Comparative Visualization: Interactive Designs and Algorithms Depending on Data and Tasks

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3. Edinburgh Napier University, UK
4. TU Wien, Austria

The Comparison Problem

Data Characteristics

	Quantitative Data		Qualitative Data	
	Continuous	Discrete	Ordinal	Categorical
Interpolate	✓			
Difference	✓	✓		
Sort	✓	✓	✓	
Match	✓	✓	✓	✓

Task Characteristics

WHY to compare?

WHAT to compare?

HOW to compare?

Comparison Types

1-to-1 comparison

1-to-many comparison

many-to-many comparison

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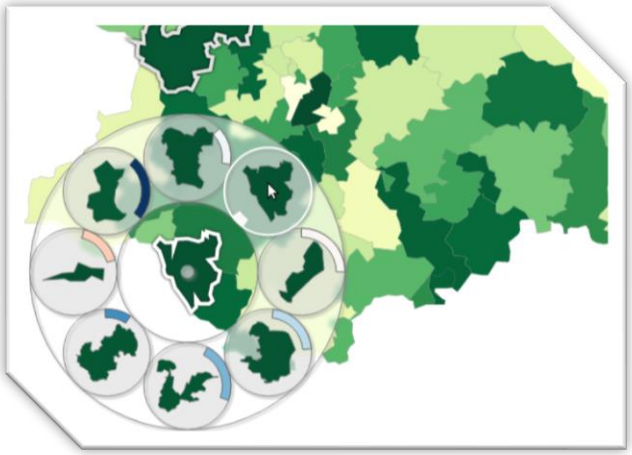
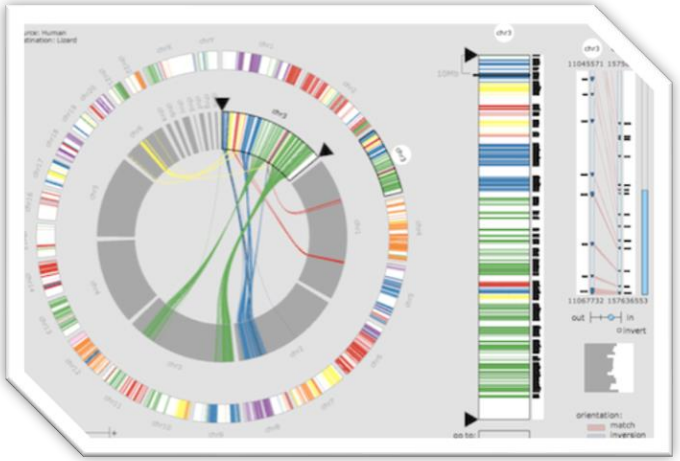
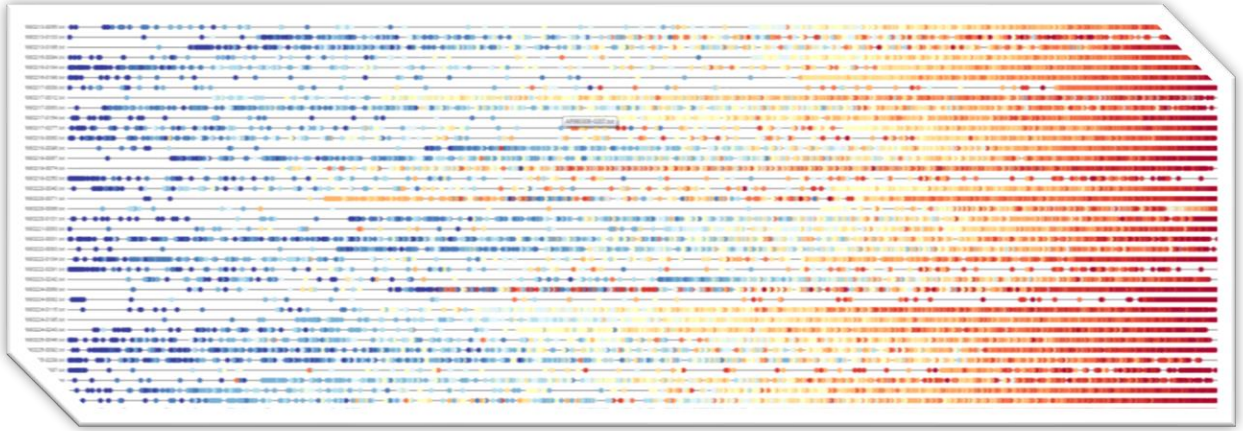
Visual Design & Interaction



CompaRing [Tominski 2016]



MizBee [Meyer et al. 2009]



Buddy Plots [Alexander & Gleicher 2016]

Task Characteristics

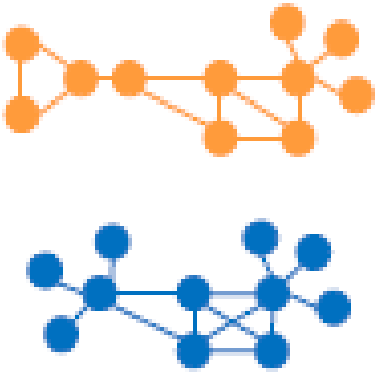
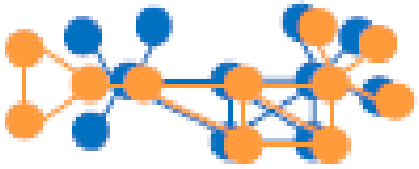
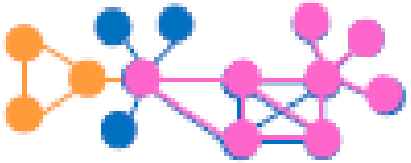
WHY to compare? | WHAT to compare? | **HOW to compare?**

How to compare?

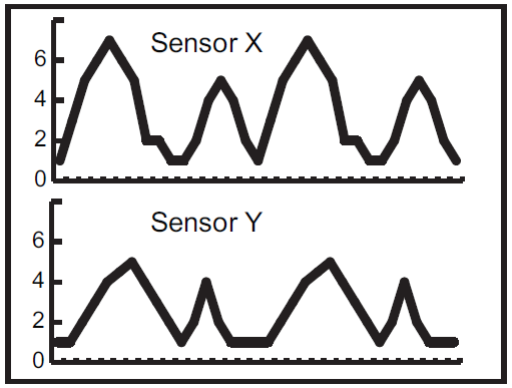
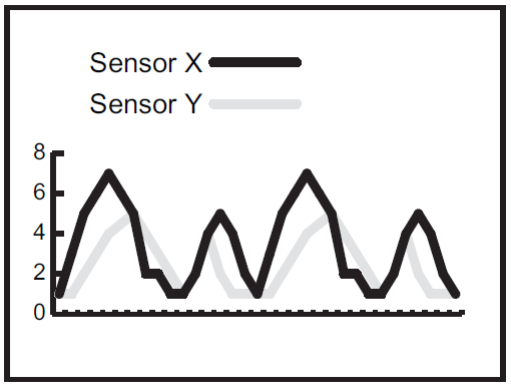
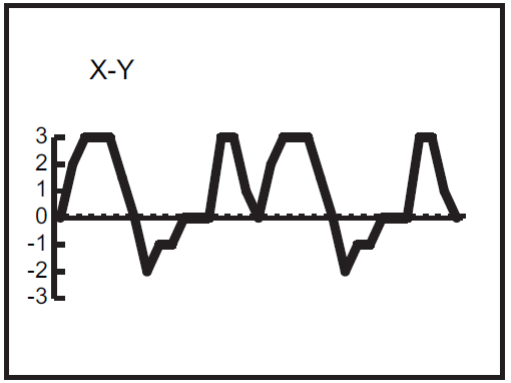
TYPES OF VISUAL COMPARISON

Speaker: Kathrin Ballweg

Basic Comparative Visualization Techniques

Juxtaposition	Superposition	Explicit Encoding
		
J	S	E

Basic Comparative Visualization Techniques: For all data types

Juxtaposition	Superposition	Explicit Encoding
		
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Basic Comparative Visualization Techniques: For all data types

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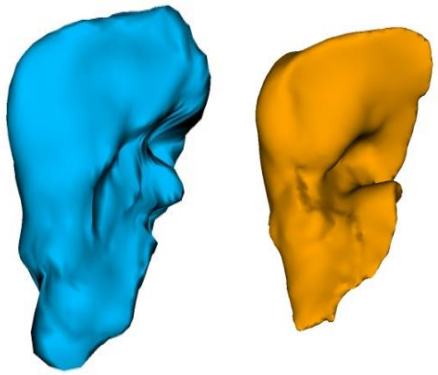	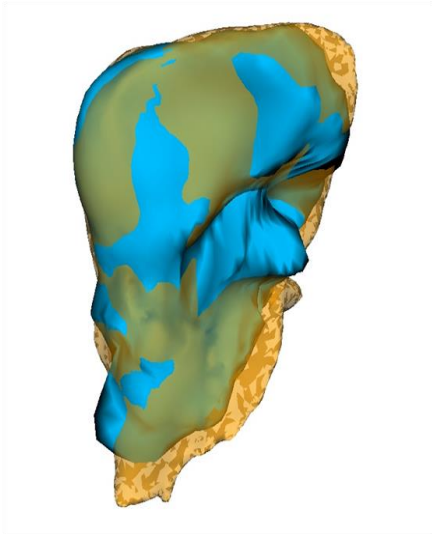	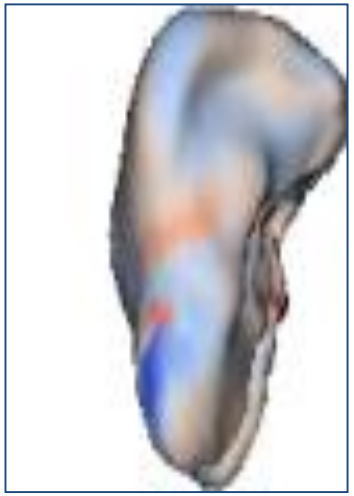
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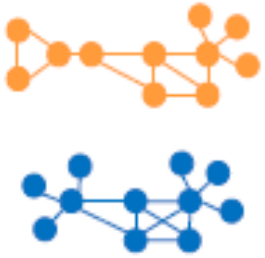
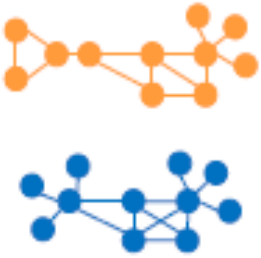


Juxtaposition

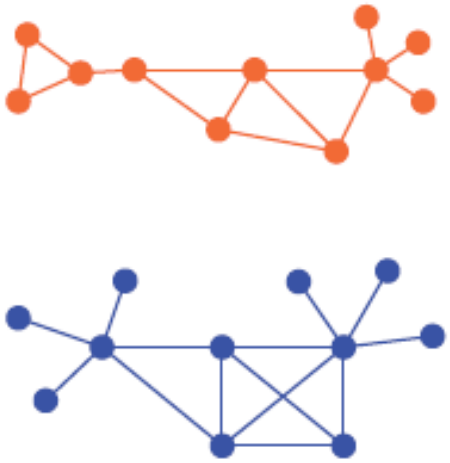
- Shows the items **next to each** other
- Easy to implement
- Requires cognitive effort to compare → Part4

- Requires a lot of space
- Works better if the items have the same layout/„shape“ - correspondence

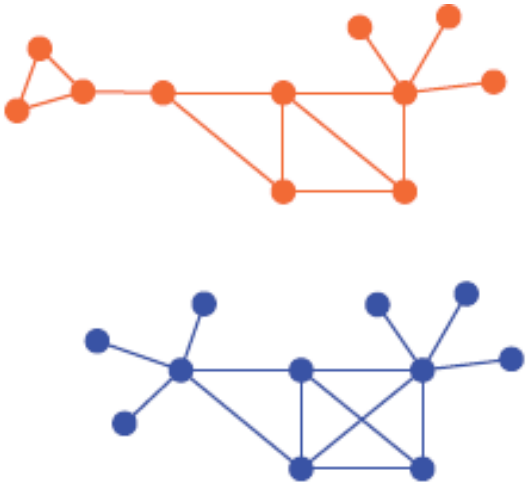
No correspondence attribute (for nodes and edges)	With correspondence attribute (for nodes and edges)
	



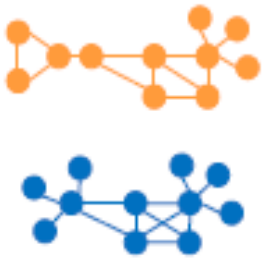
Juxtaposition



(a) Naïve Juxtaposition (each network laid out independently)



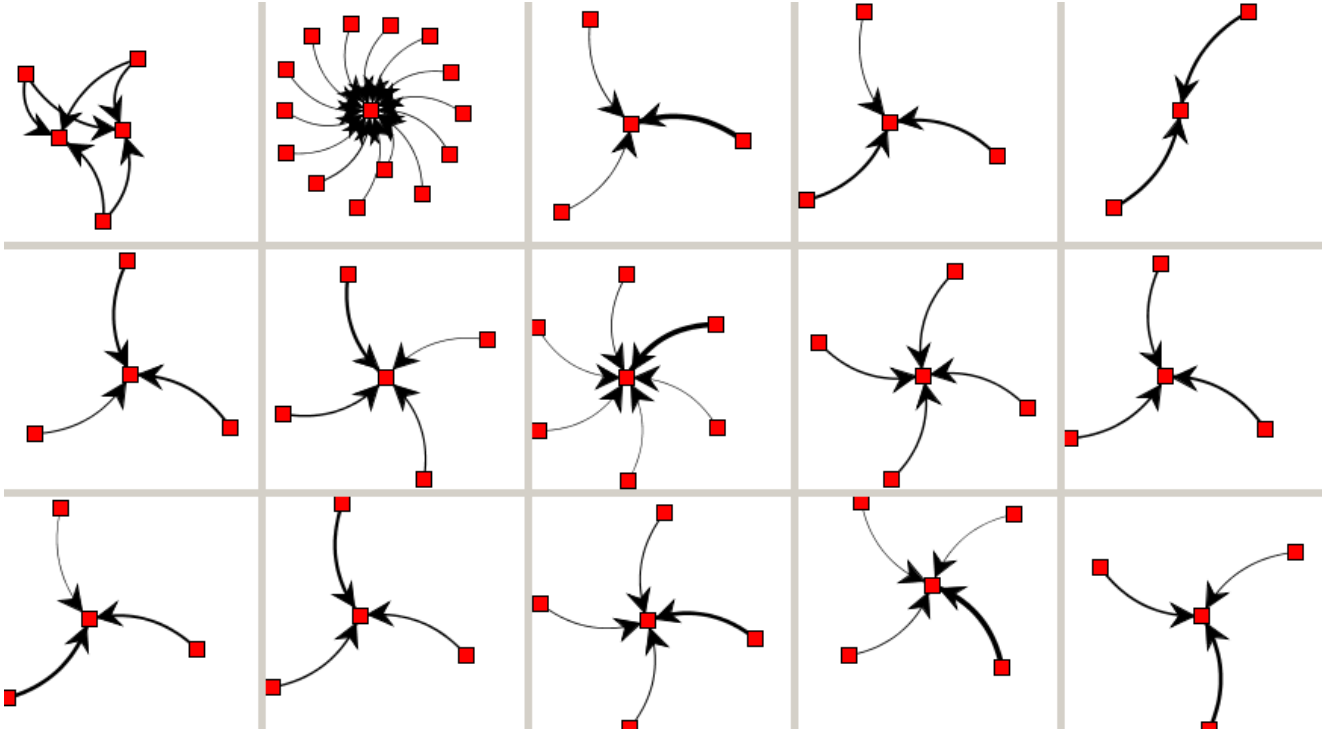
(b) Juxtaposition (using similar layouts to aid comparison)



Juxtaposition: Scalability

Example: Comparison of Company Holdings

Comparing multiple graphs by structure



Source: von Landesberger, VAST 20109

Juxtaposition: Scalability

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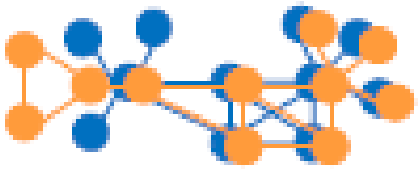
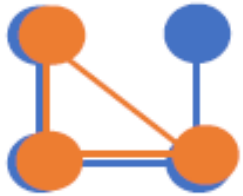
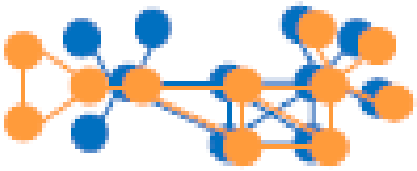


Superposition

- Shows the tems **on TOP of each** other
- Easier to spot differences
- Less space needed

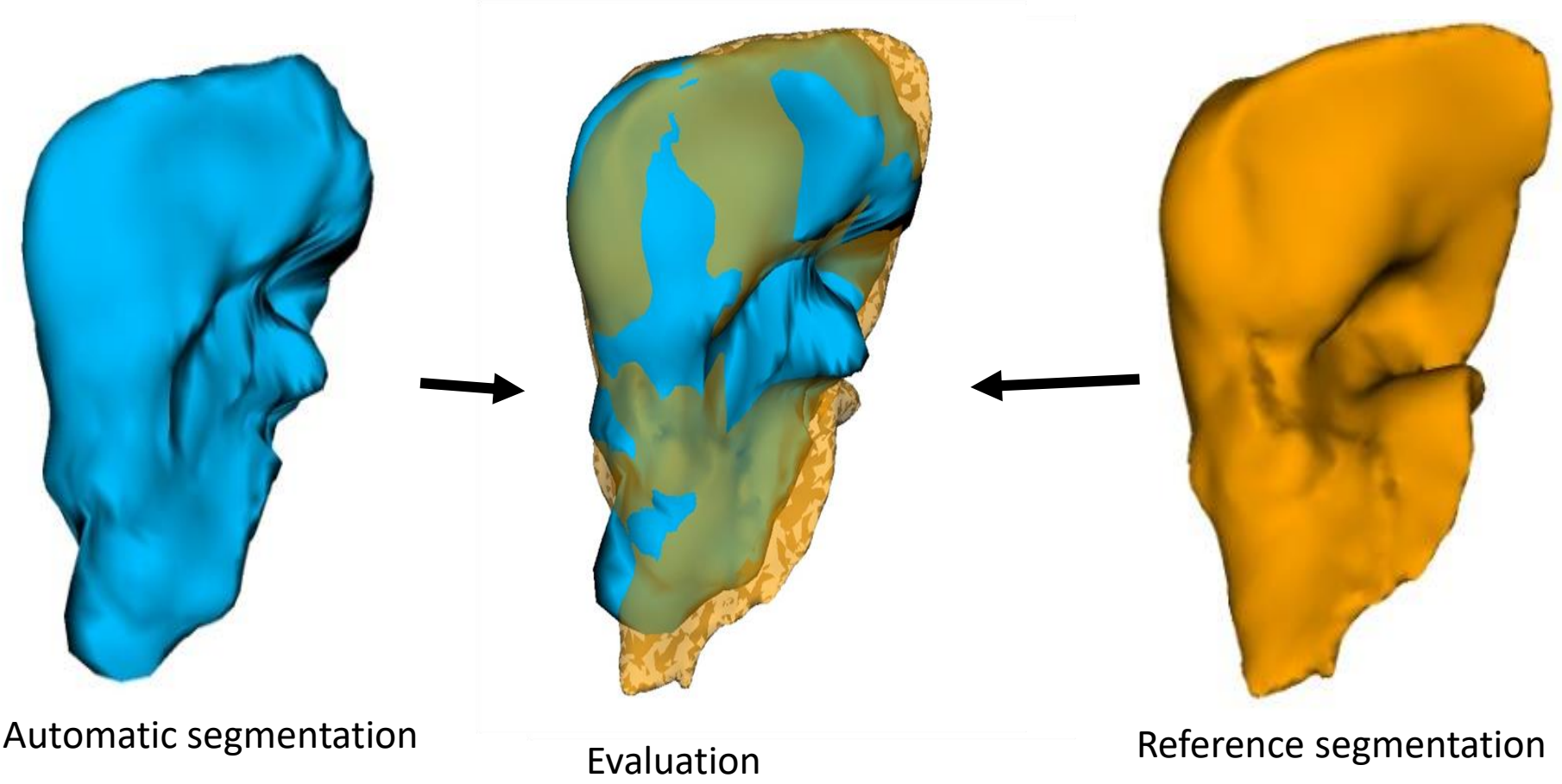
- Requires correspondence
- Depends on what is on top/bottom - overplotting

