

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

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VIS Tutorial 2018



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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

The Comparison Problem

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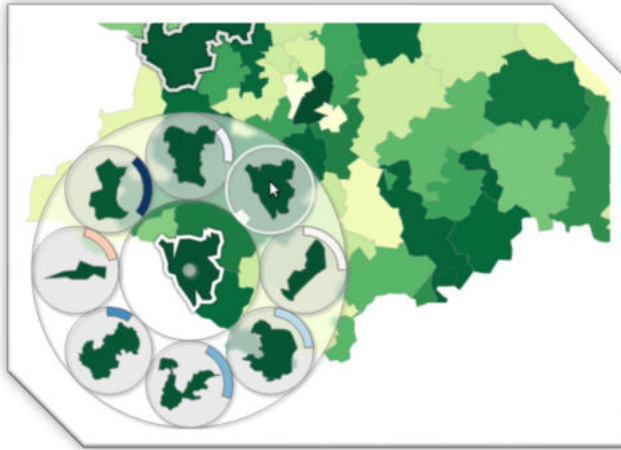
Comparison Types

1-to-1
comparison

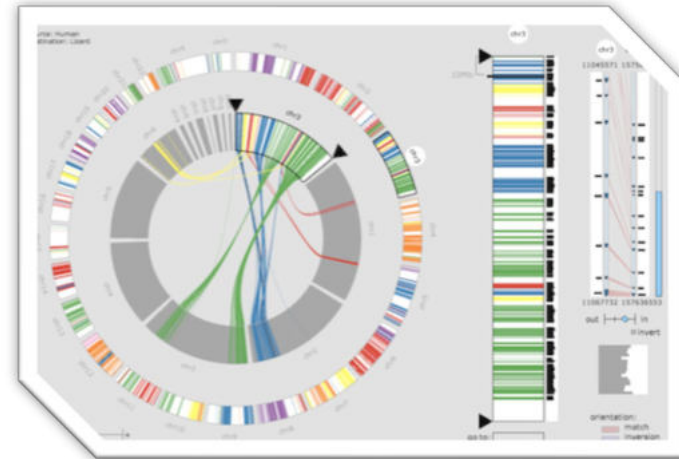
1-to-many
comparison

many-to-many
comparison

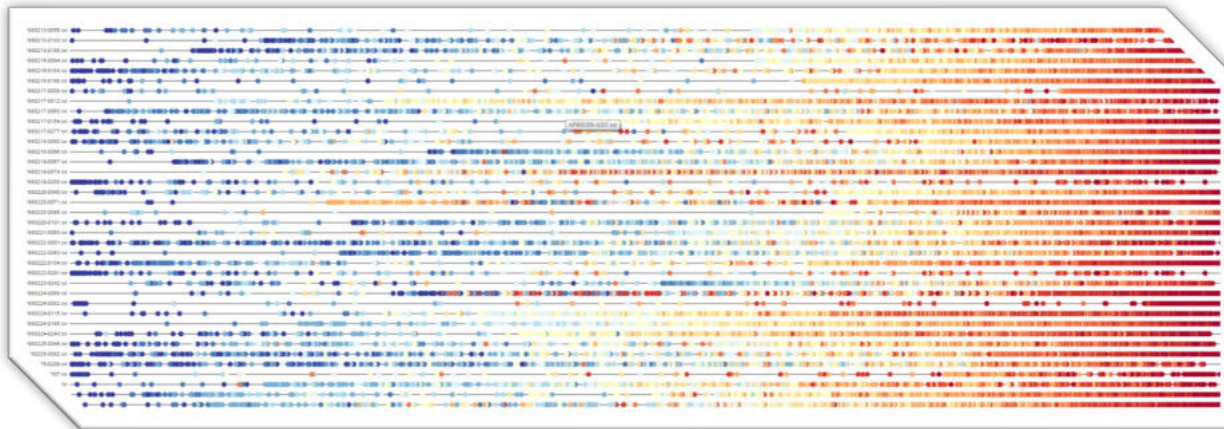
Visual Design & Interaction



CompaRing [Tominski 2016]



MizBee [Meyer et al. 2009]



Buddy Plots
[Alexander &
Gleicher 2016]

Task Characteristics

WHY to compare?

