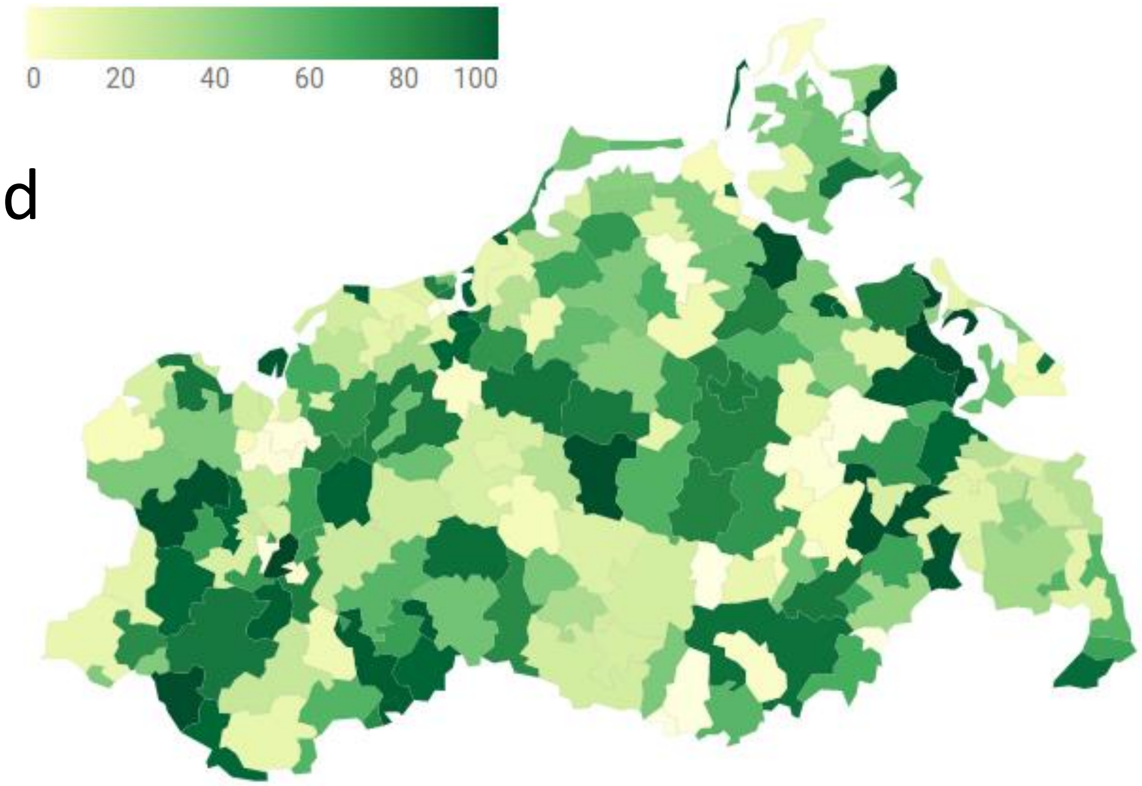
https://tinyurl.com/GraphLenses

In-situ Interaction for Visual Comparison

Visual Comparison

1. Select objects to be compared
2. Carry out visual comparison
3. Understand data in context

How to support these steps with in-situ interaction?



In-situ Interaction for Visual Comparison

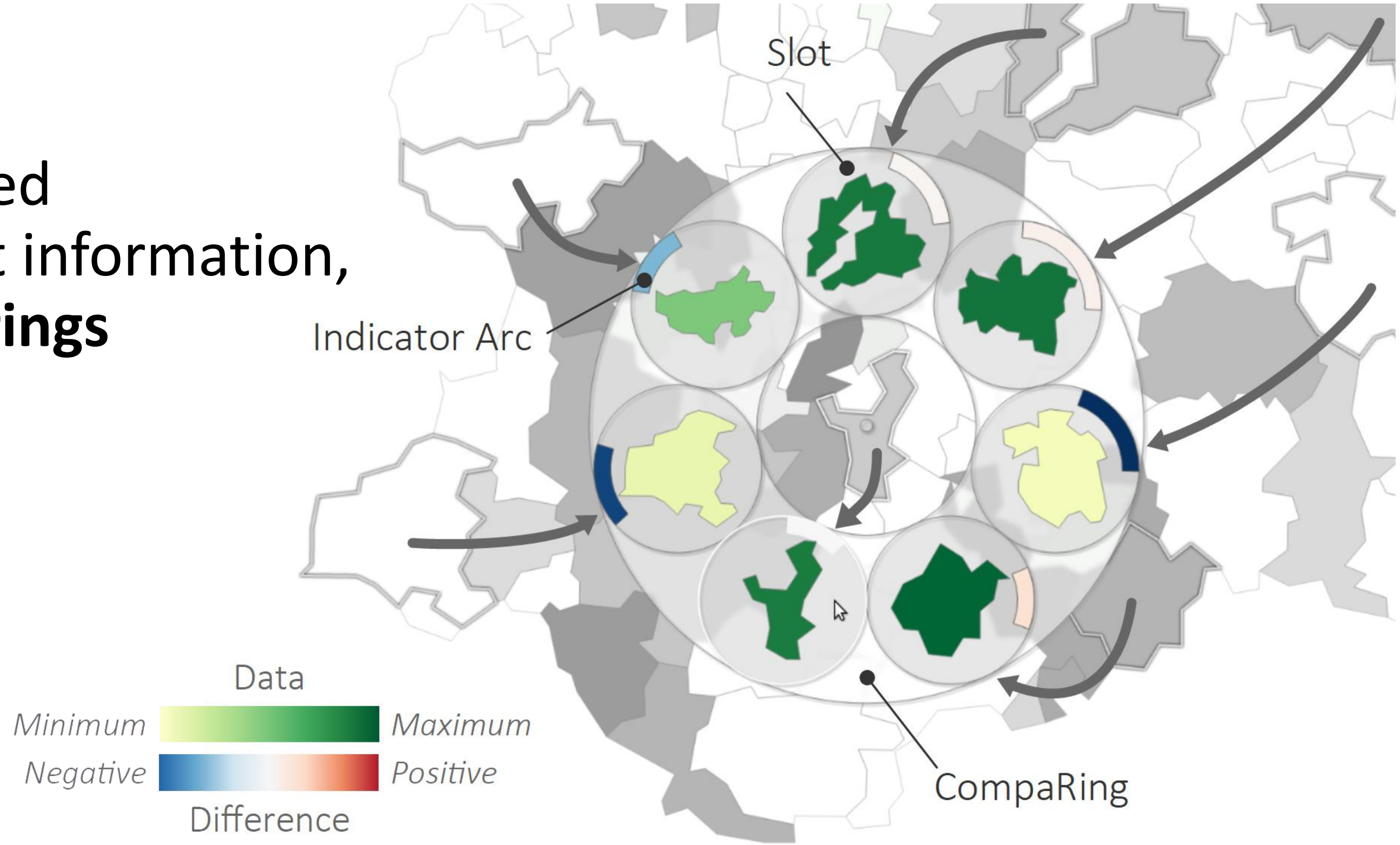
Visual Comparison with the **CompaRing** (Tominski, 2016)

Combine interactive and automatic means:

- Dynamic rearrangement of data objects to be compared
- Semi-automatic selection of comparison candidates
- Navigation shortcuts for studying data in context