No correspondence attribute (for nodes and edges)	With correspondence attribute (for nodes and edges)
	



Superposition

Example: 3D medical image segmentation



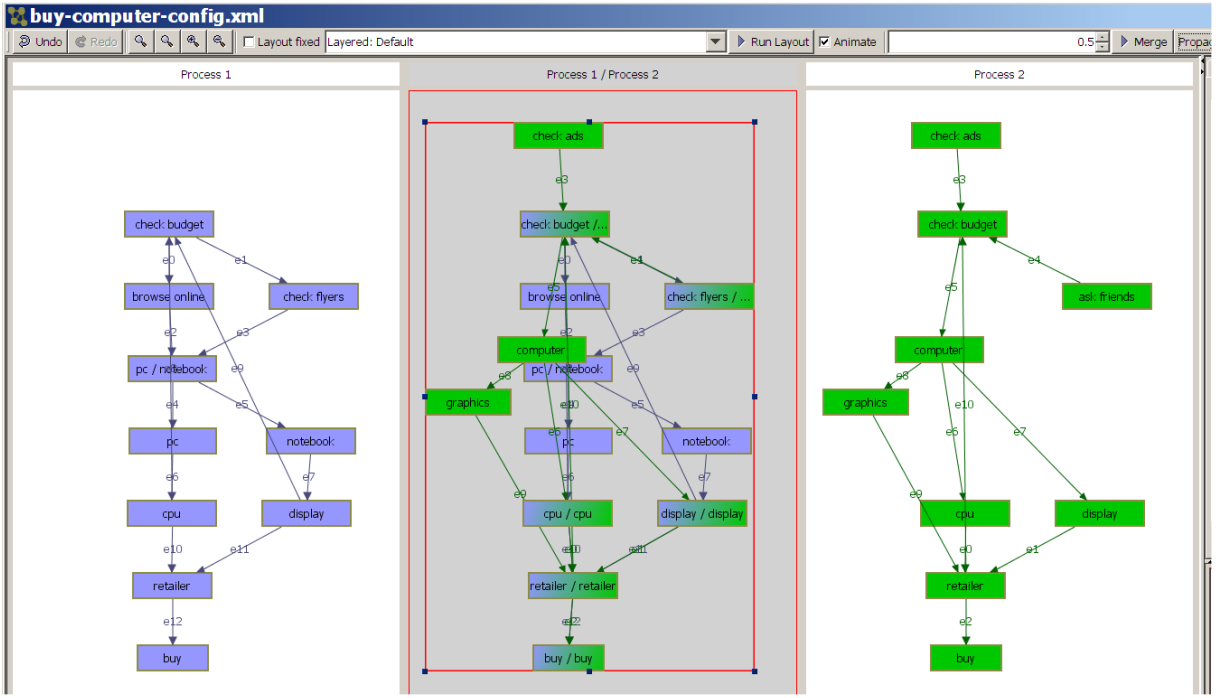
Automatic segmentation

Evaluation

Reference segmentation

Juxtapostion and Superposition

Strengths and weaknesses



Task: Graph structure - existence

Characteristics:

- Combination of 2 visualization techniques
- Juxtaposition with various layouts ineffective

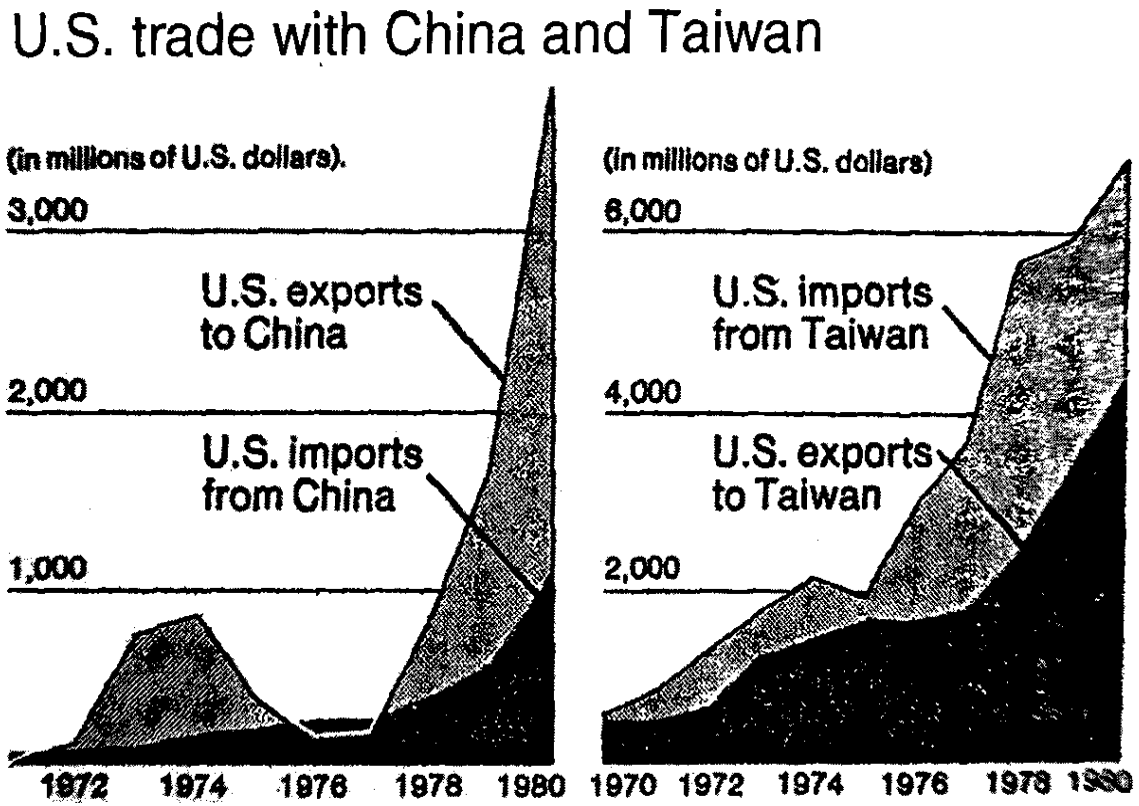
Specifics:

- Superposition (S) shall ease the identification of commonalities & differences in the graph
- Correspondences necessary for superposition

Reference: Andrews: comparison of graphs

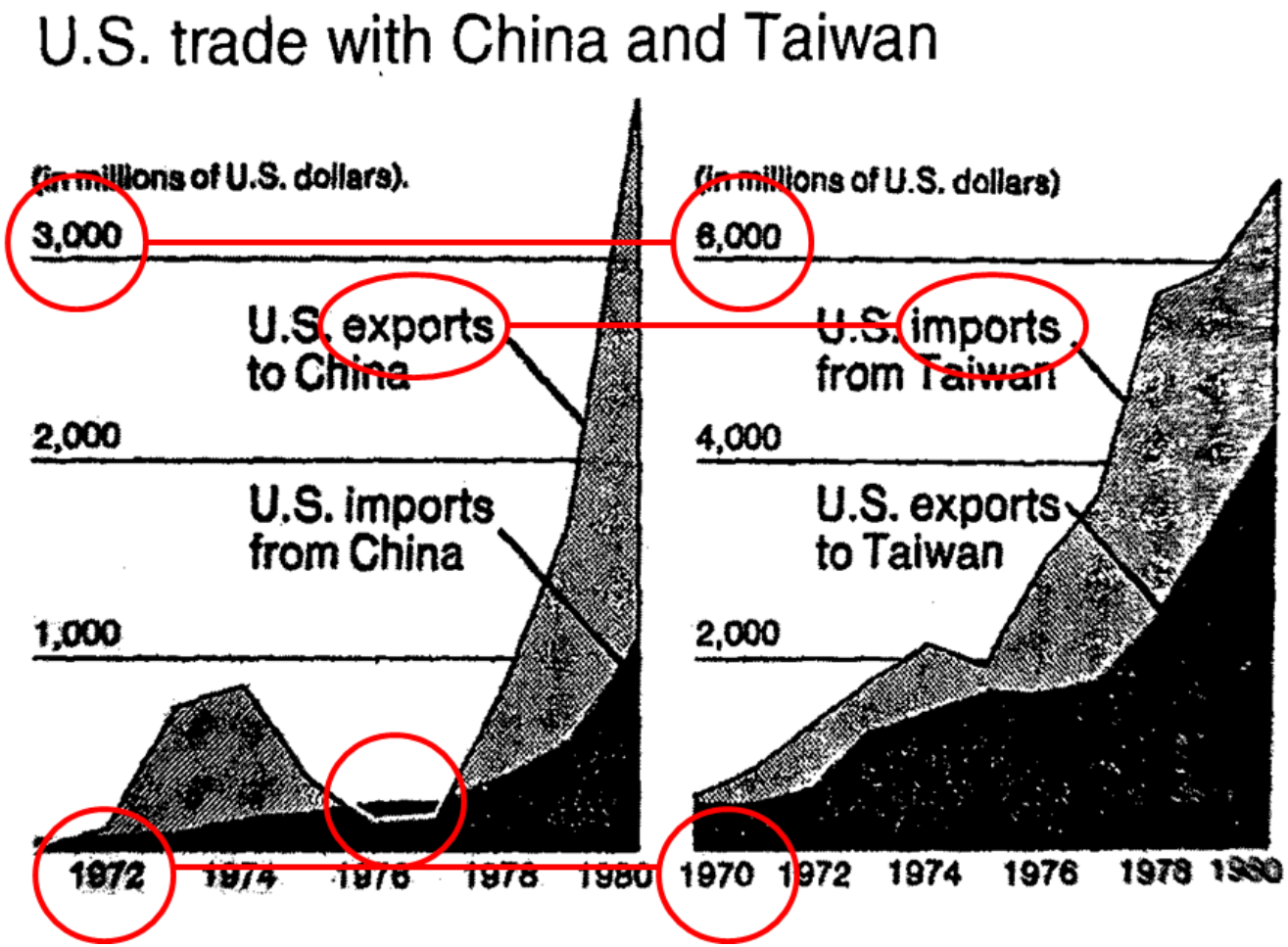
Juxta- and Superposition

Example: Juxtaposition and superposition challenges



Juxta- and Superposition

Example:

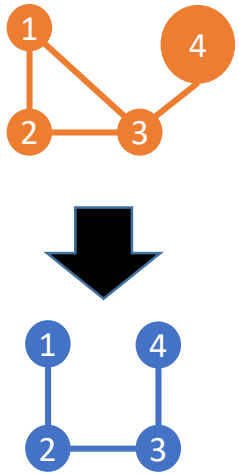
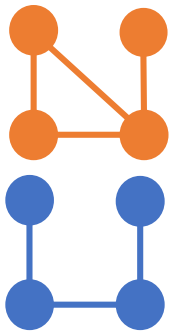
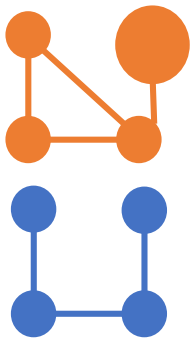
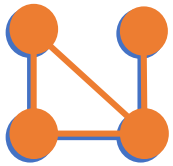
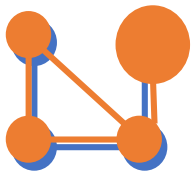
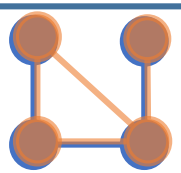
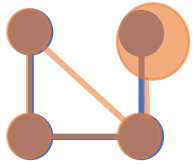


Comparison with attributes

Comparison more difficult when structure and attributes need to be compared simultaneously

Comparison with attributes

Attributes

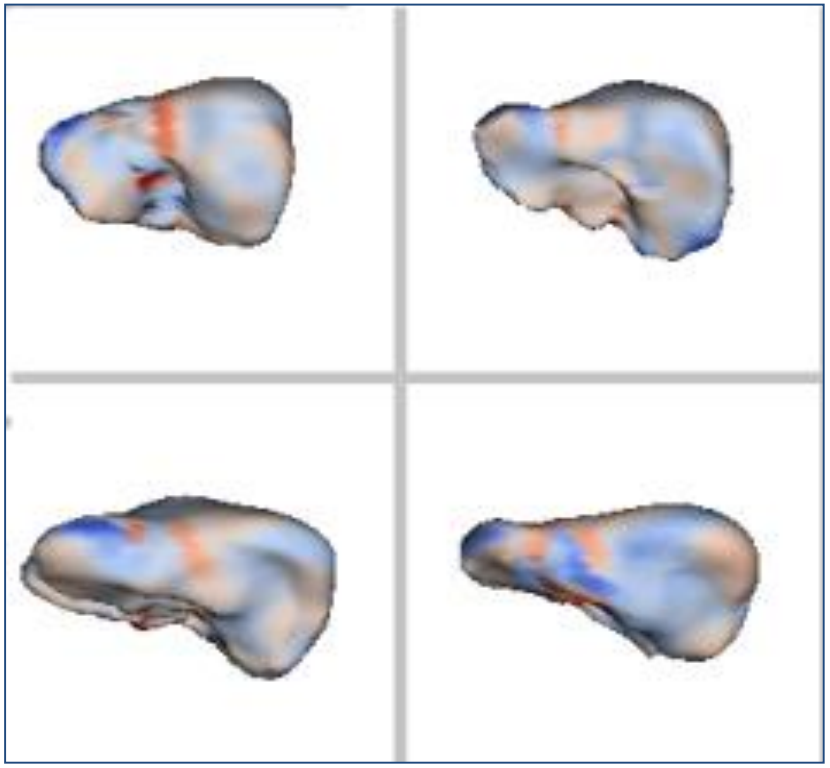
Comparison Input		Only structure	With attributes
	Juxtaposition		
	Superposition – Simple		
	Superposition – Transparent		

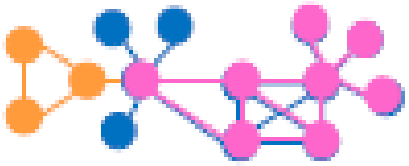
Comparison with attributes

Comparison more difficult when structure and attributes need to be compared simultaneously

Example: Comparison of segmentation quality values:

Finding regions with bad (red) segmentaion across livers very difficult!





Explicit Encoding

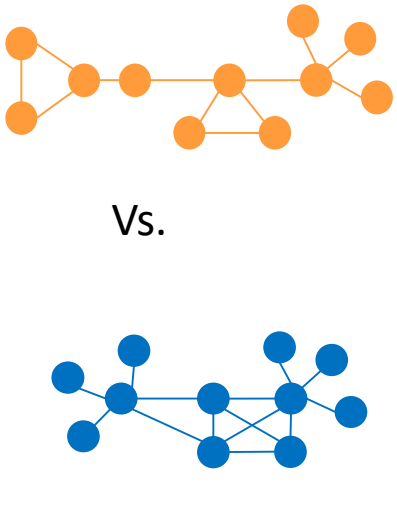
- Shows the items **WITH HIGHLIGHT** OF COMMONALITIES OR DIFFERENCES

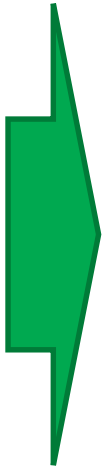
- Requires correspondence
- Requires algorithmic pre-processing (→ Part 2)
- Requires task knowledge (→ Part 1)

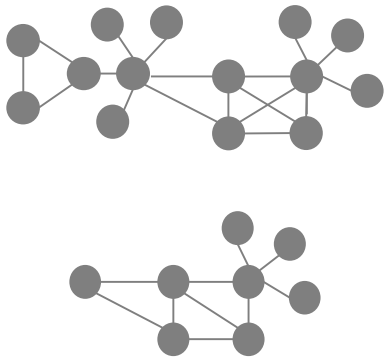
Explicit Encoding: Variants

Examples of explicit encoding variants

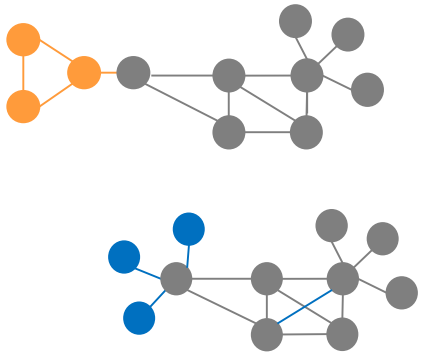
Source → Results:



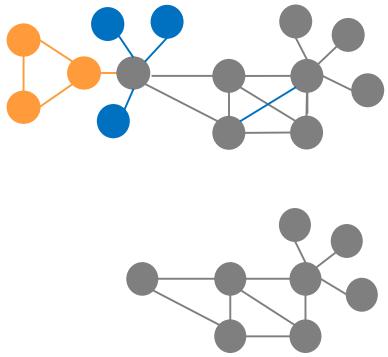




a) Explicit Encoding: Replacement (upper: union graph, lower: intersection graph)