WHAT to compare?

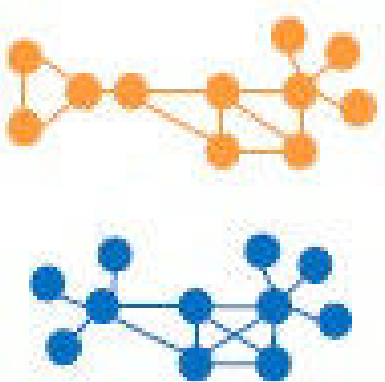
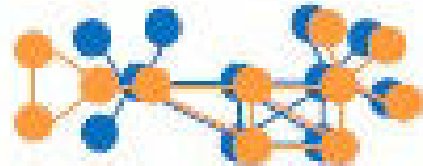
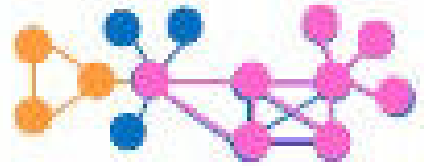
HOW to compare?

How to compare?

TYPES OF VISUAL COMPARISON

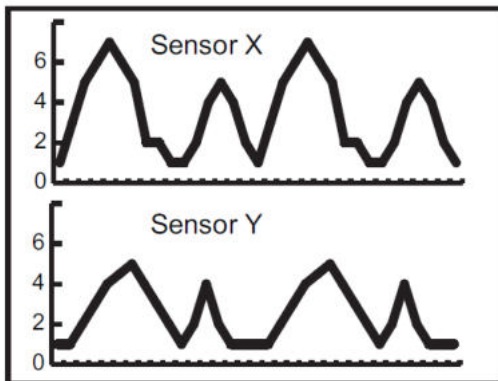
Speaker: Kathrin Ballweg

Basic Comparative Visualization Techniques

Juxtaposition	Superposition	Explicit Encoding
 <p data-bbox="367 1092 405 1163">J</p>	 <p data-bbox="956 1092 1014 1163">S</p>	 <p data-bbox="1555 1092 1613 1163">E</p>

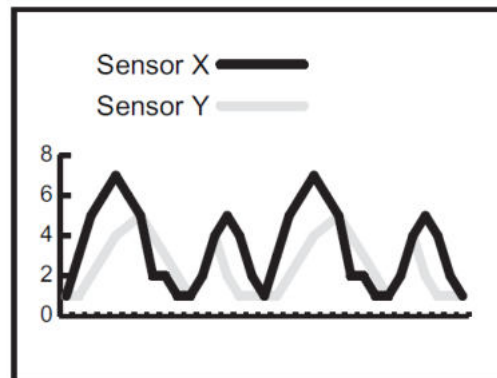
Basic Comparative Visualization Techniques: For all data types