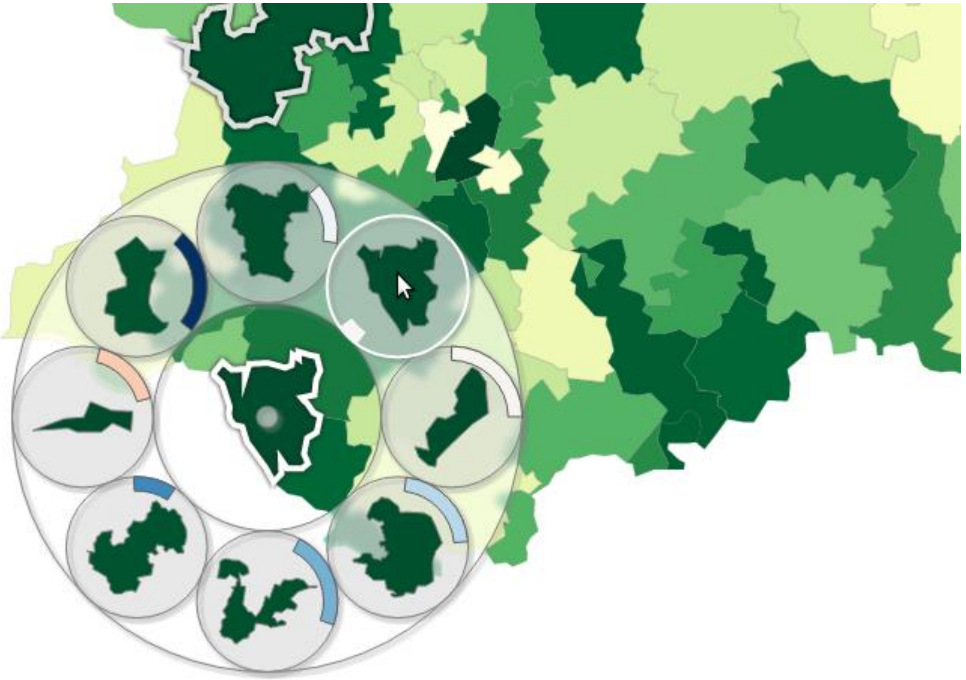
In-situ Interaction for Visual Comparison

The user does not need
to collect the relevant information,
instead the **system brings**
the information
to the user!



In-situ Interaction for Visual Comparison

- Demo: Visual comparison with CompaRing



https://tinyurl.com/CompaRingDemo

In-situ Interaction

- **Empowering the Human**
  - Flexible access to information directly where it is needed
- **Future Work**
  - In-situ interaction across views and devices
  - Conflict-free integration of several interaction modalities
  - In-depth cost analysis of in-situ interaction
  - Toolkit support
  - …

Outline

Goal: Reduce spatial, temporal, and conceptual separation to **empower the human in the loop**

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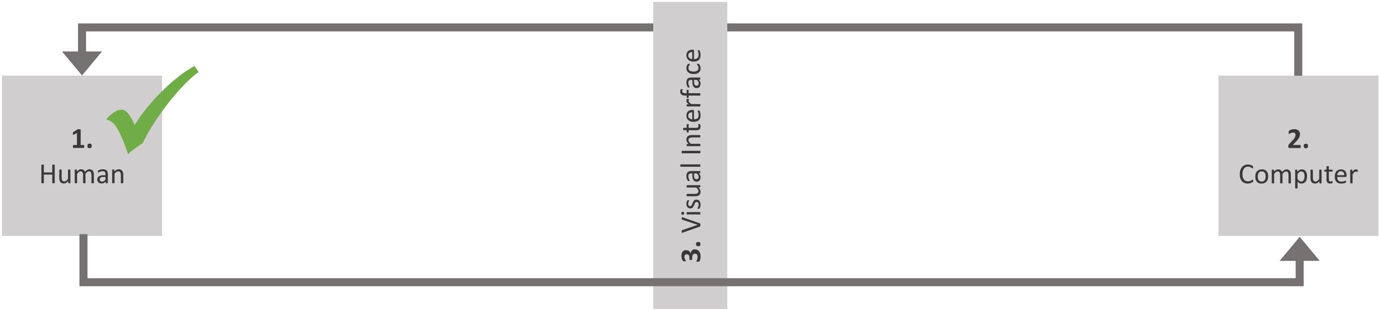


Computation for Visual Analytics

Why consider reducing temporal separation?

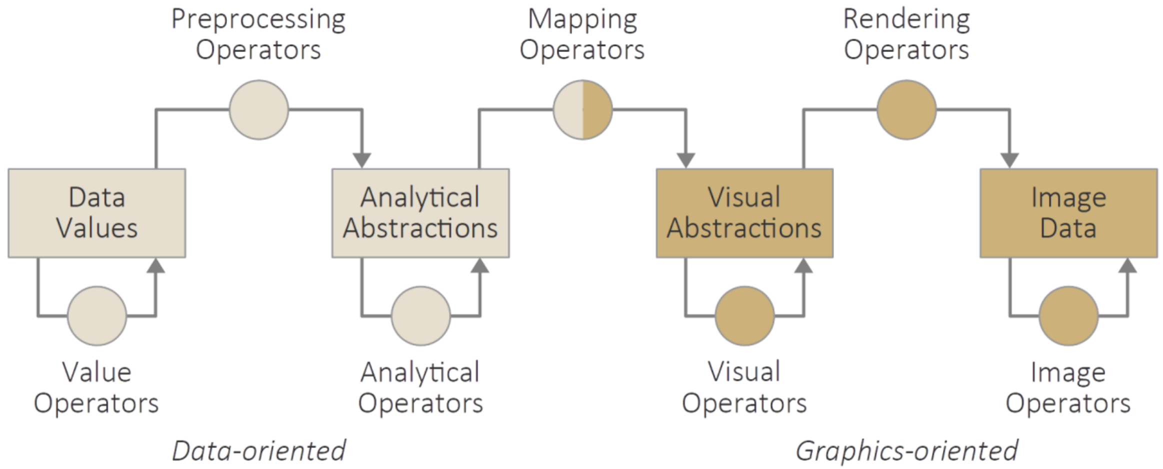
- Delays disrupt the analysis loop (Liu & Heer, 2015)
- Users turn away from unresponsive system

> "To be **most effective**, visual analytics tools must support the **fluent and flexible** use of visualizations at rates resonant with the **pace of human thought**.
>
> — Heer & Shneiderman, 2012

Computation for Visual Analytics

Standard approach: Monolithic operators process entire data

- Latency adversely effects visual data analysis
- No insight into black-box operators
- Limited control due to monolithic design



Adapted from Chi, 2000

Progressive Computation

Progressive approach (Stolper et al., 2014, Schulz et al., 2016, Turkay et al., 2017, Fekete et al., 2018)

- Generate **partial results** of increasing completeness and correctness
- Basic steps
  - Subdivide computations
  - Subdivide data
- Key advantages
  - **Responsiveness** of the system
  - **Transparency** of the involved calculations
  - **Control** of the visual data analysis

Progressive Computation

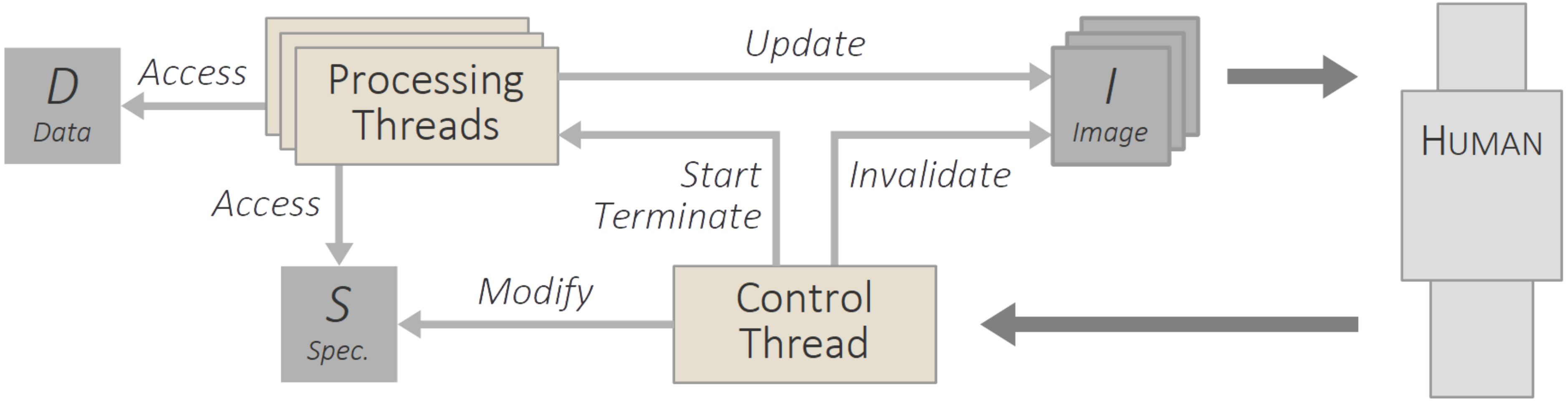
Progressive approach

> "Especially for **large datasets**, supporting **real-time interactivity** requires careful attention to **system design** and poses important research **challenges** ranging from low-latency architectures to intelligent sampling and aggregation methods.
>
> — Heer & Shneiderman, 2012