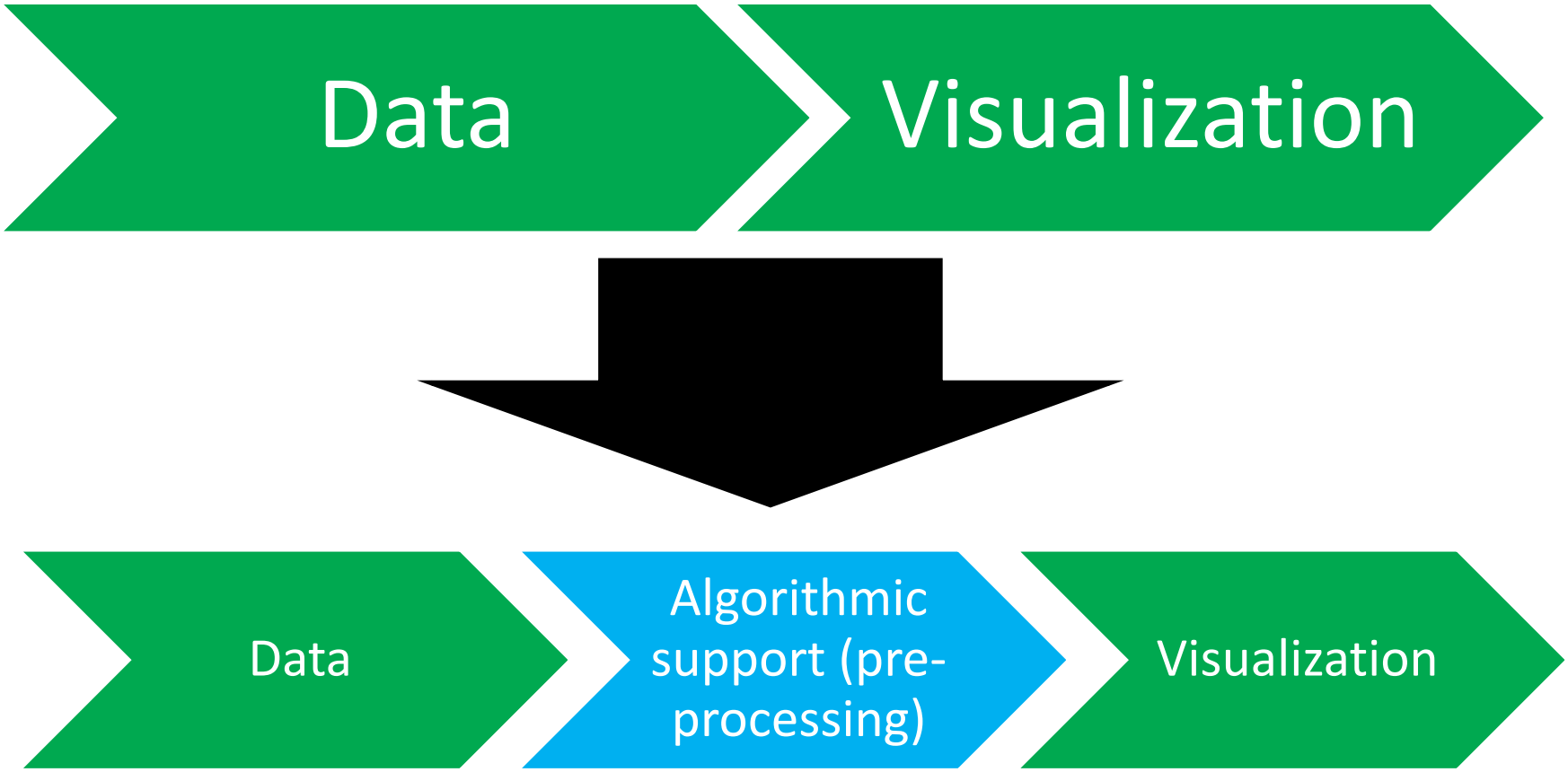
b) Juxtaposition + Explicit Encoding: Additive (Intersections added)



c) Explicit Encoding: Additive (members of the intersection shown added to one of the union graphs)

ALGORITHMIC SUPPORT FOR VISUAL COMPARISON

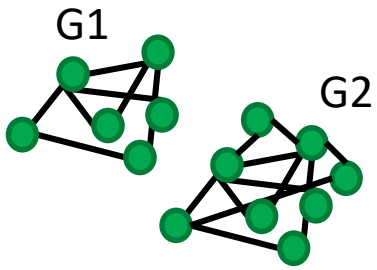
Algorithmic Support



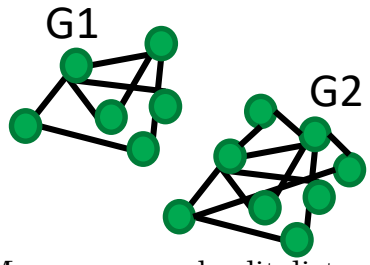
Motivation

- Calculation of correspondences (→ 1:1 match in Part 2)
- Explicit encoding requires differences or similarities
- Juxtaposition does not scale for many items
- …

Degree of Algorithmic Support

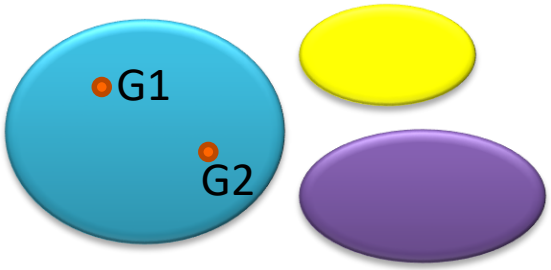


Visualization of the data with no further visual aid



Sim. Measure – graph edit distance: 6

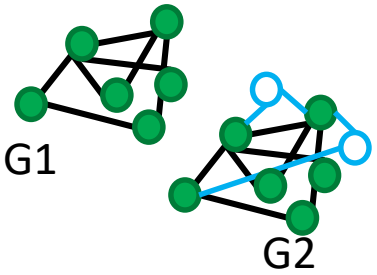
Similarity measures



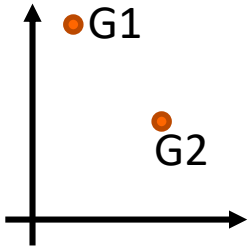
Postprocessing of the similarity measures **– e.g., clustering (SOM)**

Increasing degree of algorithmic support

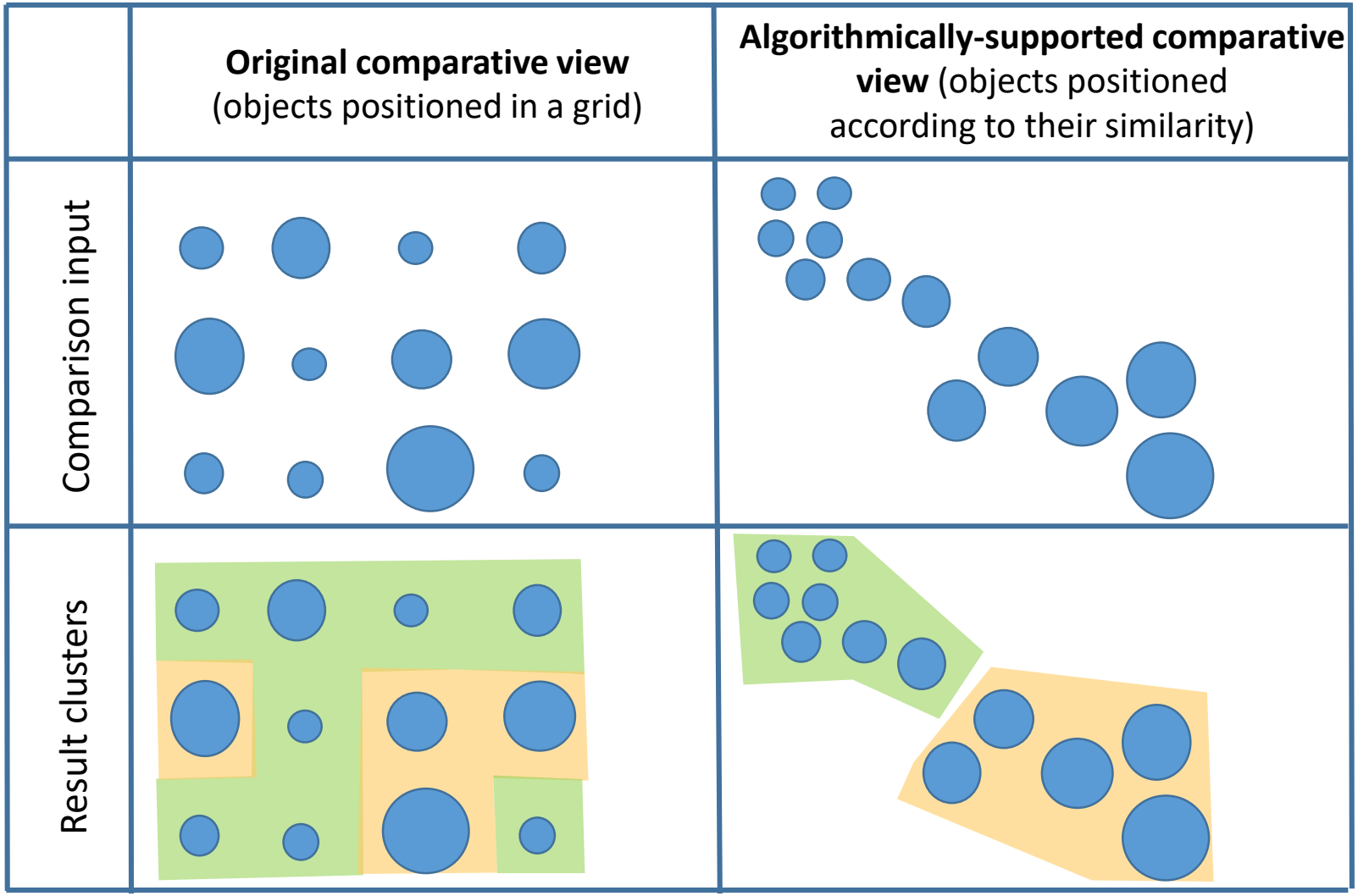
Correspondences between the data items



Postprocessing of the similarity measures **– e.g., dimensionality reduction (MDS)**

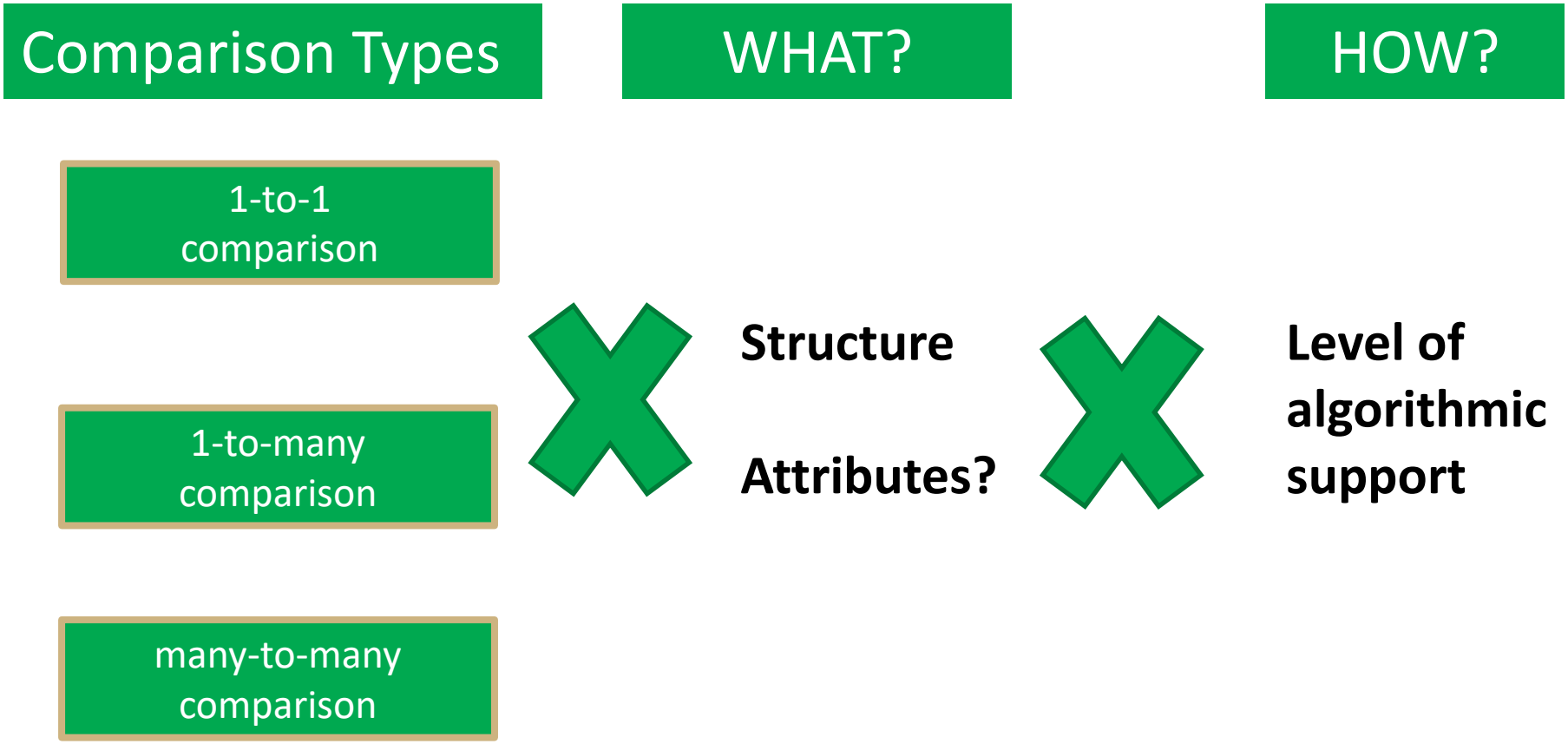


Value of Algorithmic Support: Visual Clustering

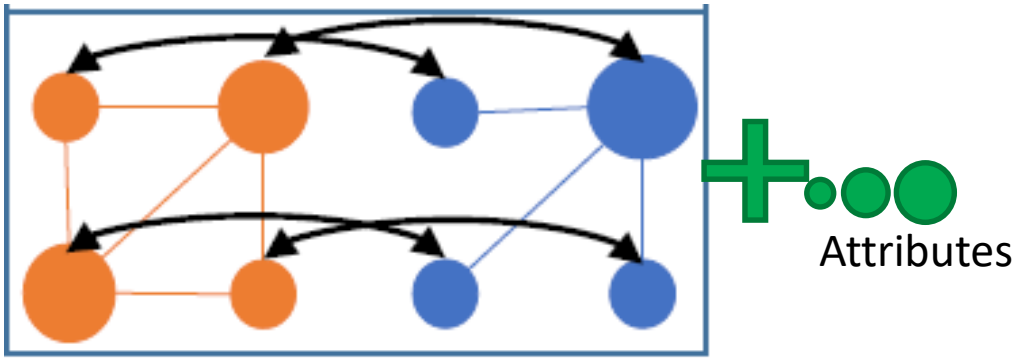


Similarity-based positioning of items makes finding clusters (i.e. groups of similar items) easier.

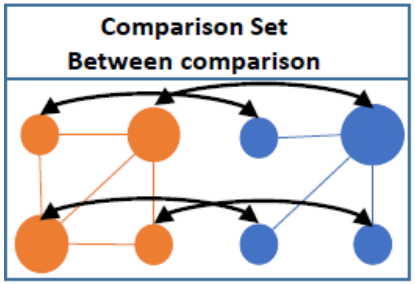
The Comparison Visualization



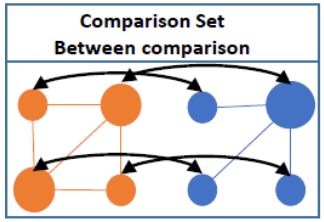
PART 1:
1-TO-1 COMPARISON



Speaker: Kathrin Ballweg



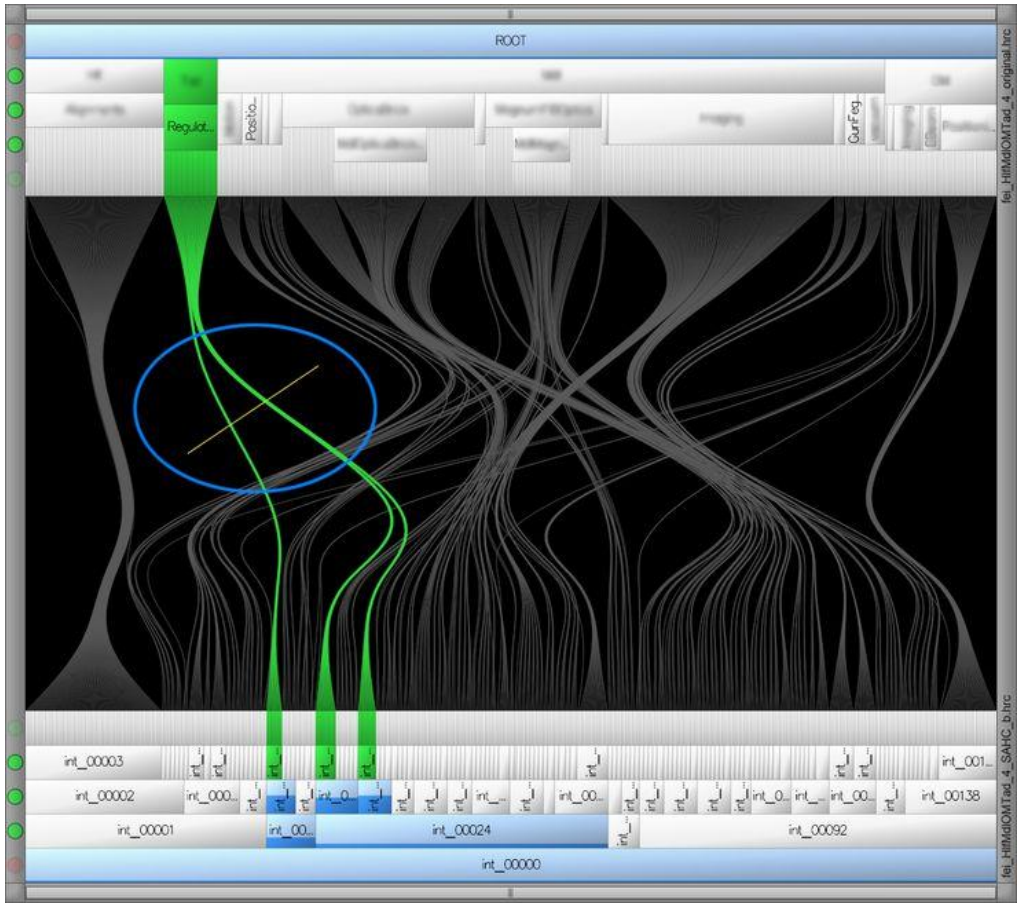
STRUCTURAL COMPARISON



J

Linking of matches

Task: Graph structure - existence



Characteristics:

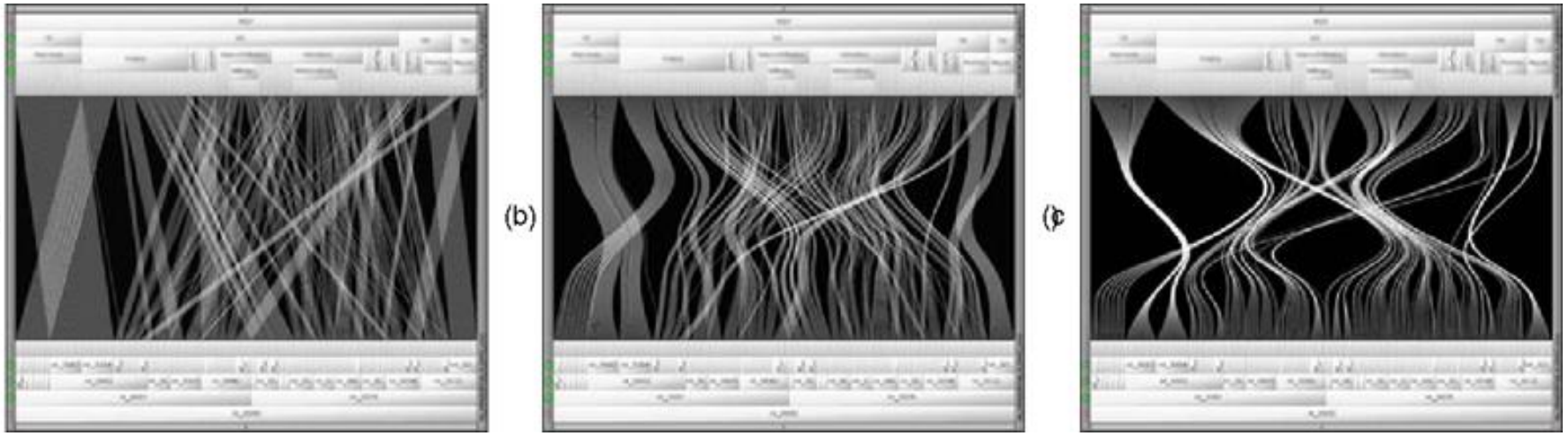
- Links are drawn between **common tree leaf nodes**
- Same leaf nodes but small different structure not visible
- How to draw links between a part which is present in the one but not in the other graph?
- Node sorting and edge bundling to reduce clutter
- Scalability issues with respect to graph size and number of links