Juxtaposition



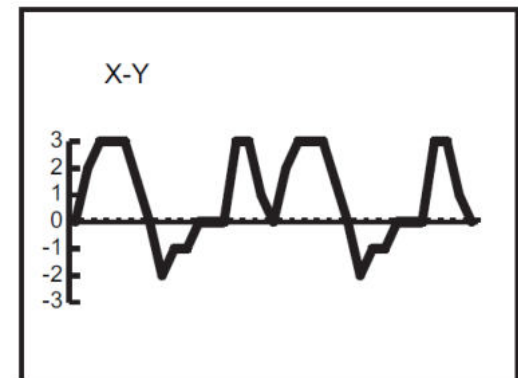
J

Superposition



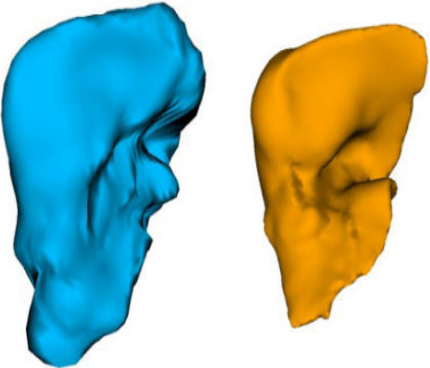
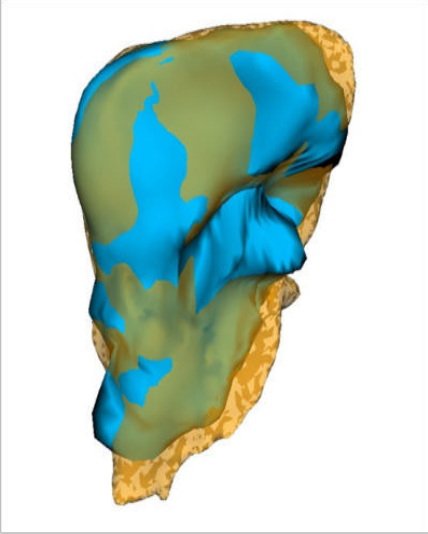
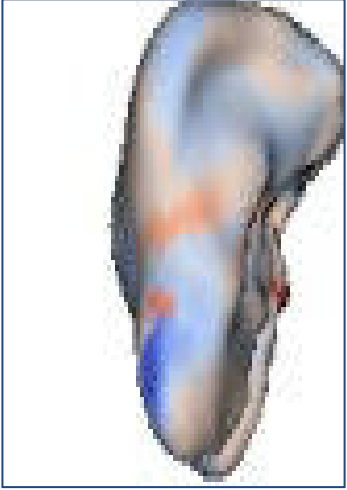
S

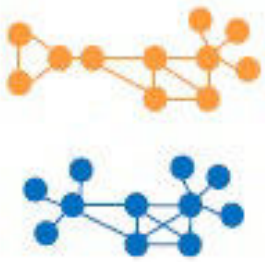
Explicit Encoding



E

Basic Comparative Visualization Techniques: For all data types

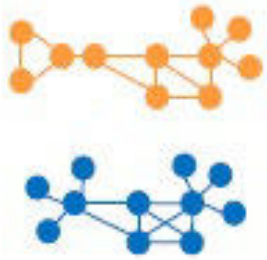
Juxtaposition	Superposition	Explicit Encoding
 <p data-bbox="369 1096 401 1163">J</p>	 <p data-bbox="962 1096 994 1163">S</p>	 <p data-bbox="1566 1096 1599 1163">E</p>



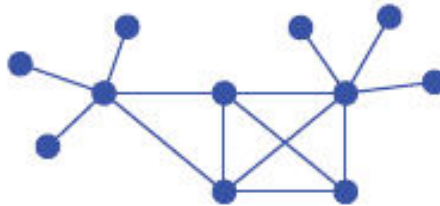
Juxtaposition

- 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

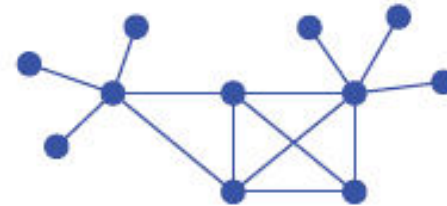
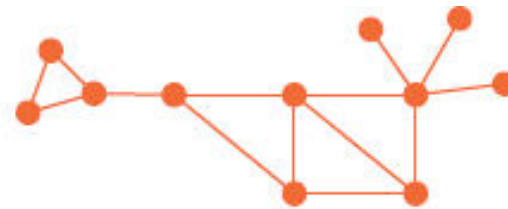
No correspondence attribute (for nodes and edges)	With correspondence attribute (for nodes and edges)