Progressive Computation

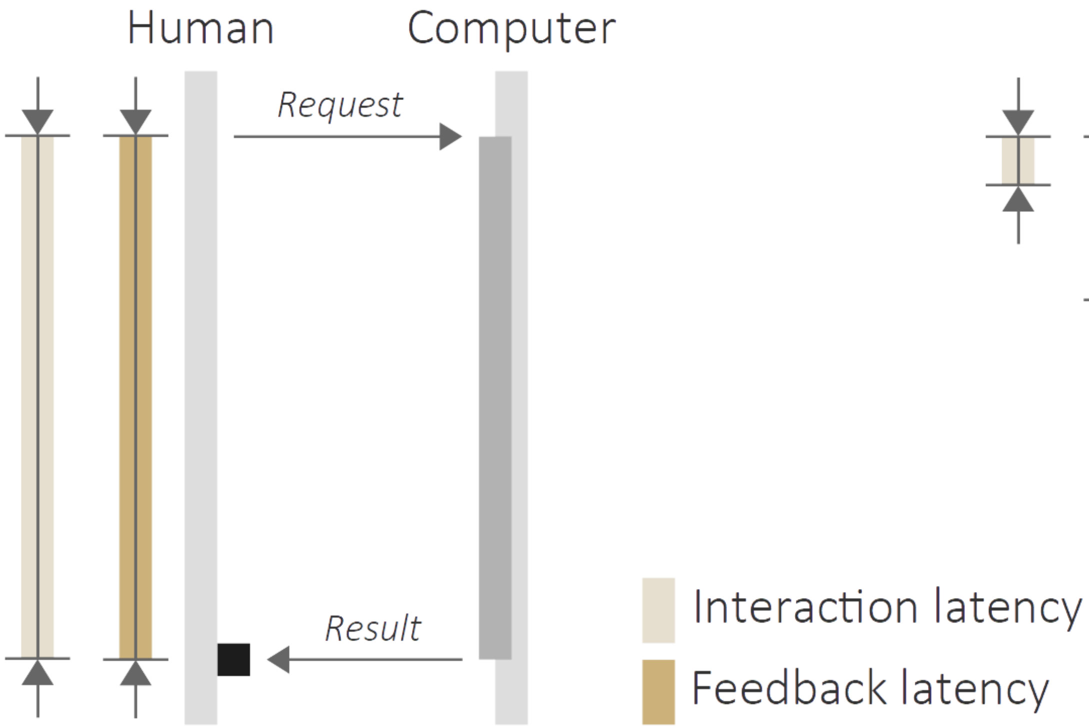
Multi-threading architecture (Piringer et al., 2009)

- Utilize control thread and multiple compute threads
- Early thread termination
- Visualization layers (incremental, semantic, LoD)