Correspondence

Data: software structure

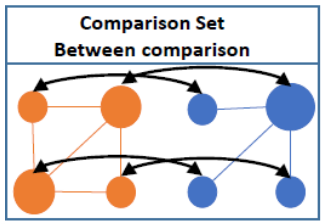
Reference: Holten and van Wijk: Visual Comparison of Hierarchically Organized Data

Linking of matches: Clutter reduction by edge bundling



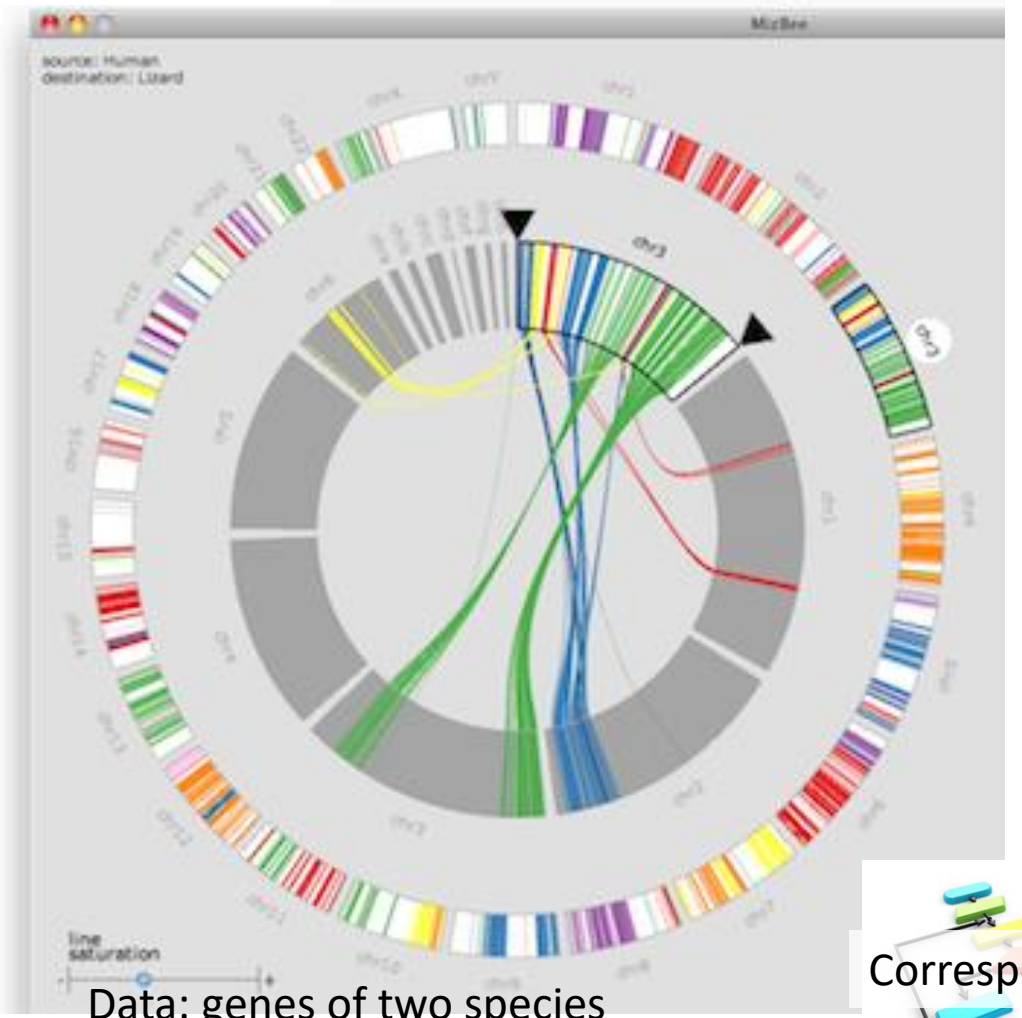
Data: software structure

Reference: Holten and van Wijk: Visual Comparison of Hierarchically Organized Data



Linking & coloring matches

J



Data: genes of two species

Reference: Munzner MizBee

Correspondence

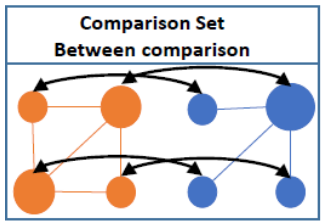
Task: Match of genes between two species – gene differences

Characteristics:

- Juxtaposition in circule
- Linking and coloring of matches
  shows nicely positional differences in genome

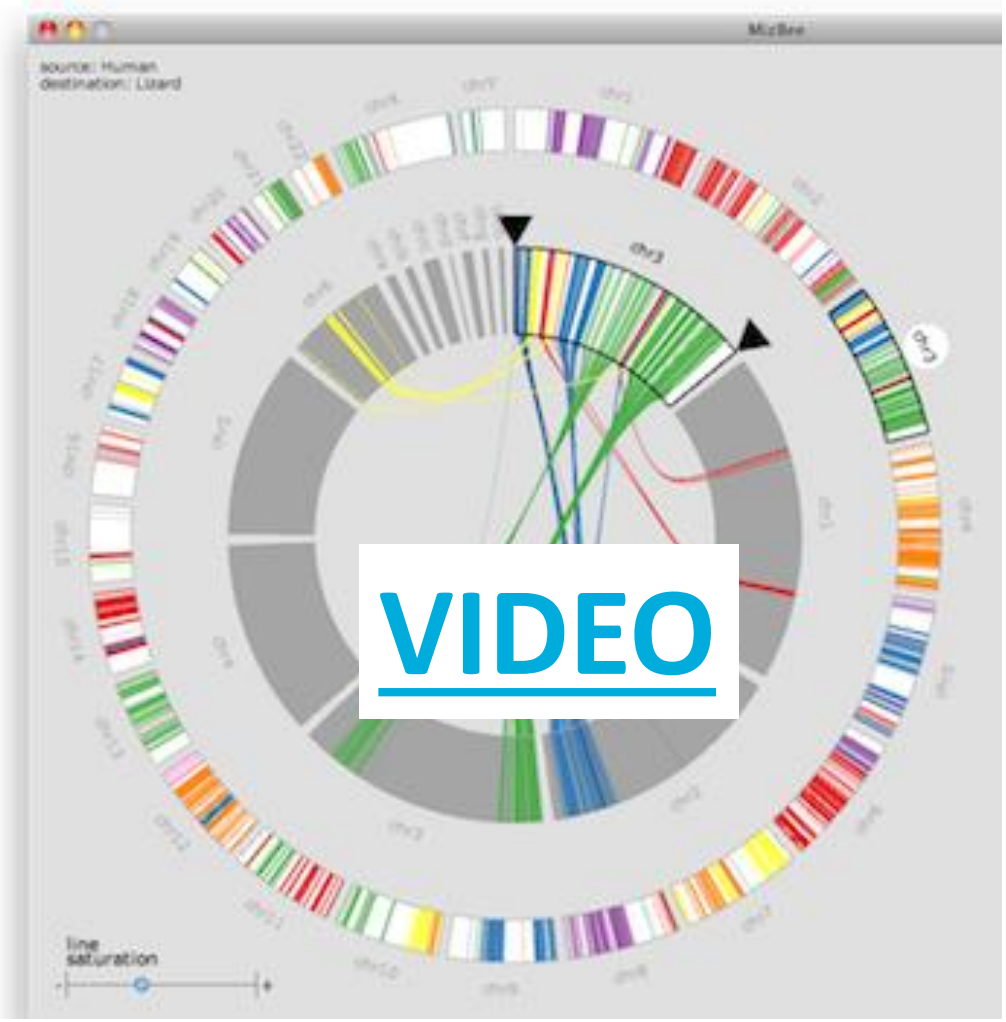
Specifics:

- Requires interaction: selecting the chromosome to be matched
- uses several views (see video) VIDEO



J

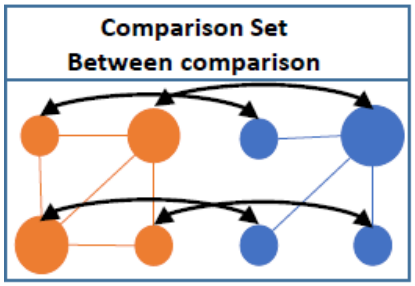
Linking and coloring matches



VIDEO

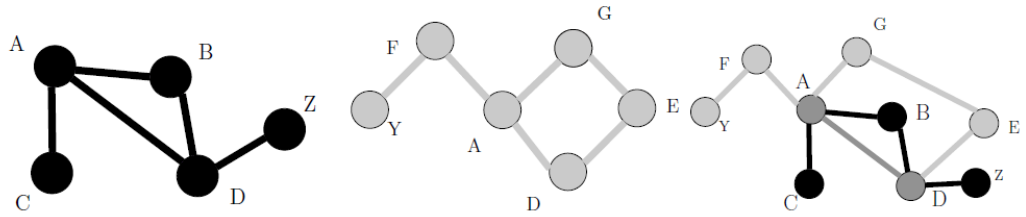
Data: genes
Reference: Munzner et al. MizBee

Mizbee: Video



S+E

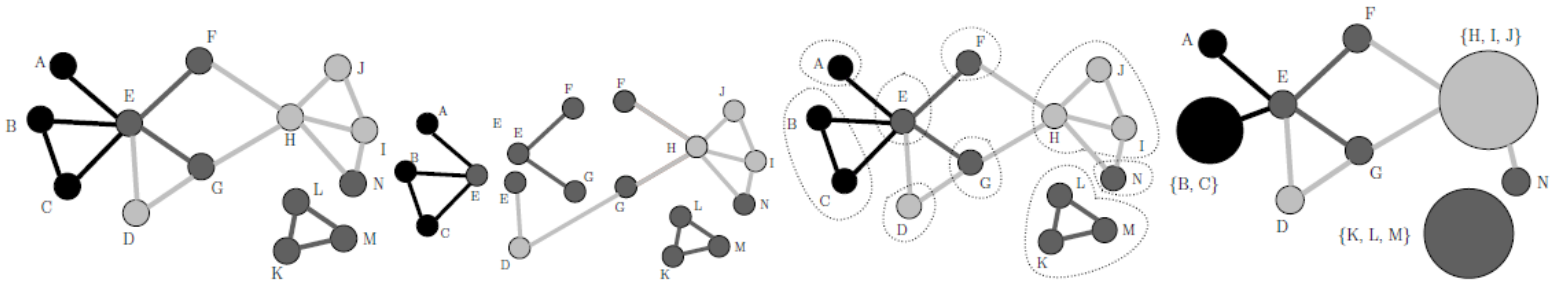
Difference-based Aggregation: Scalability



(a) Timeslice 1 (b) Timeslice 2 (c) Difference Map

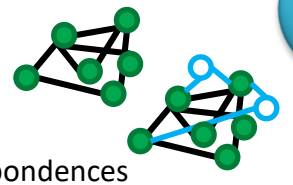
Task: Difference between **large graphs**

Characteristics:
Use of aggregation to deal with scalability and emphasize differences

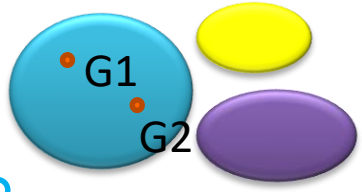


(a) Original Graph (b) Decomposition by Edges (c) Decomposition by Nodes (d) Hierarchy Graph

G2

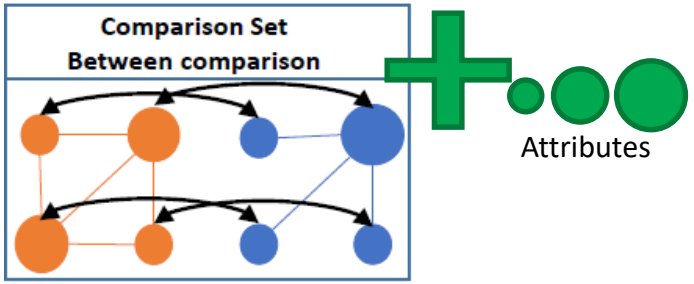


Correspondences between the data items



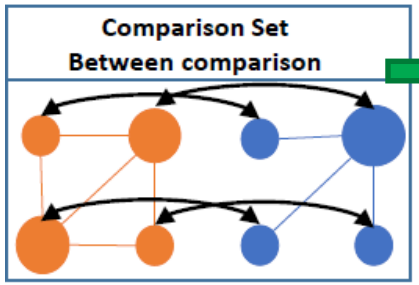
Postprocessing : Simplification by aggregation

Reference: Structural Differences Between Two Graphs through Hierarchies



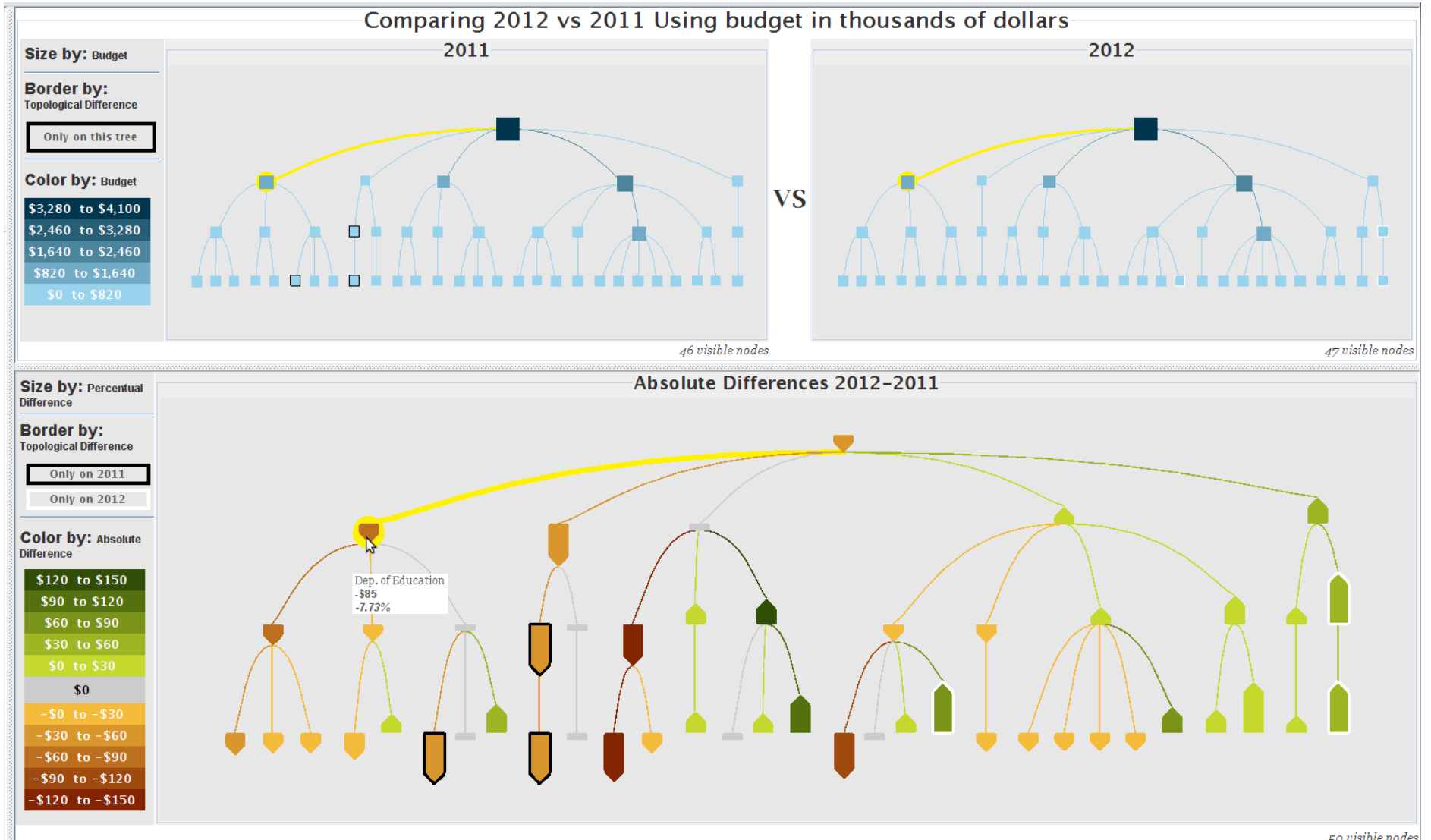
STRUCTURE AND ATTRIBUTES

Flow Chart Resource: https://3gp10c1vpy442j63me73gy3s-wpengine.netdna-ssl.com/wp-content/uploads/2018/03/flowchart.png

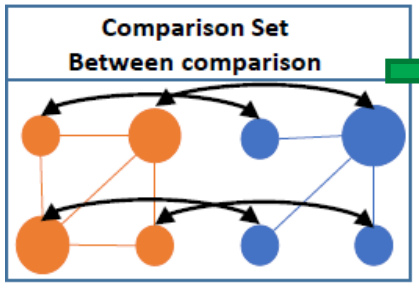


J & S & E

Visual encoding of differences

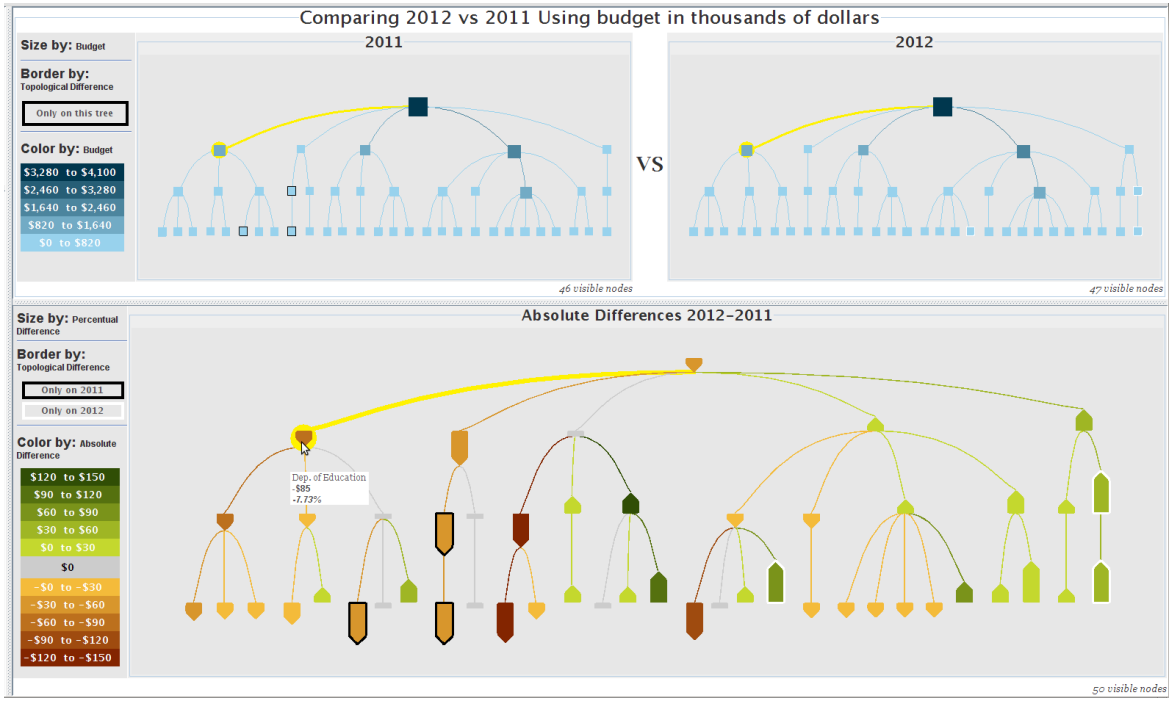


Flow Chart Resource: https://3gp10c1vpy442j63me73gy3s-wpengine.netdna-ssl.com/wp-content/uploads/2018/03/flowchart.png