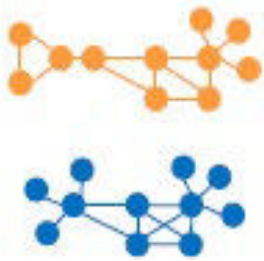
Juxtaposition



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



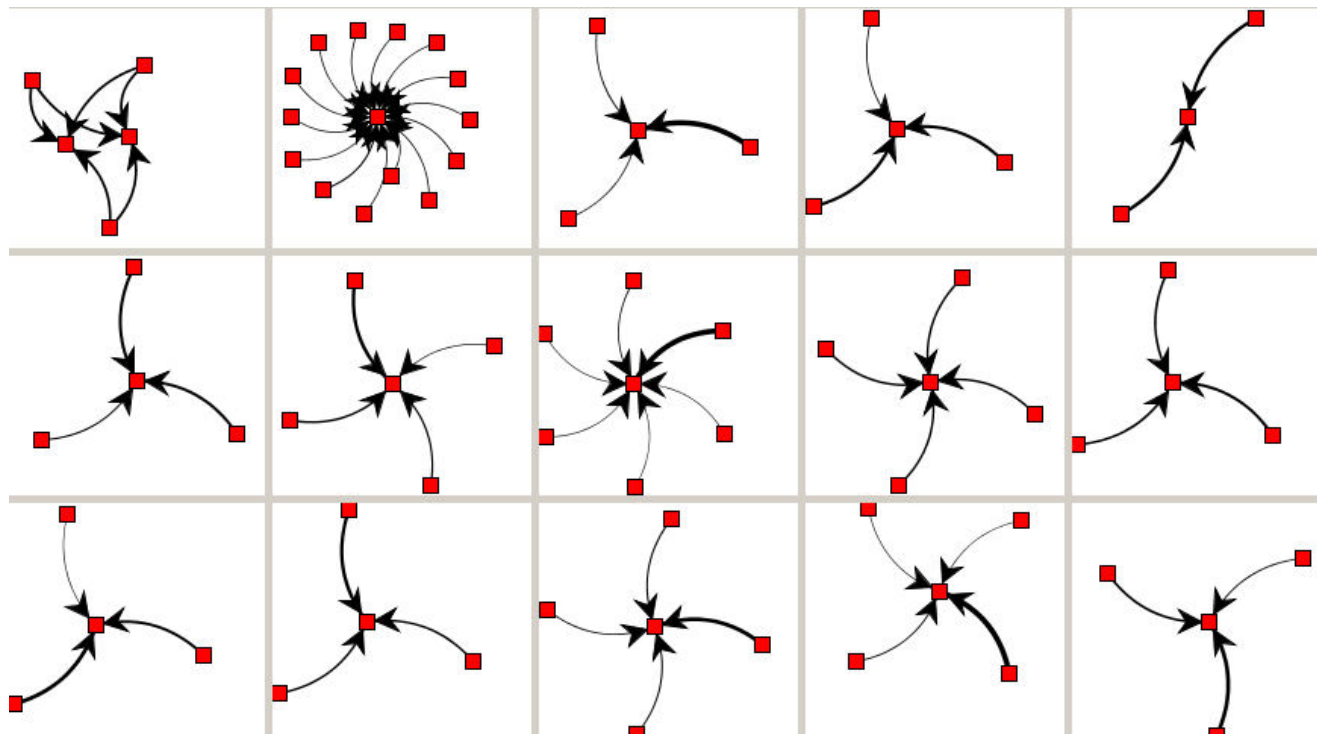
(b) Juxtaposition (using
similar layouts to aid
comparison)