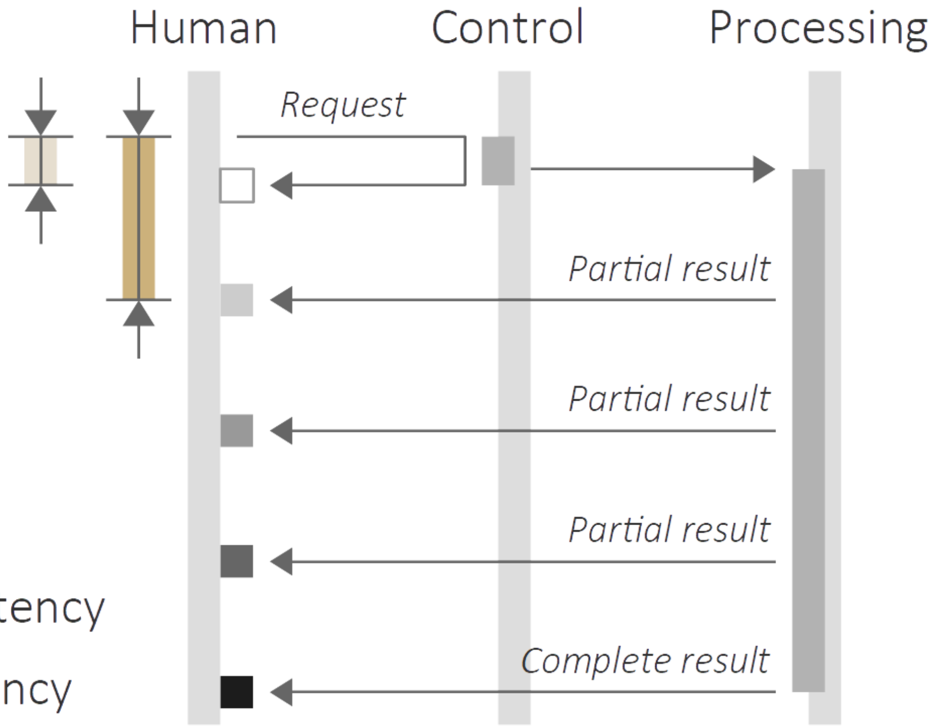


Benefits of Progressive Computation

- Standard approach

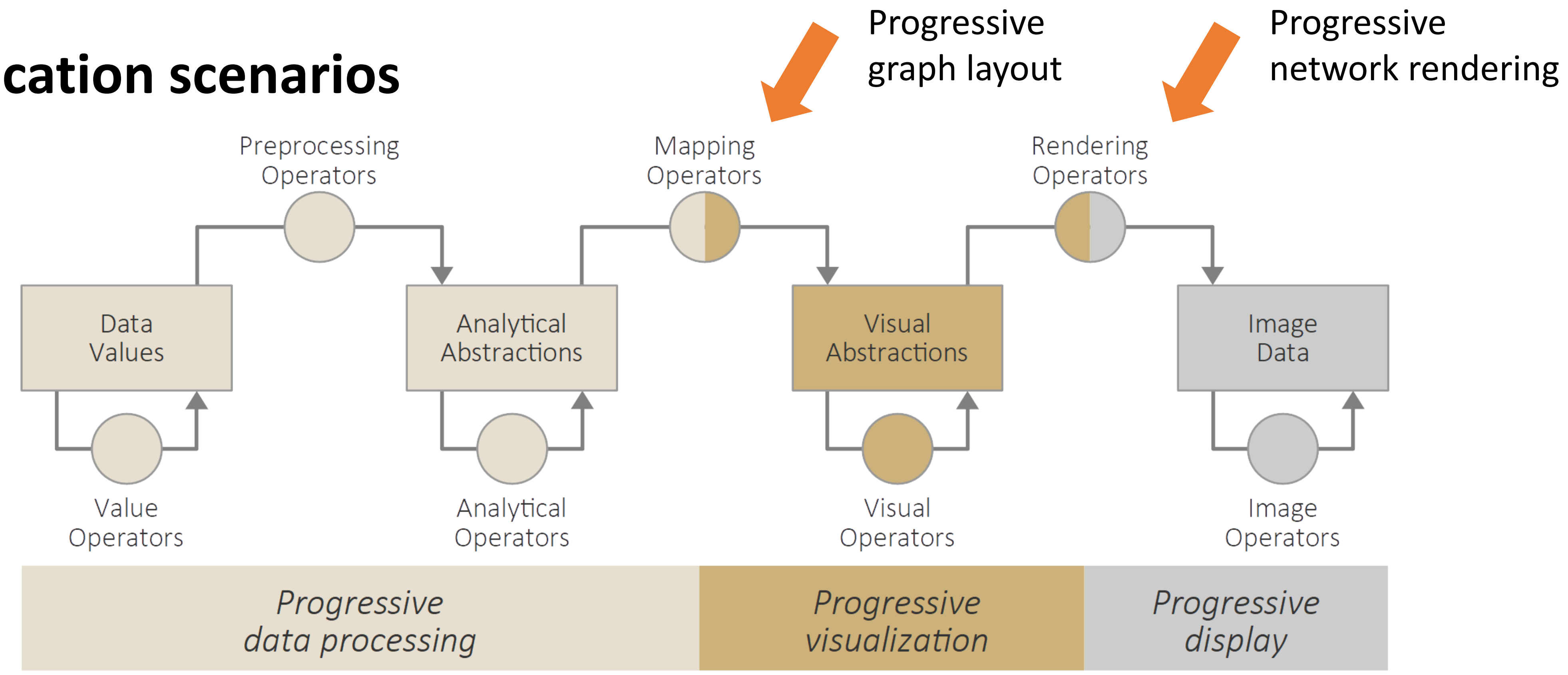


- **Progressive approach**

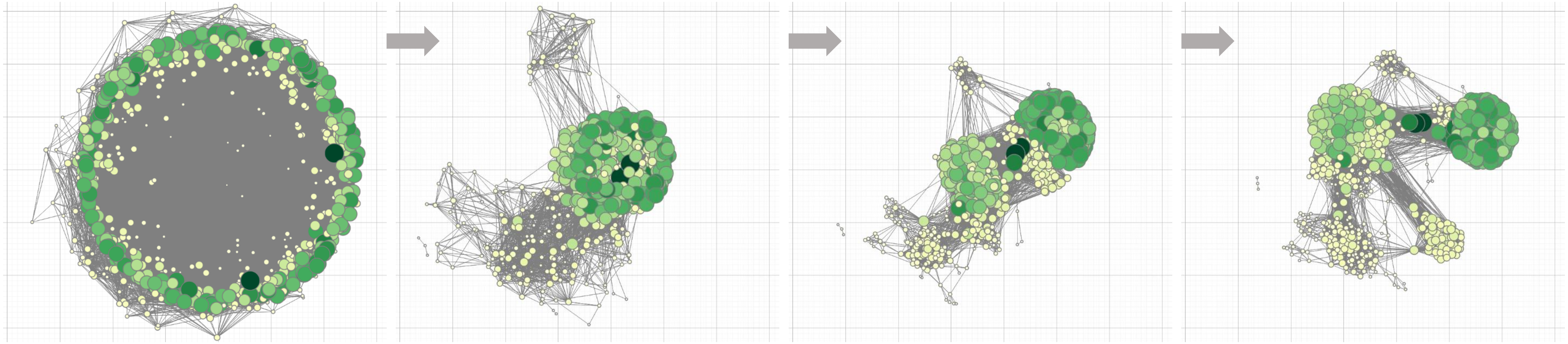


Applications of Progressive Computations

- **Application scenarios**



Progressive Graph Layout

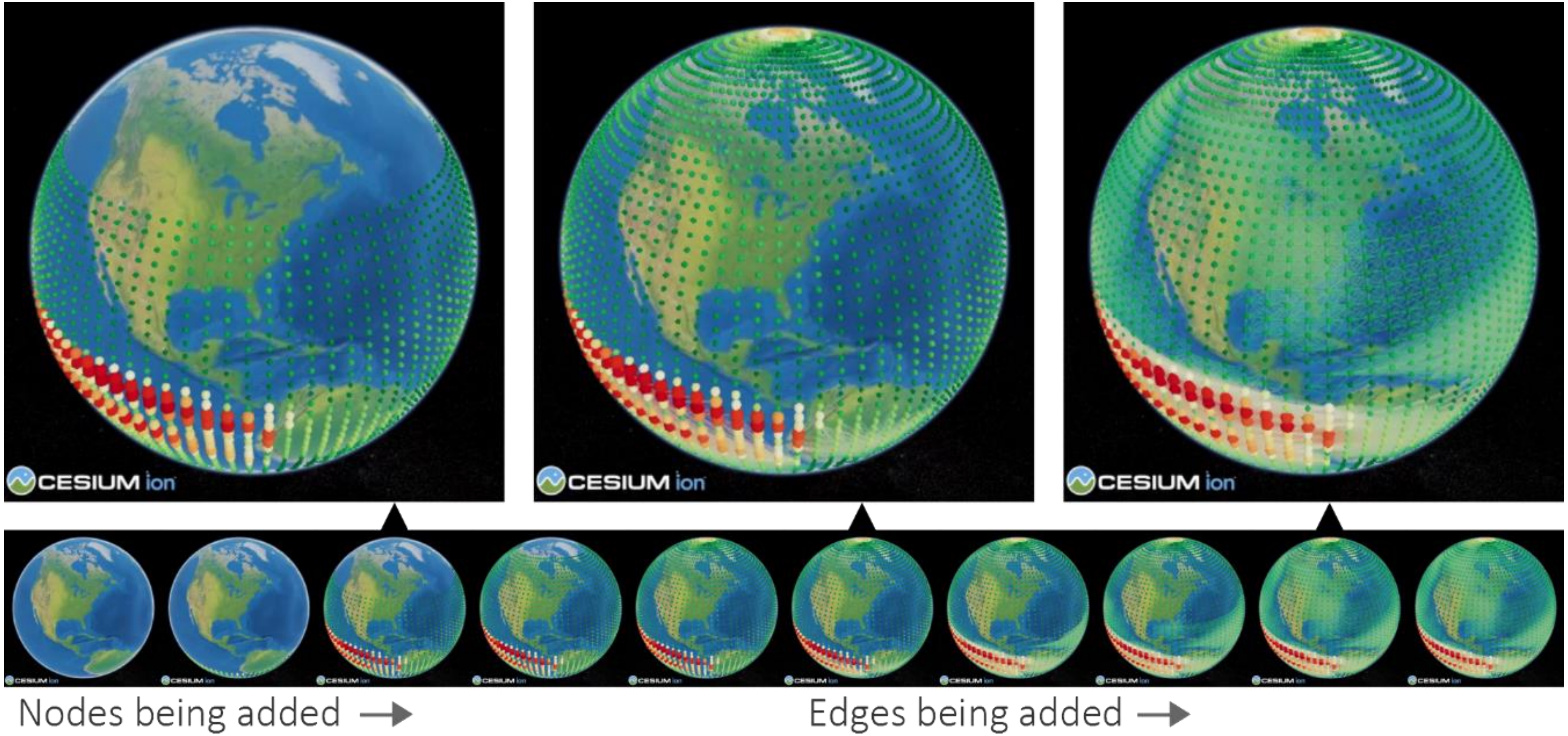


- Social network with 747 nodes and 60,050 edges
- Refine layout with increasingly accurate positions

Progressive Network Rendering

- Climate network
  with 6,816 nodes and
  232,940 edges
- Globe with nodes as
  3D spheres and edges as
  curved 3D lines
- Combined semantic
  and incremental chunking

Progressive Network Rendering



Progressive Computations

- **Empowering the Human**
  - Timely visual feedback and better control and insight into computations
- **Future Work**
  - Compile time
    - Guidelines and strategies for chunking data and subdividing processing best
    - Utilize new capabilities of programming languages (co-routines, generators, async, etc.)
  - Run time
    - Methods for determining and communicating the quality of intermediate results
    - Strategies for reacting to user interactions (caching, prefetching, provenance, …)
    - …