J & S & E

Visual encoding of differences



Task:

- Graph structure & attribte

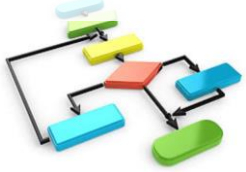
Characteristics:

- Node-link diagram
- Explicit encoding of differences for values and structure
- Union tree of the two trees required

Specifics:

- Union tree works well only for similar trees
- High cognitive burden of encoding

Correspondence – union tree
Attribute difference

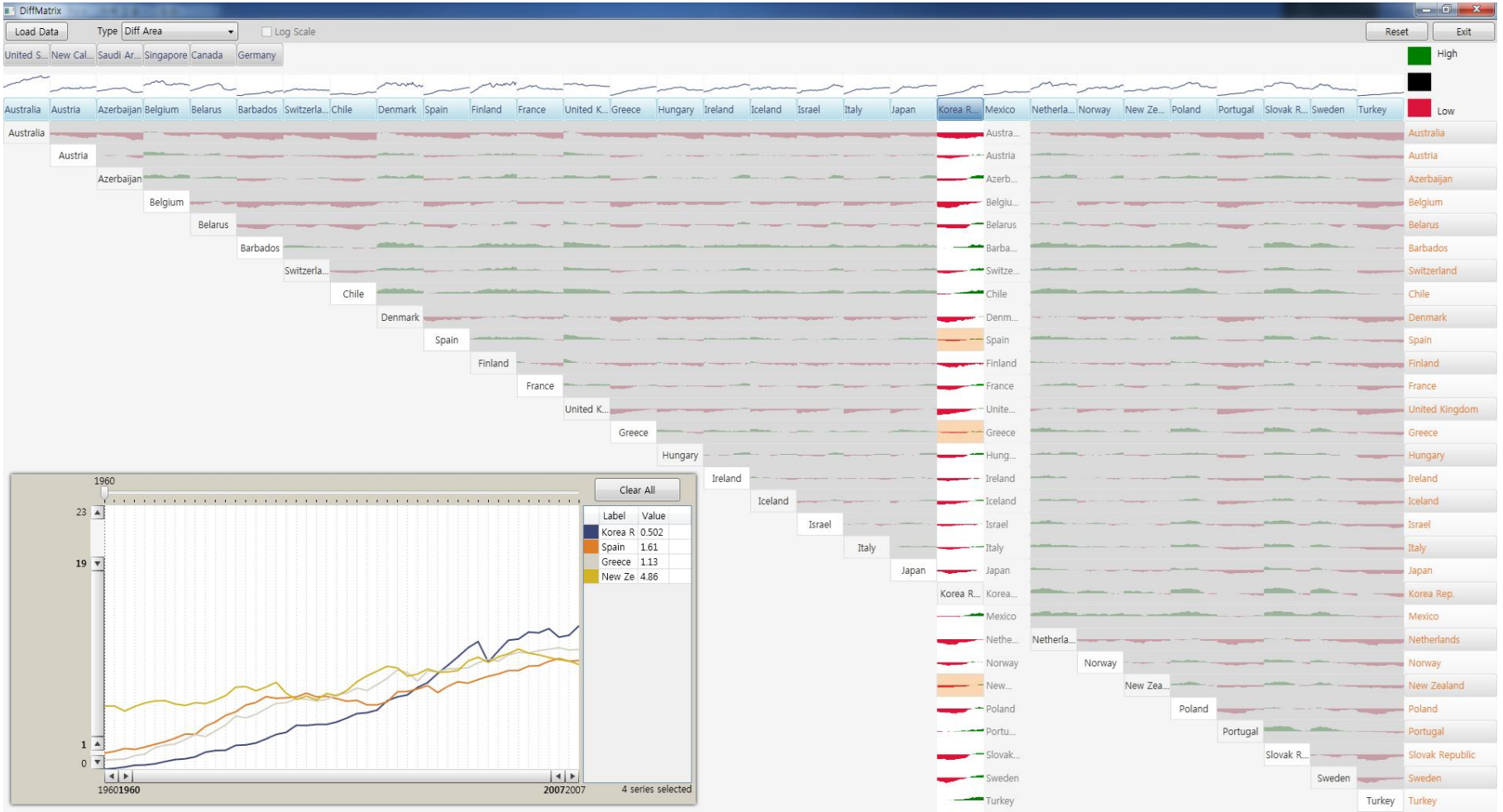


Reference: Interactive Visualizat ıg Two Trees
With Structure and Node Value

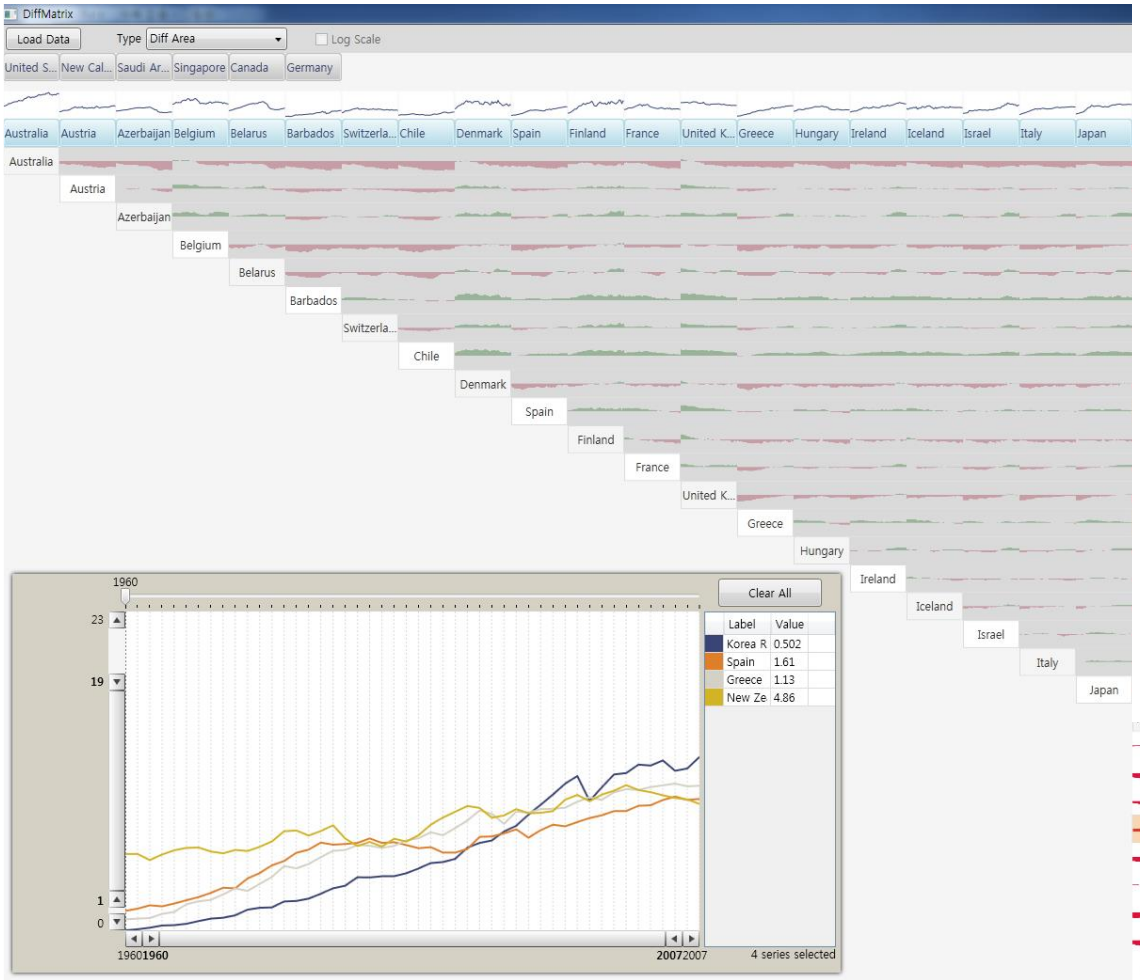
SPECIAL CASES

N times 1-to-1 Comparison

Time Series: N times 1-to-1 Matrix-based View



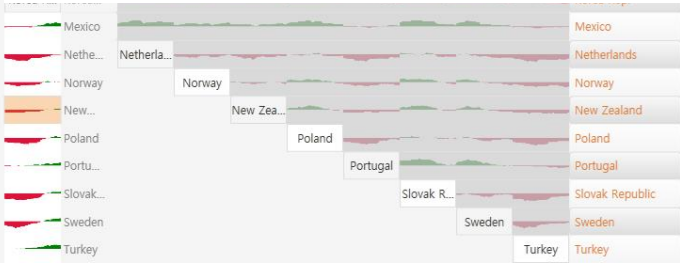
Time Series: N times 1-to-1 Matrix-based View



Task: Pairwise Comparison of many time series

Characteristics:

Matrix view leads to small space for pairwise comparison views
→ design evaluation
→ additional detailed view needed for **selected** pairs (manual inspection required)



Data: Economic time series for countries

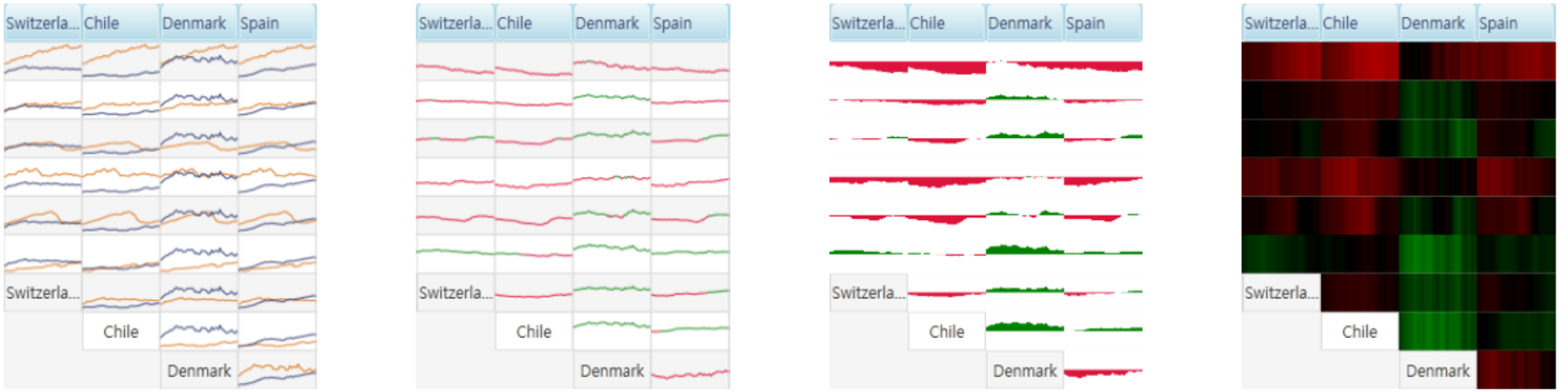
Time Series Comparison Visual Designs: Evaluation

Superposition

Explicit encoding 1

Explicit encoding 2

Explicit encoding 3

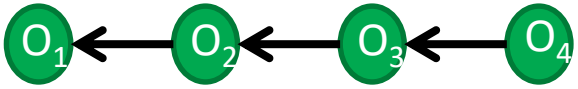


(a) Dual lines (b) Diff line (c) Diff area (d) Diff heatmap

Figure 2: *Four visual representations for each cell in the matrix to help users see the difference between two time series.*

Result: Diff area works best in this case

Reference: DiffMatrix: Matrix-based Interactive Visualization for Comparing Temporal Trends

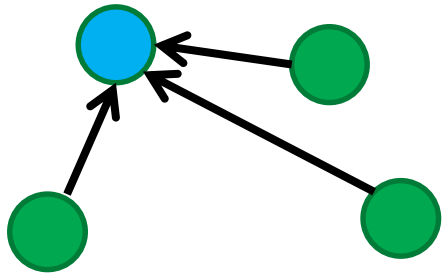


Flow Chart Resource: https://3gp10c1vpy442j63me73gy3s-wpengine.netdna-ssl.com/wp-content/uploads/2018/03/flowchart.png

N times 1-to-1 Comparison

J & S & E

Reference: Bach et al. GraphDiaries



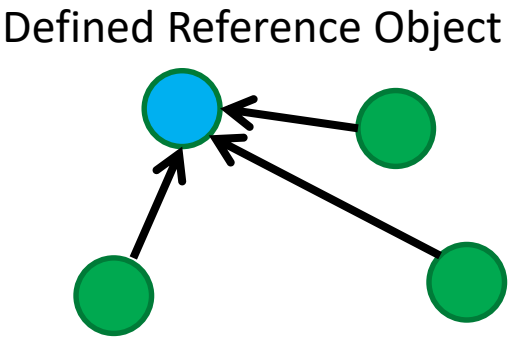
PART II: 1-TO-MANY COMPARISON

Speaker: Kathrin Ballweg

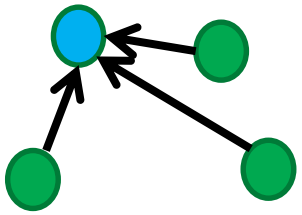
1: many Comparison

Definition:

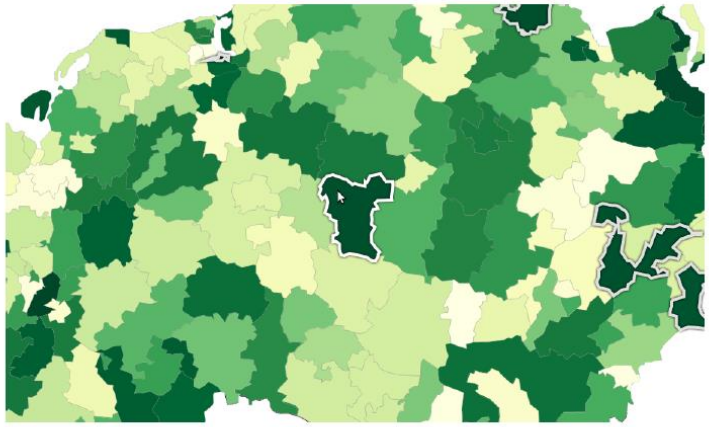
- one reference object
- several (>1) compared items to which the reference object is compared



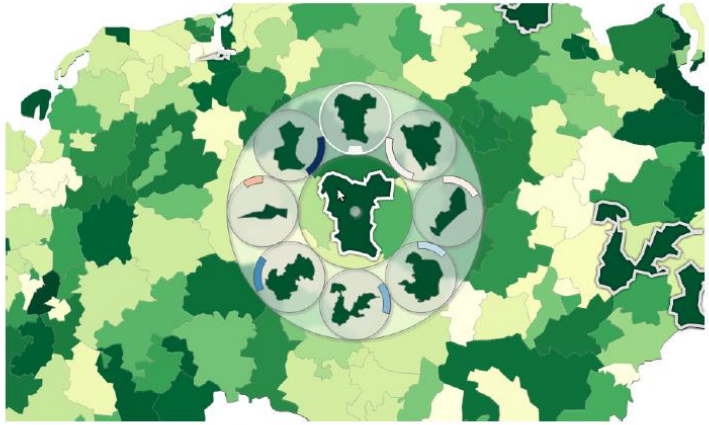
Defined Reference Object



Juxtaposition: Interactive Support



(a) Zoomed-in view.



(b) The CompaRing with indicator arcs.