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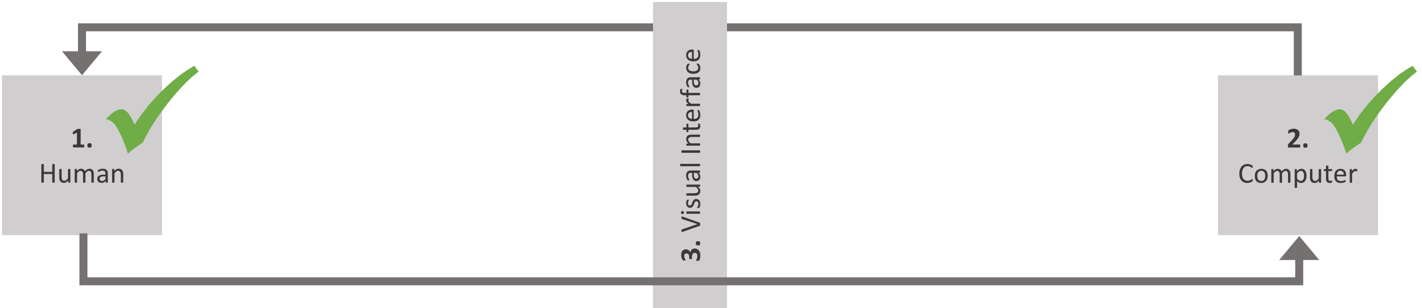


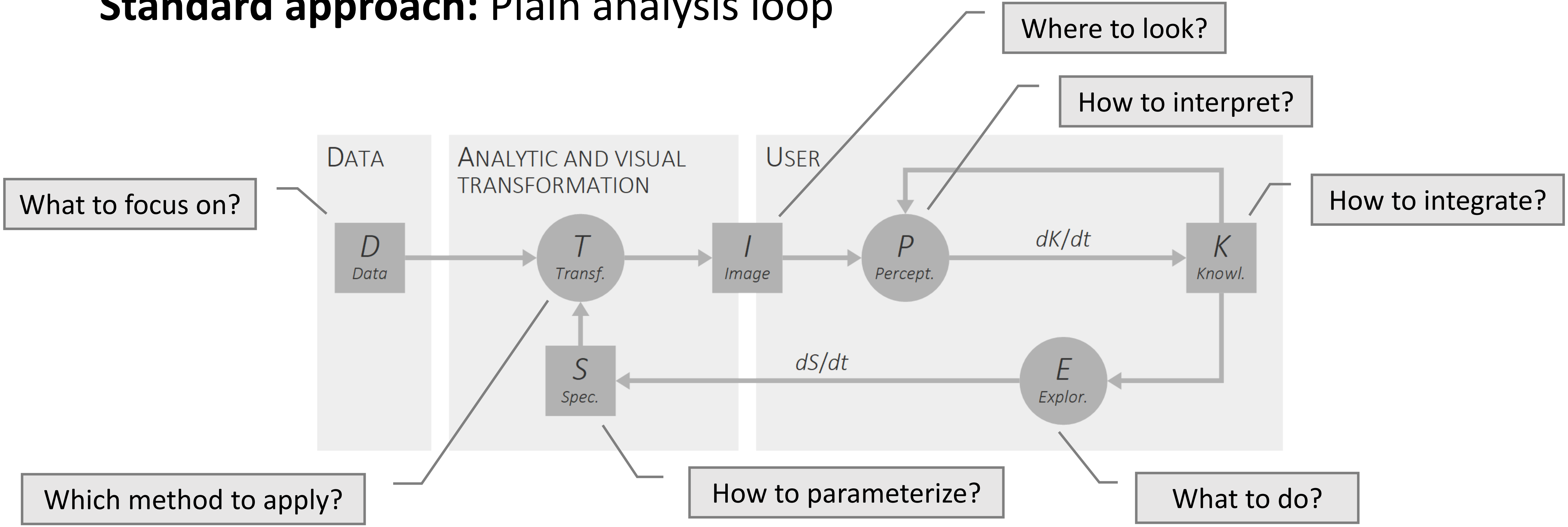
Insight Generation with Visual Analytics

Why consider reducing conceptual separation?

- Complex data and tasks lead to complex workflows and tools
- Users face many potentially non-trivial questions
  - Which algorithm, which view, which parameter value, …
- If questions cannot be answered,
  analysis loop stops and analytic progress is hindered

Insight Generation with Visual Analytics

Standard approach: Plain analysis loop



Insight Generation with Visual Analytics

Guided approach

- Keep the analysis loop going
- Provide support where needed

Adapted from Schulz et al., 2013

- Definition

> “**Guidance** is a computer-assisted **process** that aims to actively resolve a **knowledge gap** encountered by users during an **interactive** visual analytics session.
>
> — Ceneda et al., 2017

Aspects of Guidance

- **Knowledge gap** – Why is guidance needed?
- **Input** – What information can be utilized for providing guidance?
- **Output** – How is guidance conveyed and how does it look like?
- **Degree** – How much help does guidance provide?

Aspects of Guidance

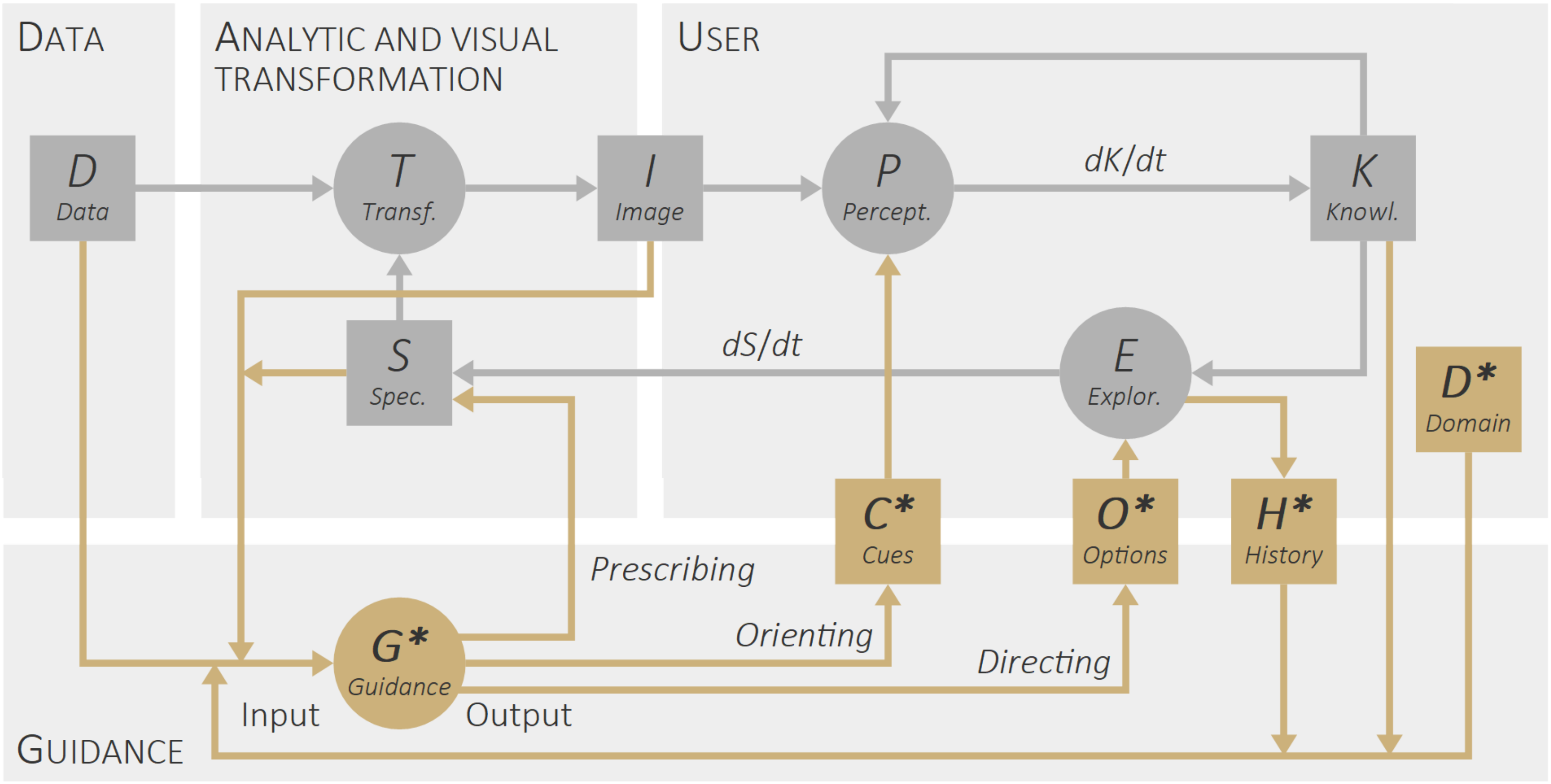
- **Knowledge gap** – Why is guidance needed?
  - Type: Target (what?) and/or path (how to get there?)
  - Domain: Data, tasks, methods, users, infrastructure

- **Input** – What information can be utilized for providing guidance?
  - Information derived from the data
  - Visualization images, parameter specification
  - Domain conventions, user knowledge, data analysis history

Aspects of Guidance

- **Output** – How is guidance conveyed?
  - Visual cues to indicate
  - Options to be selected
  - Automatic specification
- **Degree** – How much help does guidance provide?
  - Low: Orienting
  - Medium: Directing
  - High: Prescribing

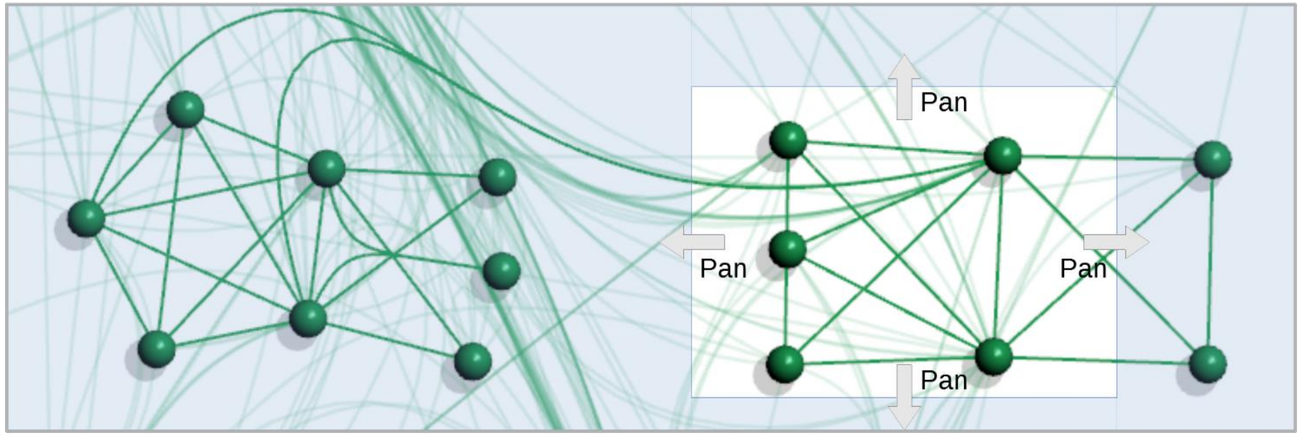
Conceptual Model of Guidance

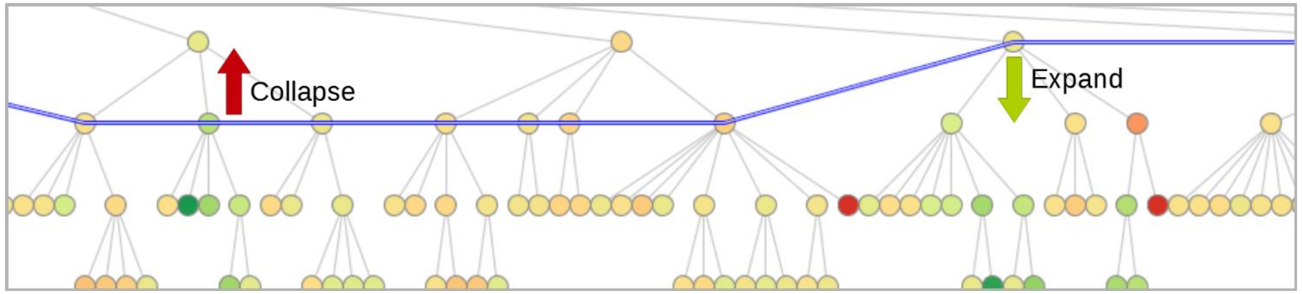


Example of Guidance

Navigation Recommendations for Hierarchical Graphs (Gladisch et al., 2013)

- Data and task
  - Hierarchically clustered graph
  - Navigation
    - Horizontal (pan)
    - Vertical (expand/ collapse nodes)
- Knowledge gap
  - Target: Where to go next?

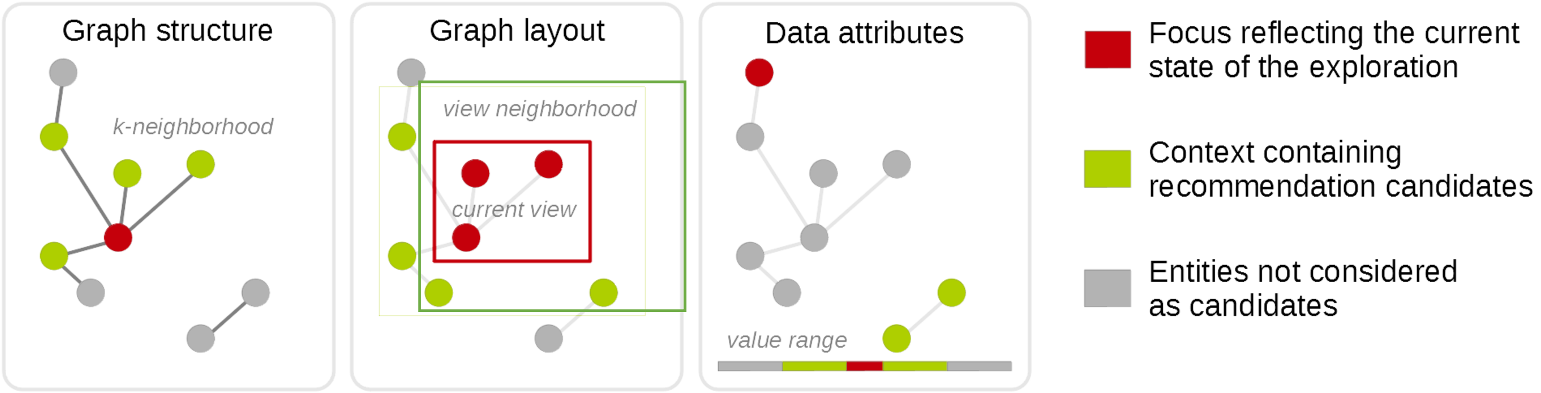




Example of Guidance

Navigation Recommendations for Hierarchical Graphs (Gladisch et al., 2013)