Reference: Tominski, CompaRing

Task: Compare one region to other regions.
Challenge: geographic regions far away
→ difficult to compare

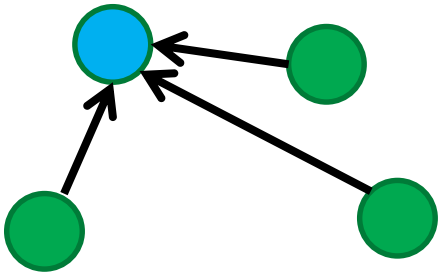
Characteristics:

- Interaction brings the compared items close to the reference object for easier comparison

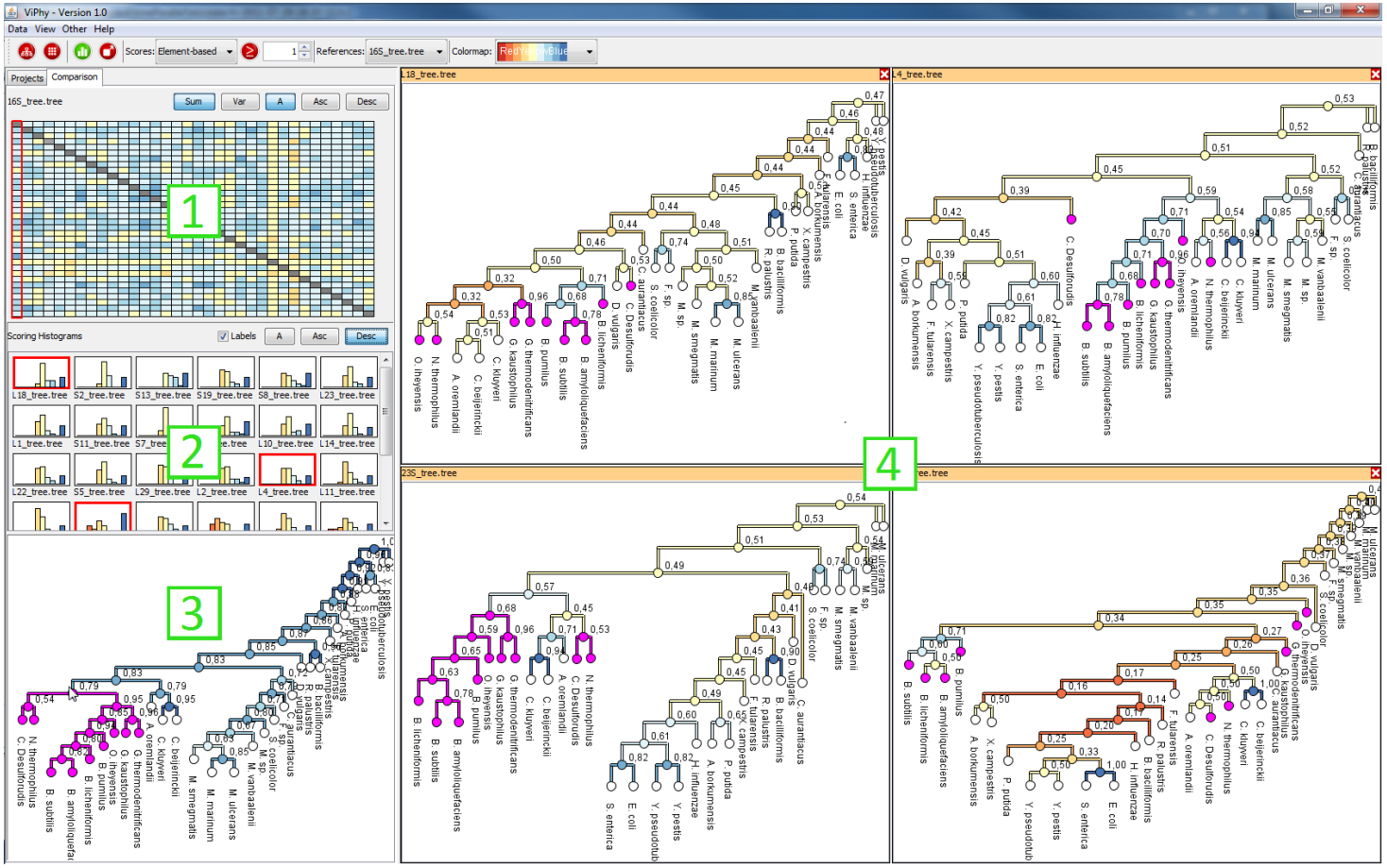
Specifics:

- Requires interaction
- Ring structure supports 1:many comparison well as it puts reference in the middle

Defined Reference Object



Explicite Encoding and Juxtaposition

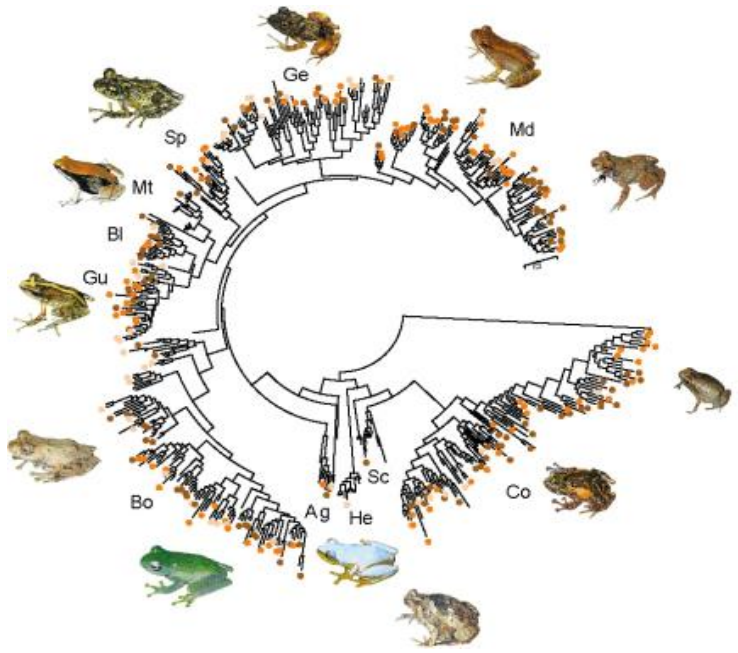


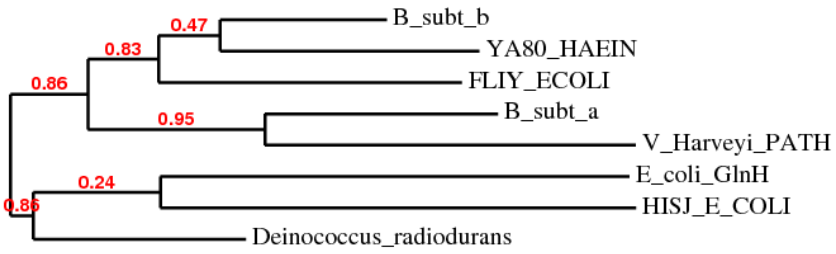
Motivation

- Analysis phylogenetic trees
- Describe evolutionary relatedness

- Can be calculated based on various sources

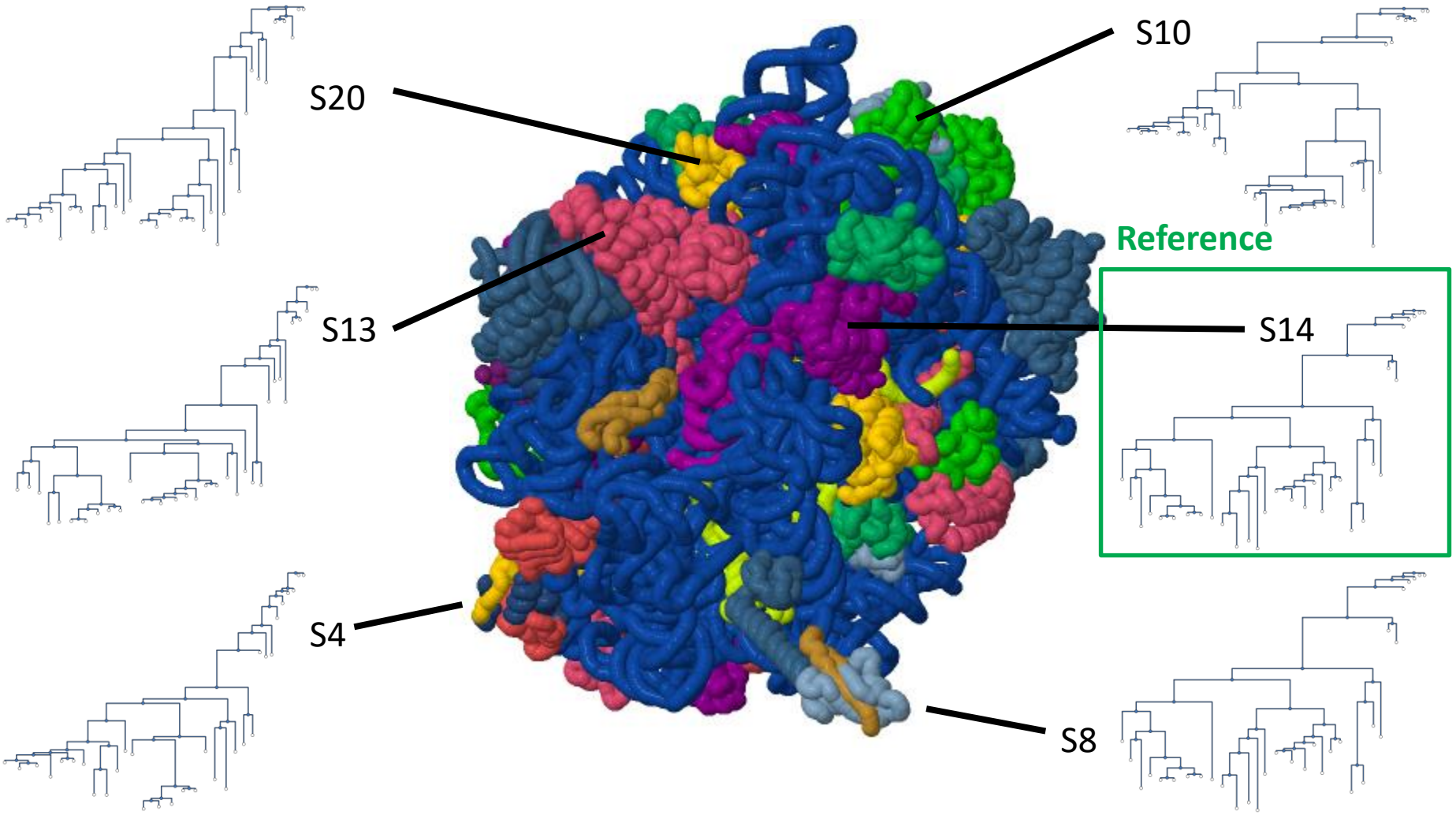
- Popular Source: Ribosome
  - Assembles proteins
  - Present in every living organism





ViPhy.org

1 reference and 33 other trees



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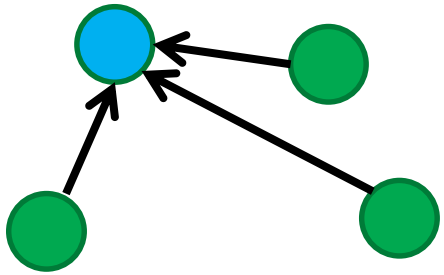
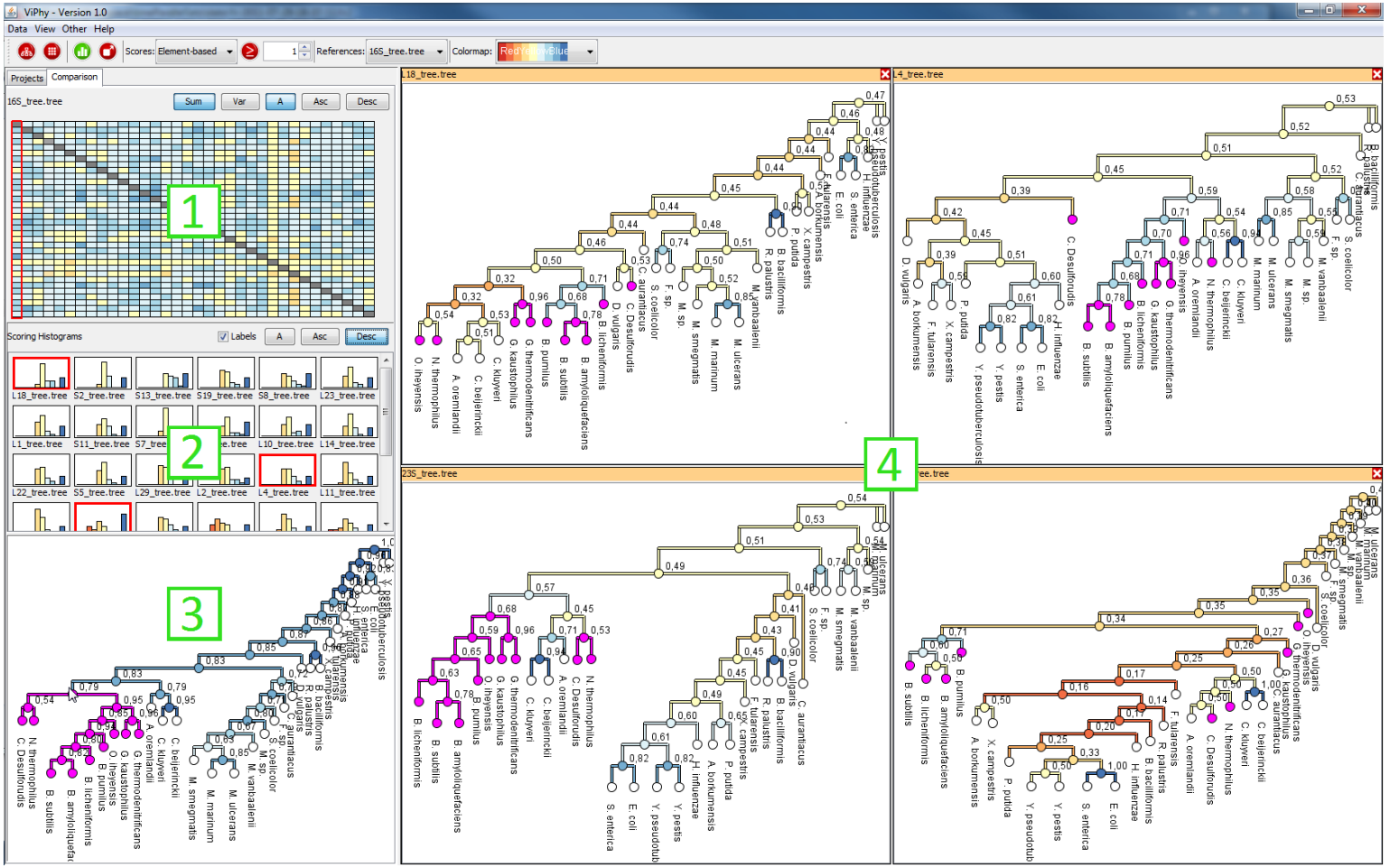
Defined Reference Object



Explicite Encoding and Juxtaposition



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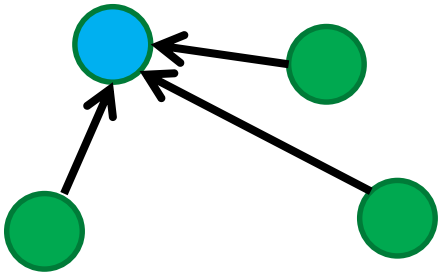
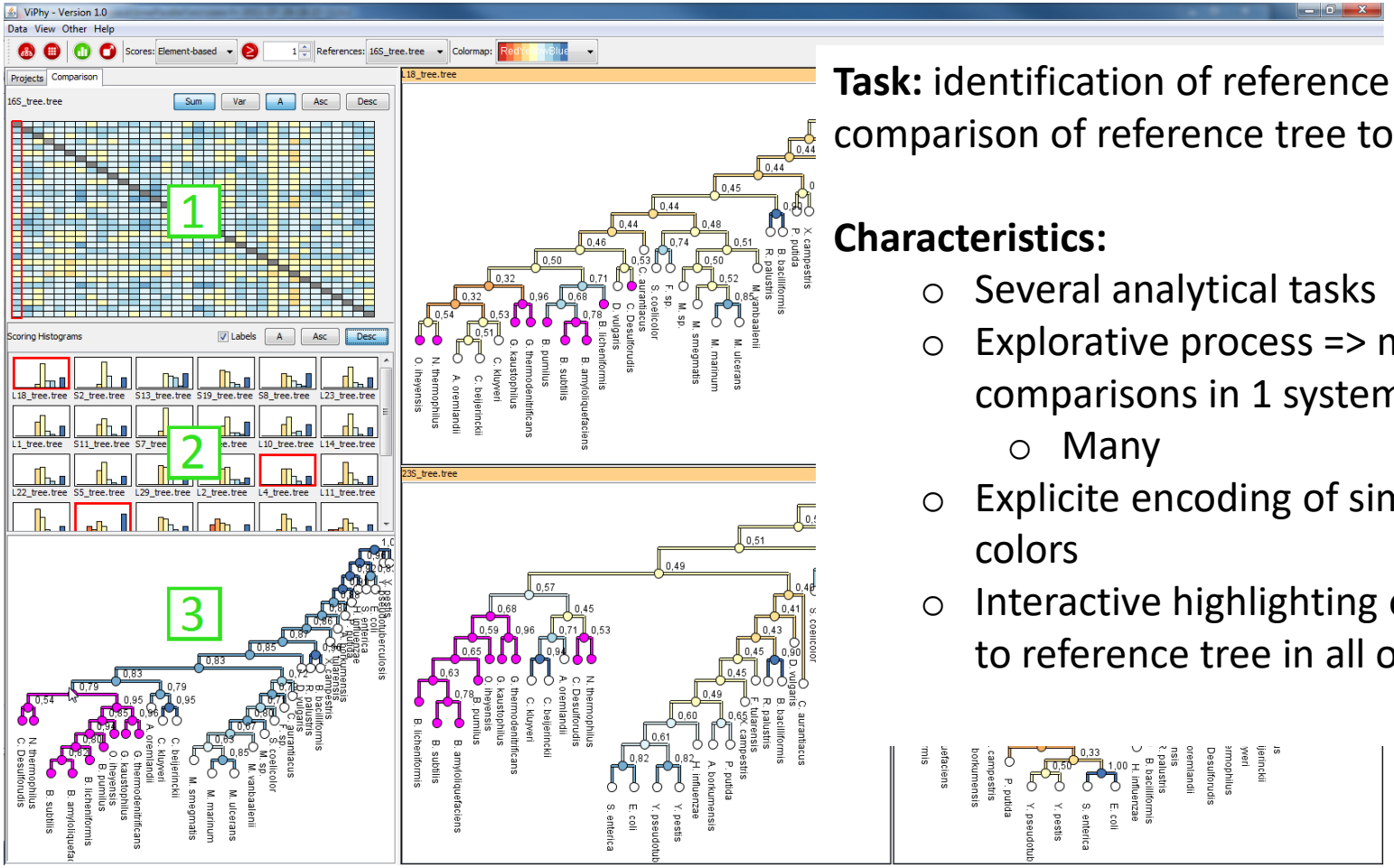
Defined Reference Object



Explicite Encoding and Juxtaposition



Task: identification of reference tree and comparison of reference tree to many other tre

Characteristics:

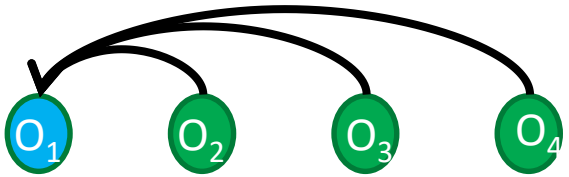
- Several analytical tasks
- Explorative process => many types of comparisons in 1 system
  - Many
- Explicite encoding of similarity values as colors
- Interactive highlighting of similar subtre to reference tree in all other trees

ViPhy.org

ViPhy.org

Interactive Comparison of Multiple Trees

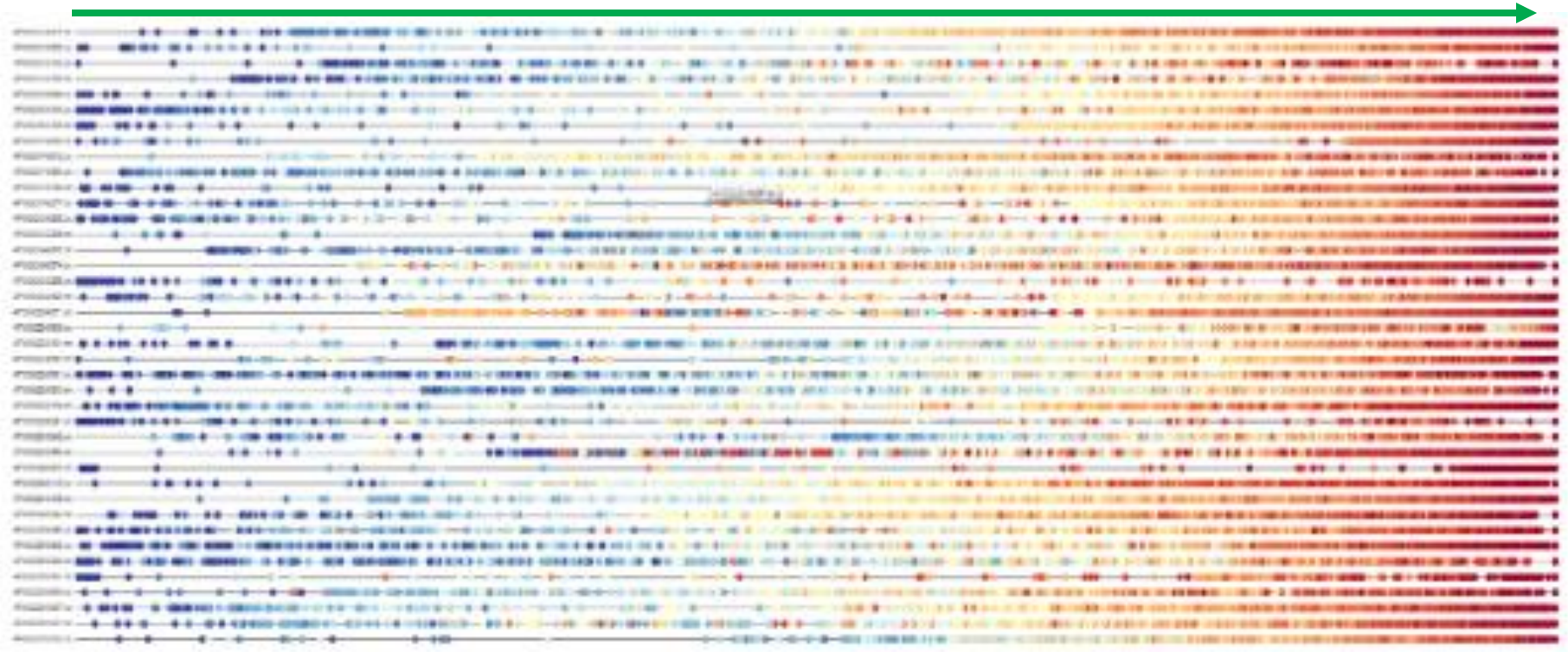
S. Bremm, T. von Landesberger, M. Heß, T. Schreck, P. Weil, K. Hamacher
Technische Universität Darmstadt, Germany



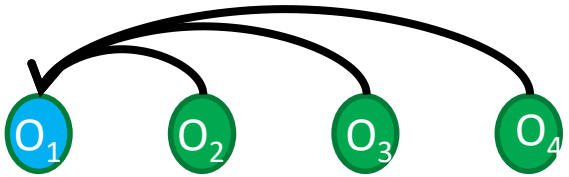
Absolute Reference

Many times 1:many

Distance to reference



Reference: Gleicher et al.