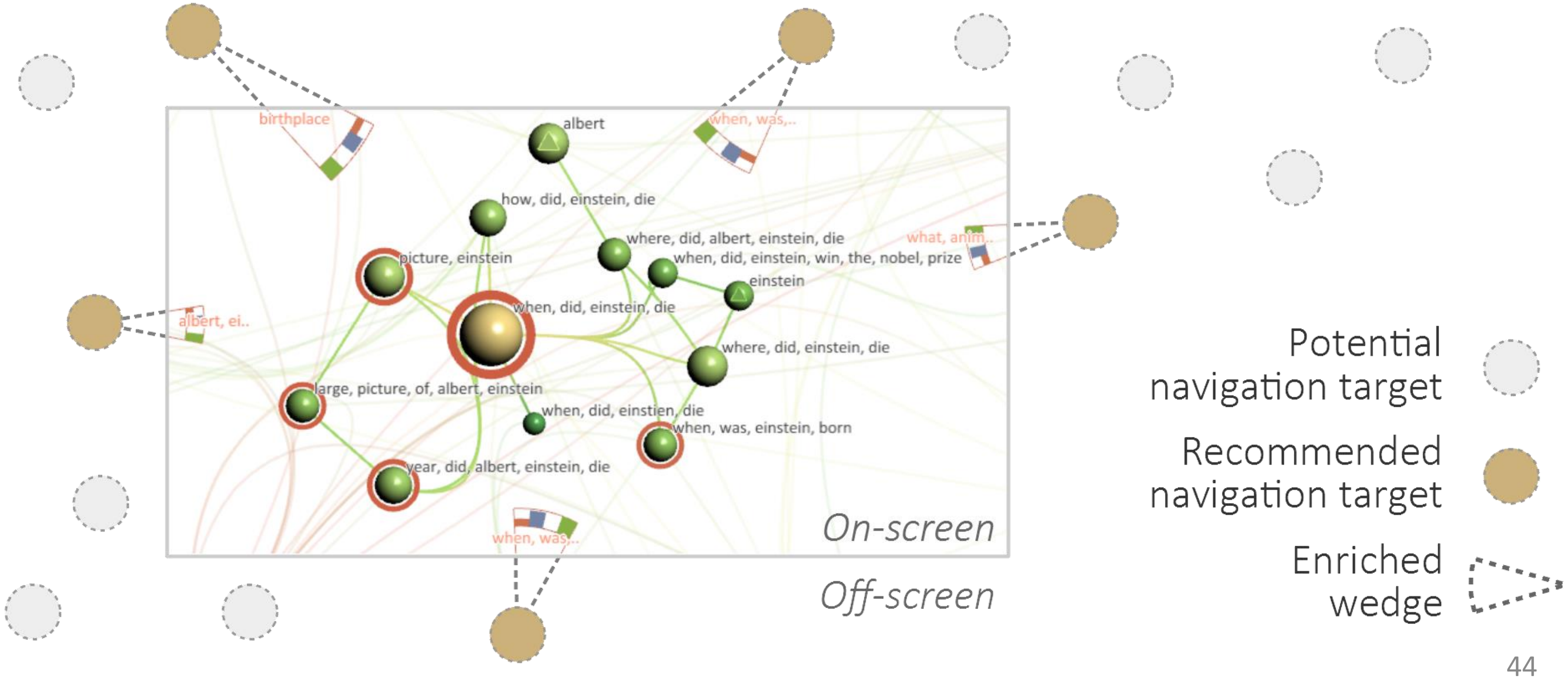
- Guidance input: Data, specification, domain, history, user
  1. Collect recommendation candidates (data)
  2. Rank and select candidates via degree-of-interest (DoI) function
     - Distance to focus (specification)
     - A-priori interest (domain)
     - User interest (user)
     - Visited state (history)



Example of Guidance

Navigation Recommendations for Hierarchical Graphs (Gladisch et al., 2013)

- Guidance output and degree
  - Visual cues indicate potentially interesting navigation targets
    - *Wedges* for horizontal navigation
    - *Pulsing rings* for vertical navigation



Guidance

- **Empowering the Human**
  - Computer-generated assistance to overcome conceptual hurdles
- **Open Questions** (Ceneda et al., 2020)
  - How can the knowledge gap be inferred by the system?
  - How can the knowledge gap be conveyed to the system?
  - When is the right moment to provide guidance?
  - What degree of guidance is appropriate?
  - What are suitable means to guide the user?
  - …

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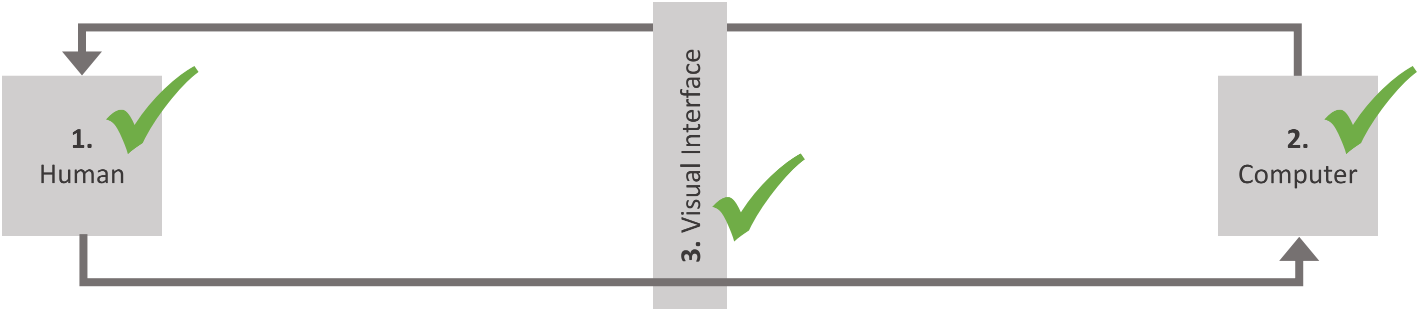


Empowering the Human in the Loop

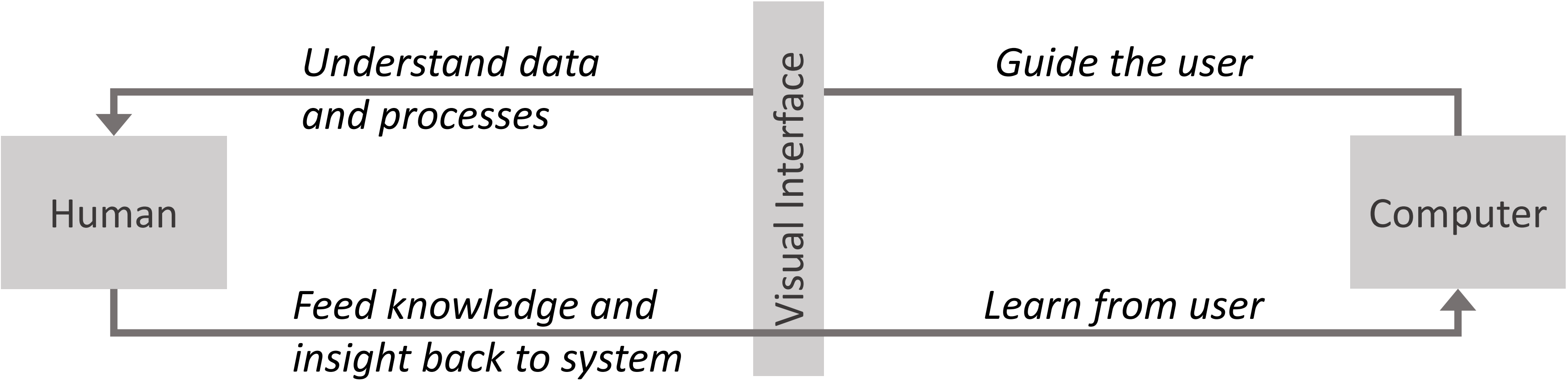
Take-home messages

1. Go beyond standard VA GUI and strive for in-situ interaction
2. Consider progressive computations to reduce latency
3. Think of how to assist users during the analysis process

Empowering the Human in the Loop

What next?

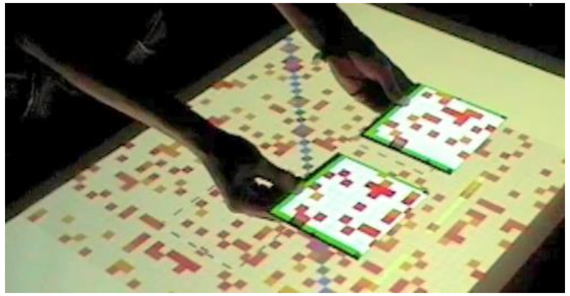
- Foster integration of computation, visualization, and interaction
  - Make algorithms work progressively
  - Design visualization techniques for flexible information access
  - Strive for more natural and direct interaction
  - True **mixed-initiative** visual analytics



Empowering the Human in the Loop

What next?