Absolute Reference

Many times 1:many

Distance to reference

Many-times 1: many comparison

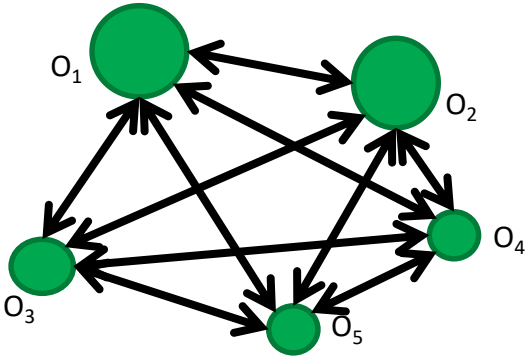
- each row is 1:many comparison
- Each dot is an item
- Reference item on the left

Agorithmic support and explicite encoding of similarit

- Similarity encoded both as color and distance to reference

Data: document topics
Reference: Gleicher et al.

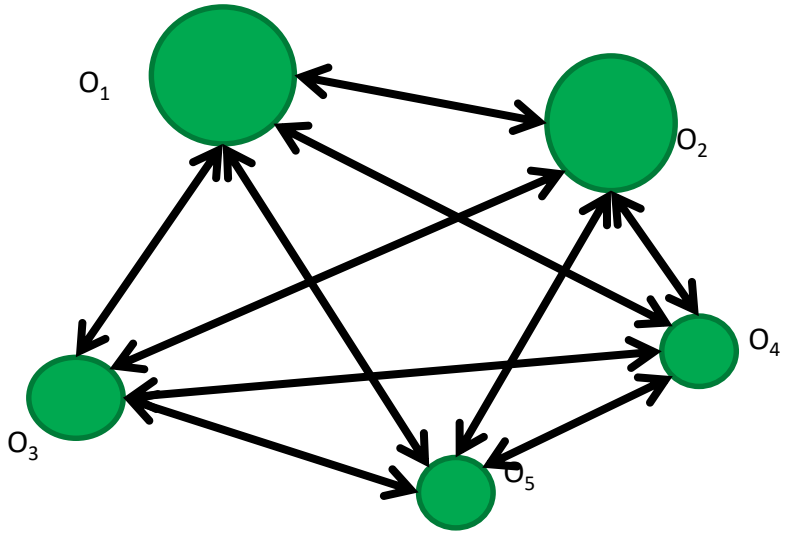
PART III: MANY-TO-MANY COMPARISON



Speaker: Kathrin Ballweg

Definition

- >2 items
- No reference
- All-to-all comparison



Challenge: Scalability
Number of ompared items

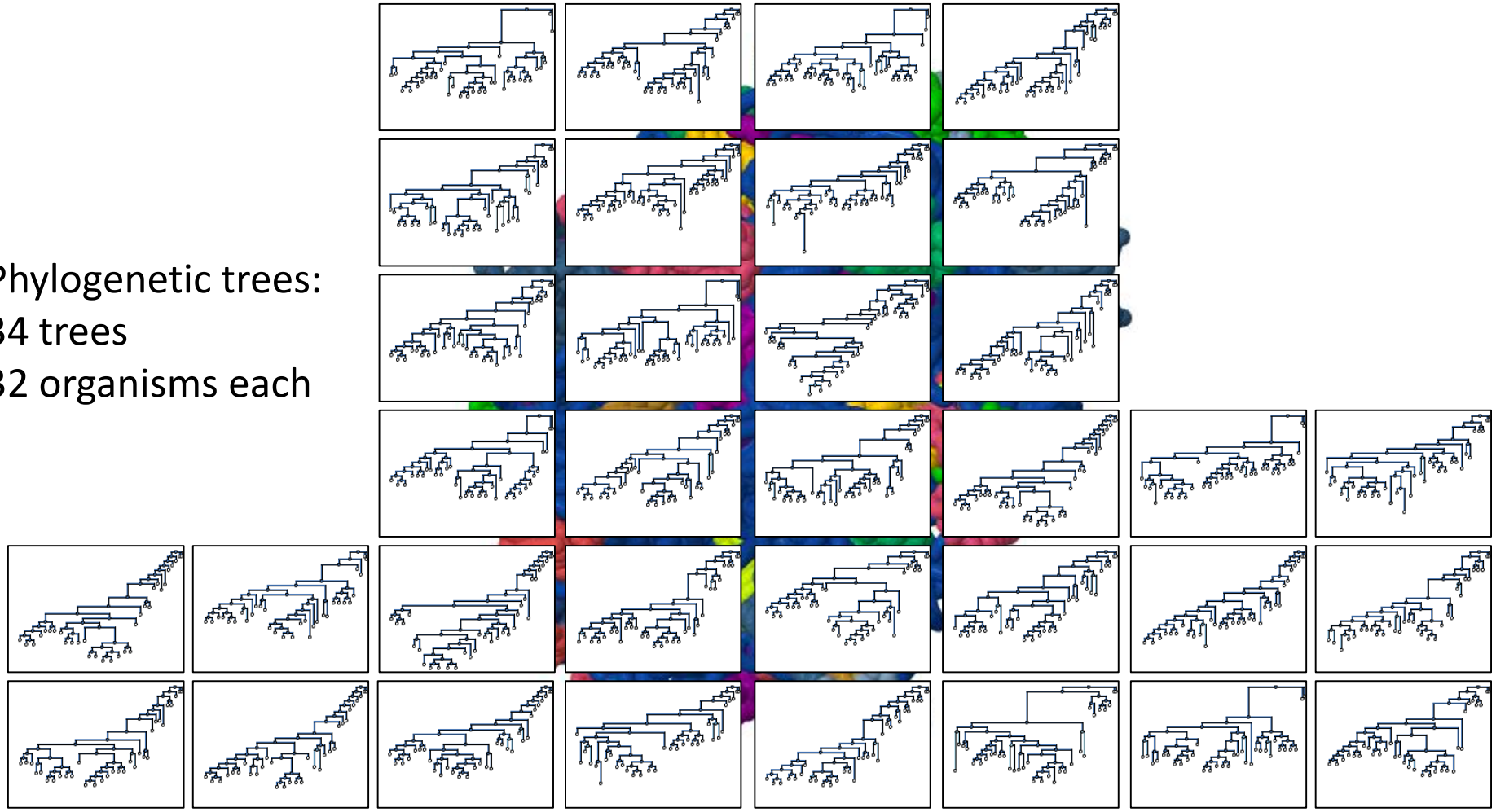
Juxtapostion:

- Limited screens space
  → out of screen
  or
  → items too small

Dataset

Juxtaposition

Phylogenetic trees:
34 trees
32 organisms each



ViPhy.org

Challenge: Scalability Number of compared items

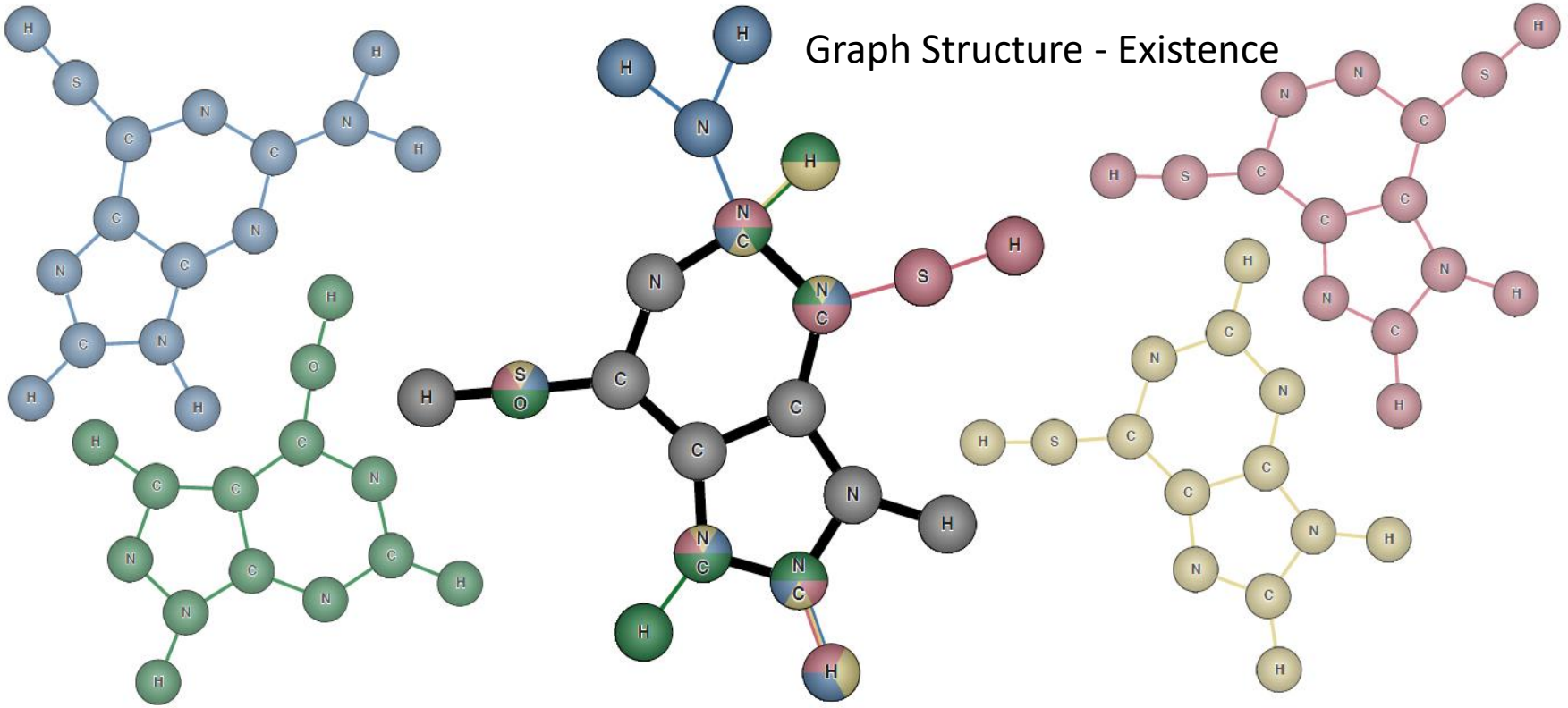
Juxtapostion:

- Limited screens space
  → out of screen
  or
  → items too small

Superposition:

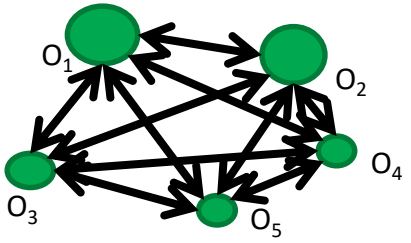
- Correspondence of many items needed
- Overplotting problems
- Usually only up to dozen of items

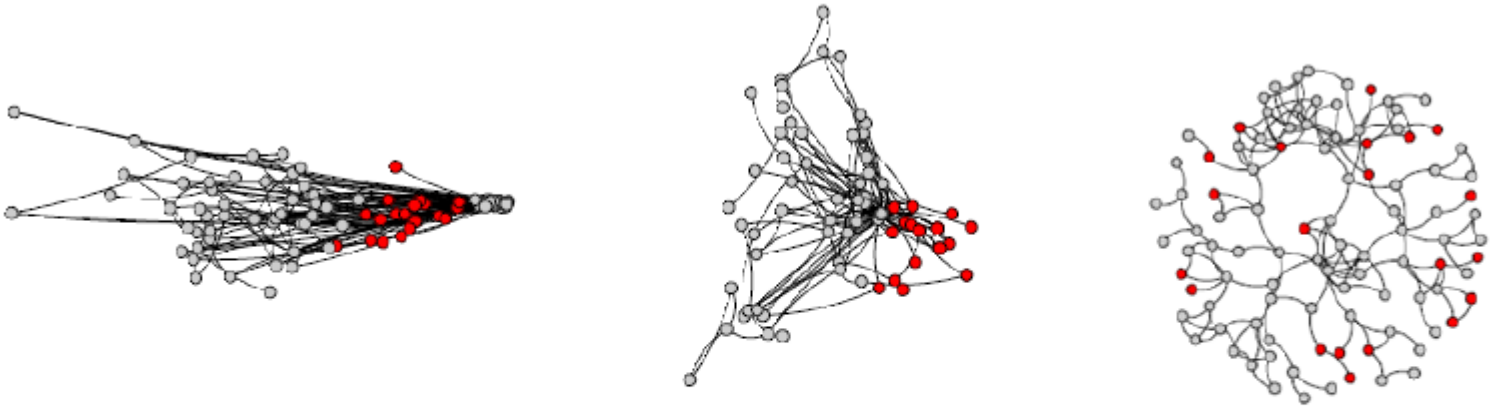
Superposition



Graph in the middle is the superposition of the four colored juxtaposed graphs around.
Challenge: supergraph creation and visual construction.
Limited perception of commonalities and differences.

Reference: Visual Summaries for Graph Collections



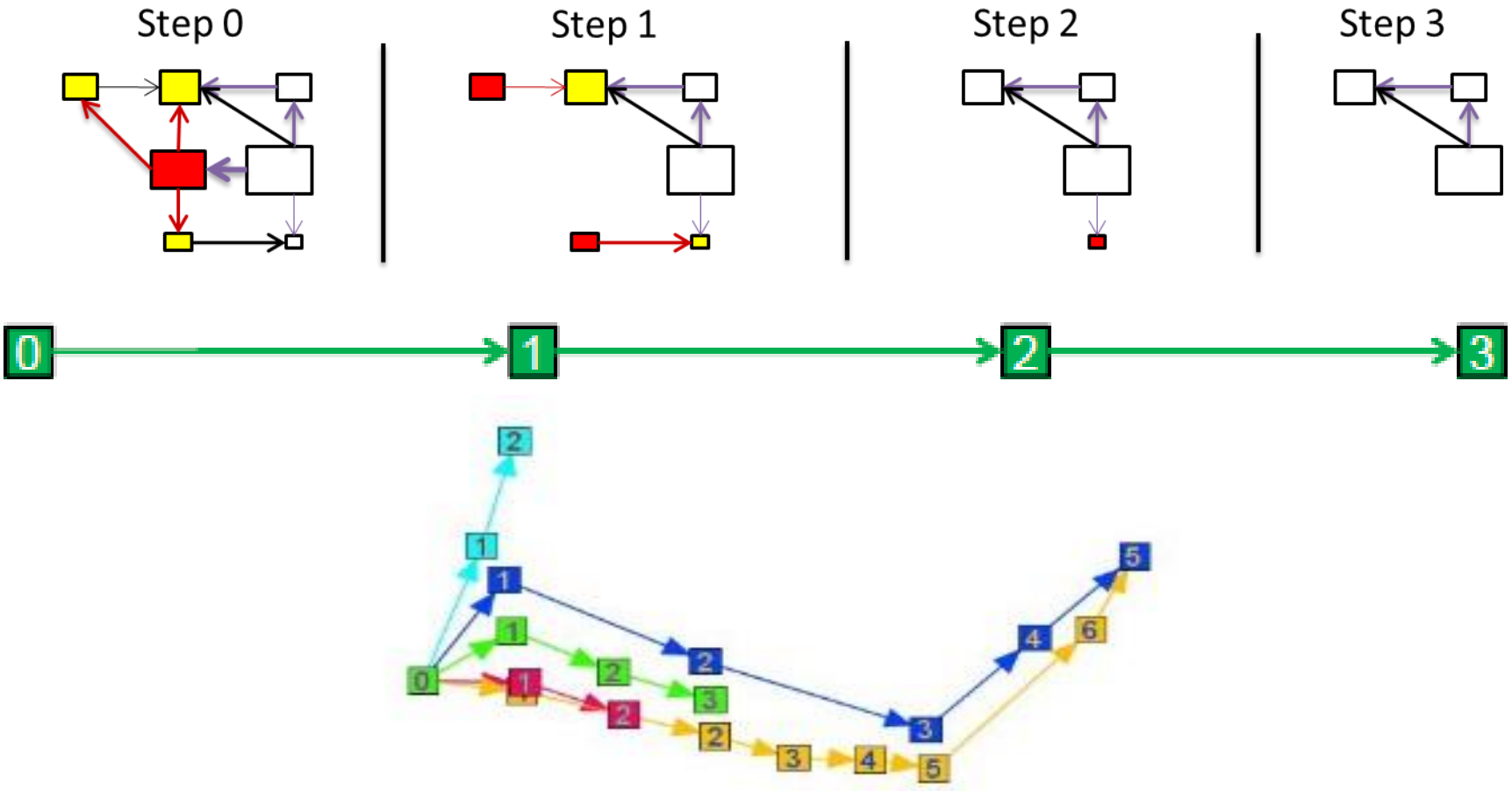


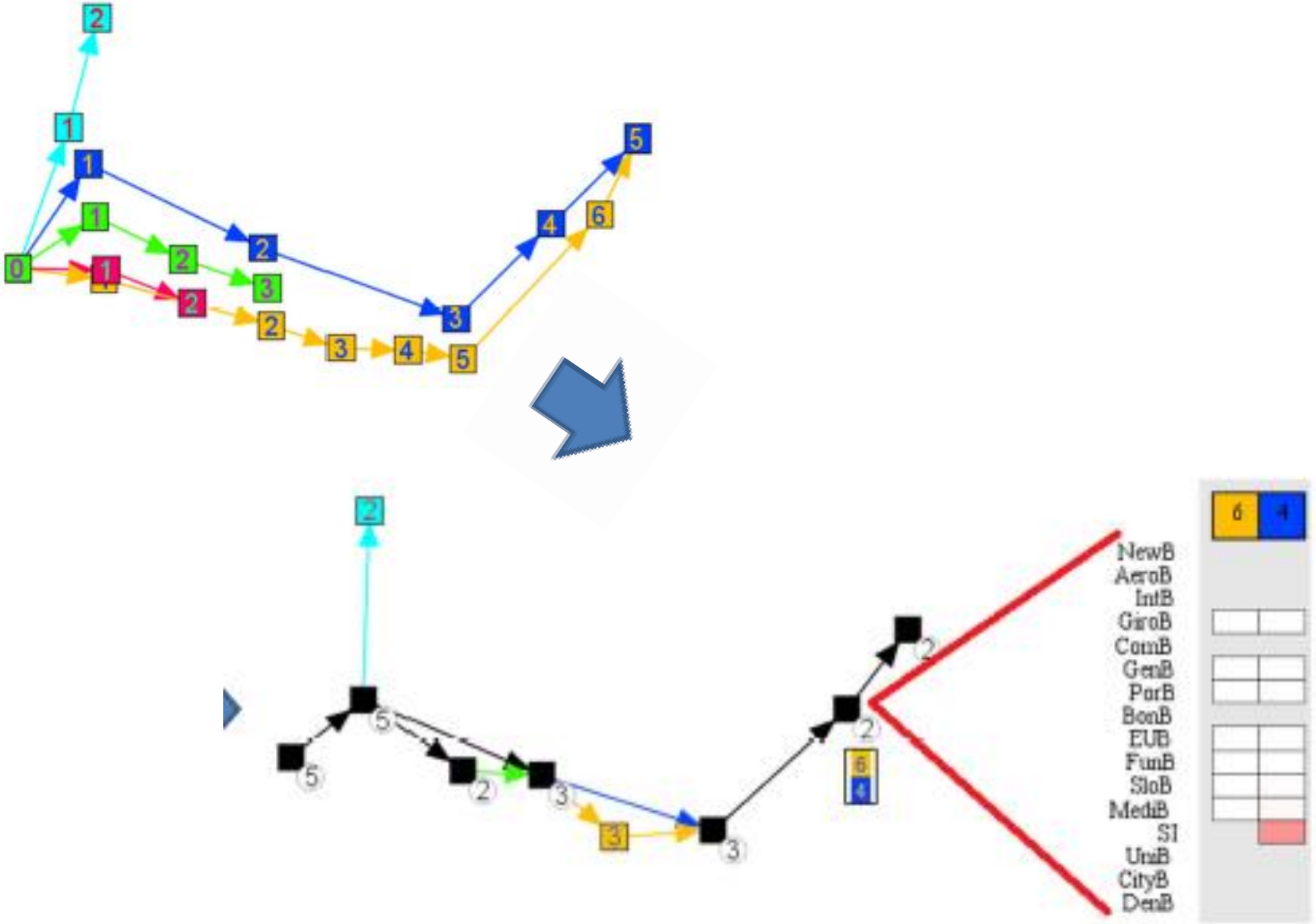
(a) MDS classic (b) MEU combined (c) Kamada-Kawai

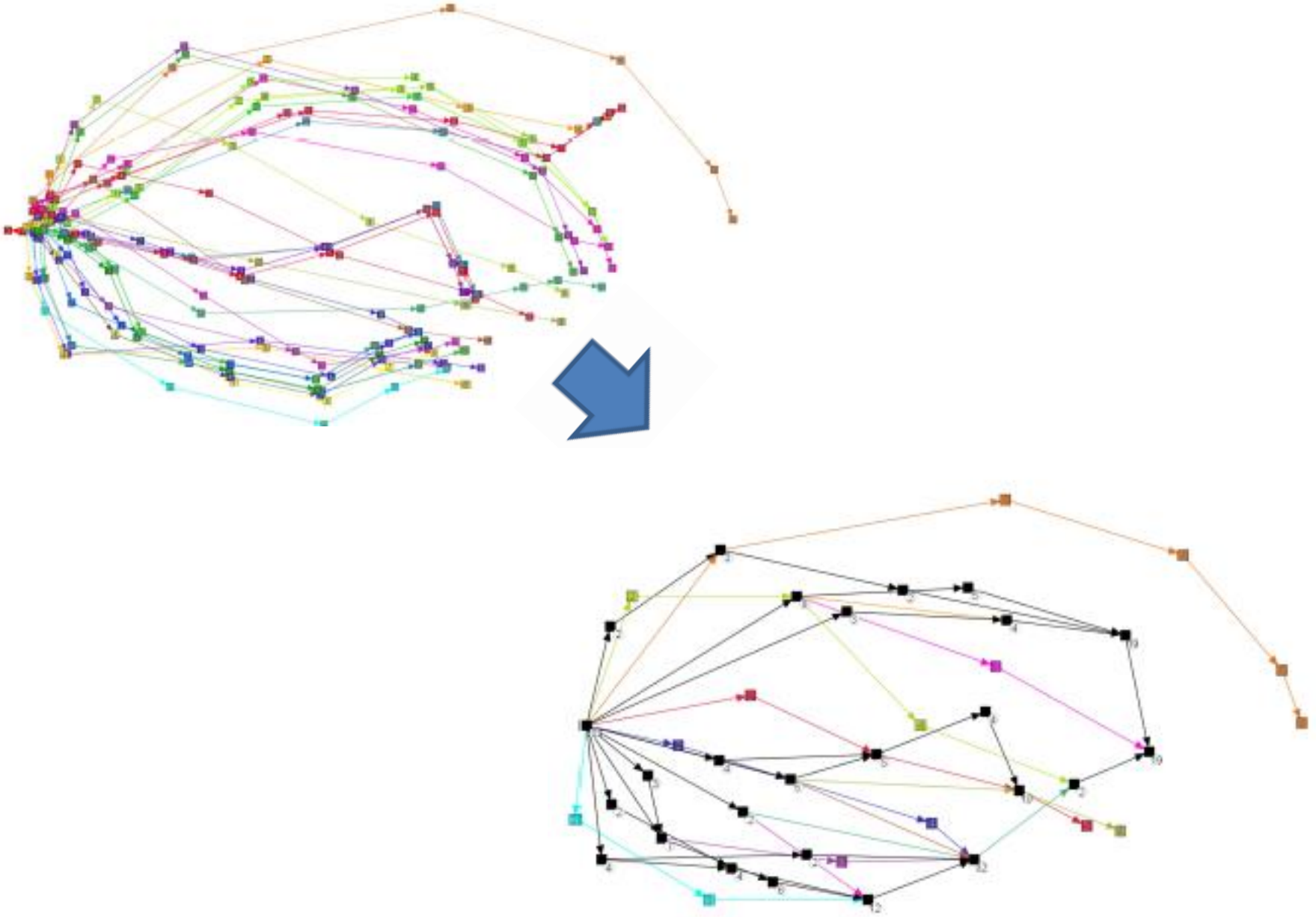
Fig. 7. Influence of the comparison specification on the graph layout when comparing similarity of nodes. Source: [84].

S. Fahnenschreiber, M. Laux, and T. von Landesberger, “On the suitability of connectivity-extended local embedding for drawing multivariate graphs,” in VMV, 2014, pp. 127–134.

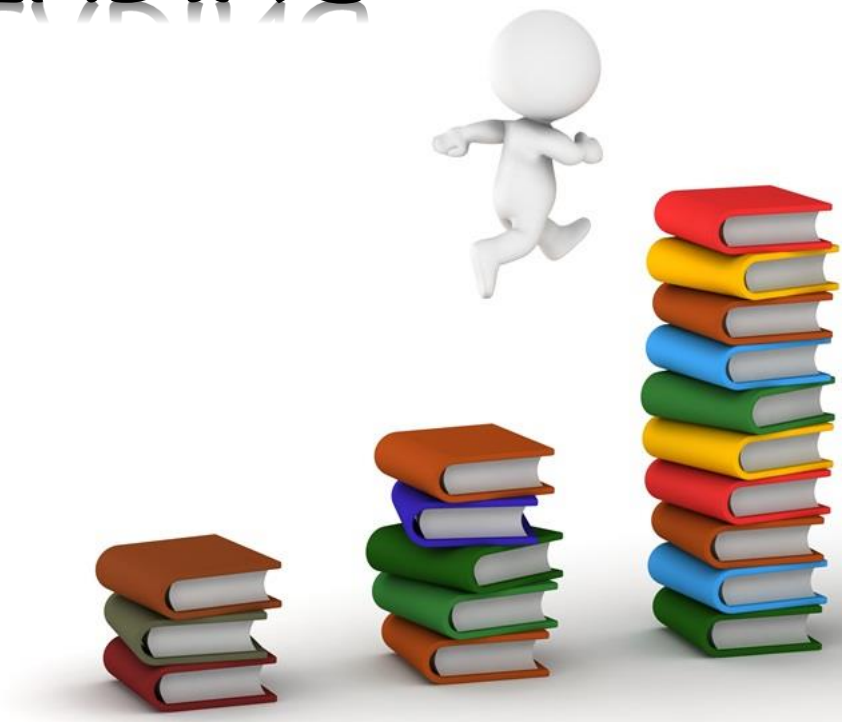
Many-to-Many Comparision of Cascade Simulations




NewB
AeroB
IntB
GiroB
ComB
GenB
PorB
BoomB
EUB
FunB
SloB
MediB
SI
UniB
CityB
DemB



FURTHER READING



https://libraryeuroparl.files.wordpress.com/2015/03/eprs-ida-554169-higher-education-in-the-eu.png

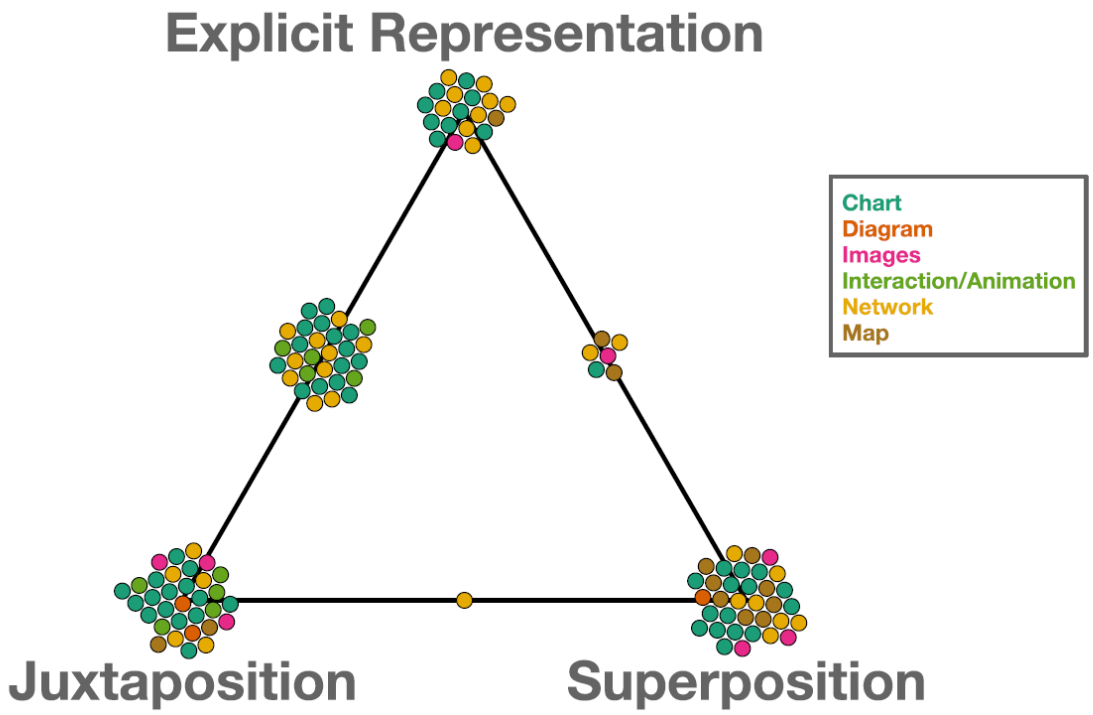


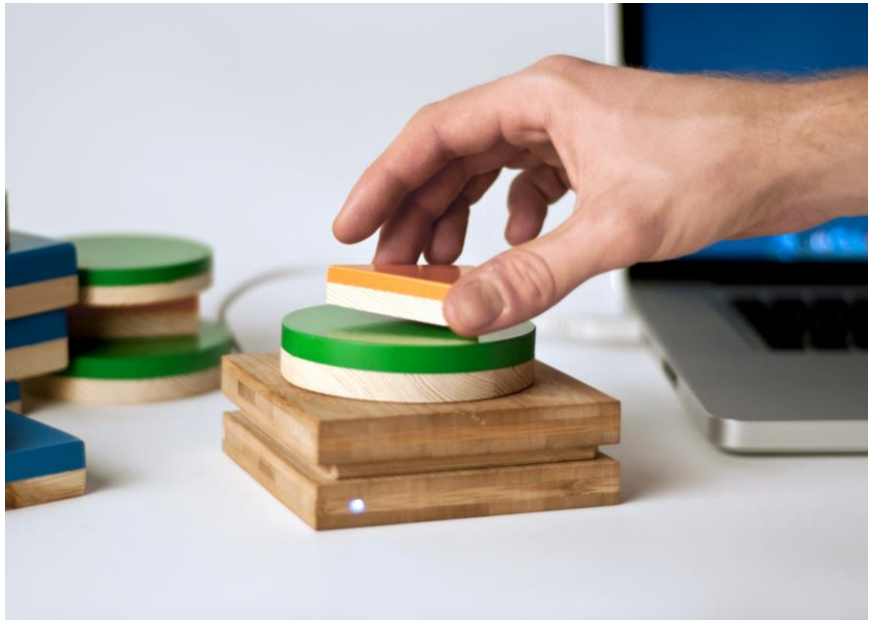
Figure 3: The design space provides three primary categories (juxtaposition, superposition, and explicit representation) with the three intermediary categories. The visualization is taken from our database of systems that we have researched. Our database includes

"A list of systems surveyed is listed in the appendix of this paper. In total, 111 systems, and 173 designs were considered (again, many systems included multiple designs). Space concerns preclude us from discussing each system, and the comparisons they contain, adequately. Instead, we provide a companion website (http://graphics.cs.wisc.edu/Vis/CompIV) for this paper that contains a full list of the various systems and comparison designs we have surveyed, along with a brief explanation of how each was categorized."

Reference: Gleicher, Michael, et al. "Visual comparison for information visualization."

INTERACTIONS

Speaker: Margit Pohl



https://libraryeuroparl.files.wordpress.com/2015/03/eprs-ida-554169-higher-education-in-the-eu.png

Interactions – Gleicher 1

Gleicher (2018)

Traditionally, comparison has been categorized as a single broad category. This is insufficient.

Actions:

- identify
- measure
- dissect
- connect
- contextualize
- communicate

Interactions – Gleicher 2

Gleicher (2018)

Juxtaposition, superposition, explicit encoding

Juxtaposition:

- brushing and linking

Superposition

- goal: reduce clutter
- focus+context, details on demand

Interaction: address scalability issues

Interactions – Tominski et al 1

Tominski, Forsell, Johansson (2012)

Naturally inspired interaction

- Interactive specification of comparison object
- Interactive relocation to suit comparison
- Interactive resolving of occlusion to facilitate comparison

Interactions – Tominski et al 2

Side-by-side

Shine-through

Folding

3D, 4D

Kim et al (2017)

Occlusion in 3D data displays

Comparison mode: Interchangeable (Animation)

- Info presented sequentially
- advantage: no clutter

Superposition

- filtering
- adjusting visualization parameters

3D, 4D

Kim et al (2017)

Interaction

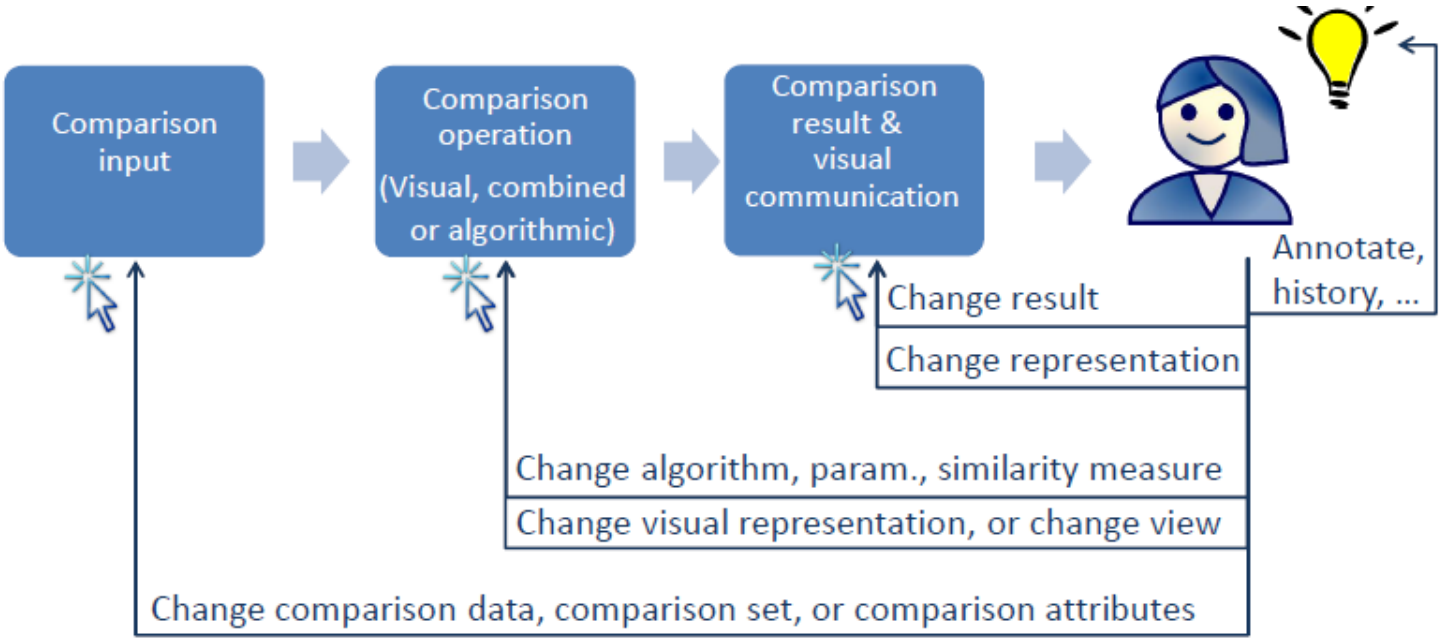


Figure 2.46.: Types of interactions in visual comparison workflows.