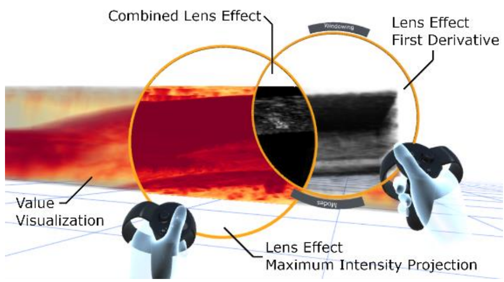
- New visual analytics environments
  - Multiple heterogeneous display environments
  - Multi-modal interaction



Tangible Views,
Spindler et al., 2011

Proxemic interaction,
Lehmann et al., 2011

Multi-display environments,
Eichner et al., 2015

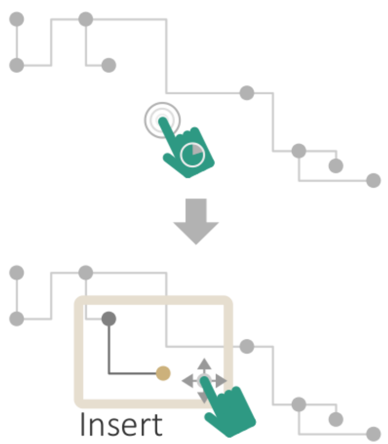


Immersive Lenses,
Kluge et al., 2019

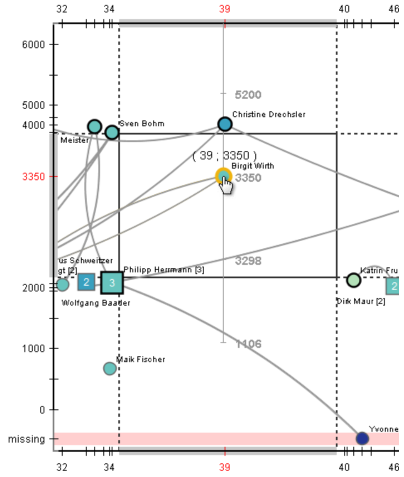
Empowering the Human in the Loop

What next?

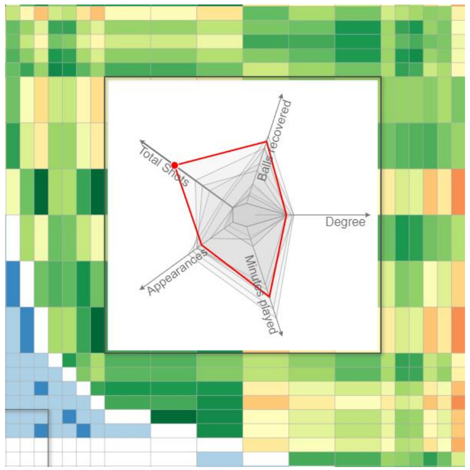
- New tasks
  - From visual **data analysis** to visual **data editing** to visual **data curation**



EditLens for graph editing,
Gladisch et al., 2014

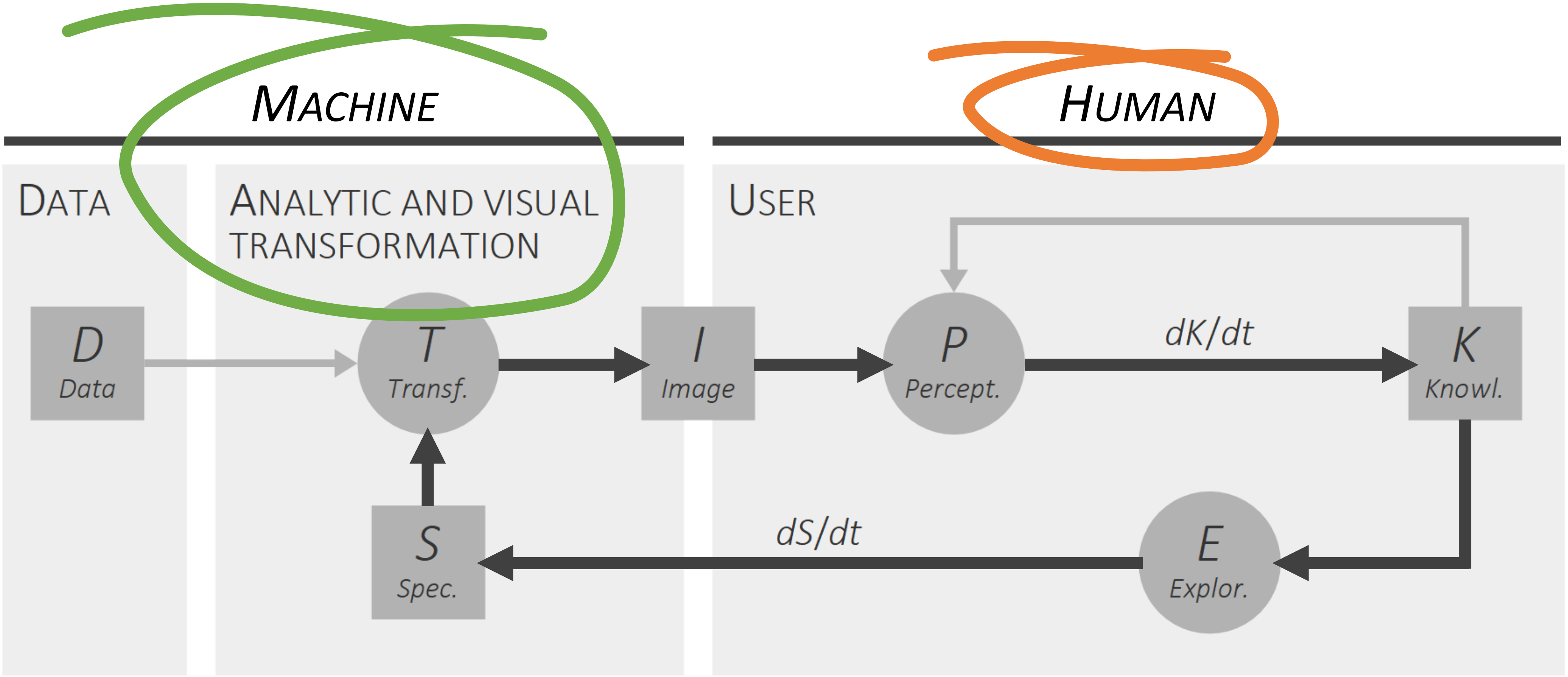


Direct editing of node attributes,
Eichner et al., 2016



Integrated analysis and editing,
Horak et al., hopefully soon

Enjoy EuroVA 2020



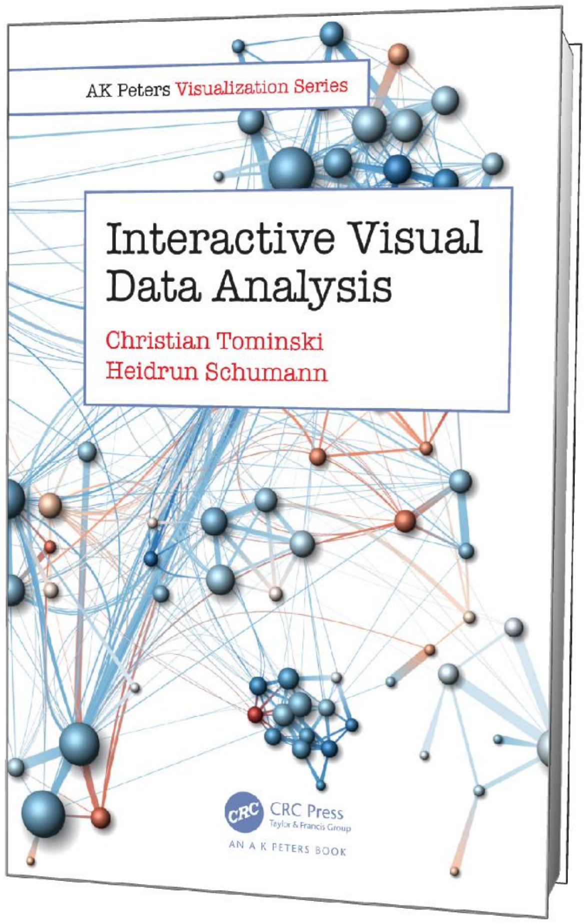
Adapted from van Wijk, 2006

Enjoy EuroVA 2020

Thank you!

- Organizers
- Collaborators
- Audience

- Heidrun “Heidi” Schumann



https://ivda-book.de