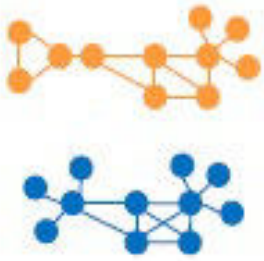


Juxtaposition: Scalability

Example: Comparison of Company Holdings

Comparing multiple graphs by structure



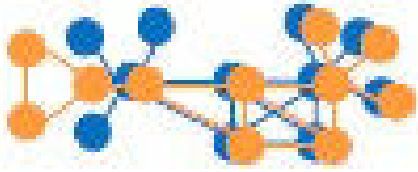


Juxtaposition: Scalability

Example: Comparison of Company Holdings


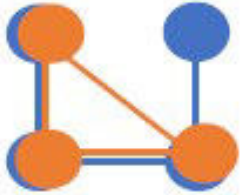
Comparing multiple graphs by structure

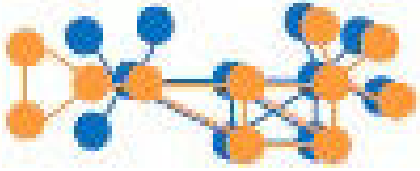




Superposition

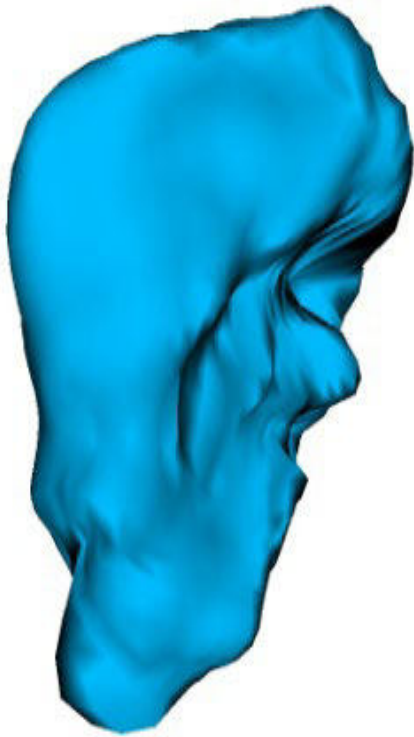
- Shows the terms **on TOP of each** other
- Easier to spot differences
- Less space needed
- Requires correspondence
- Depends on what is on top/bottom - overplotting

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

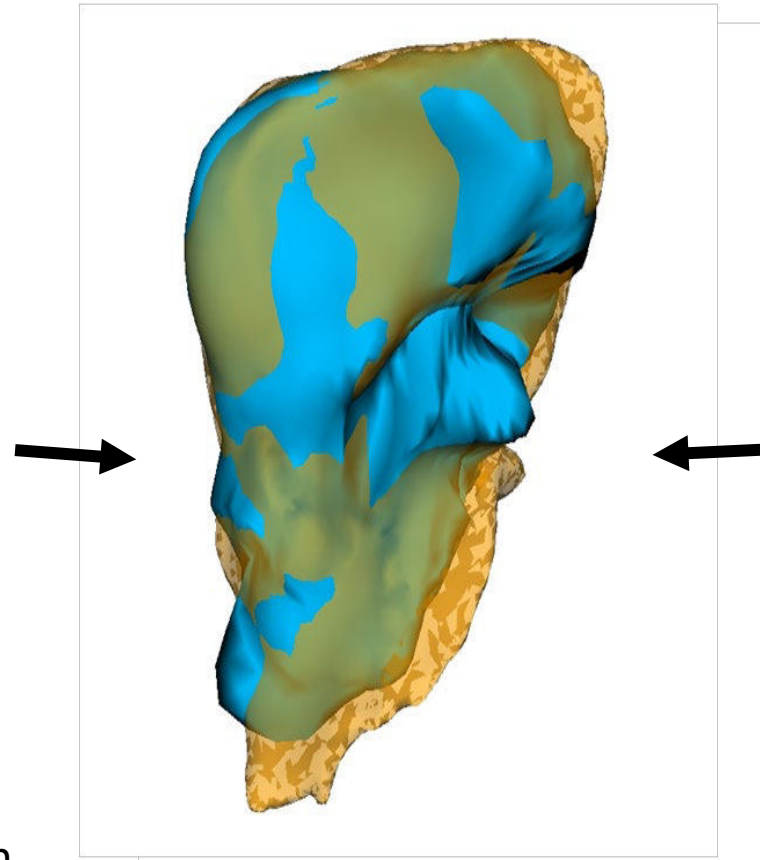


Superposition

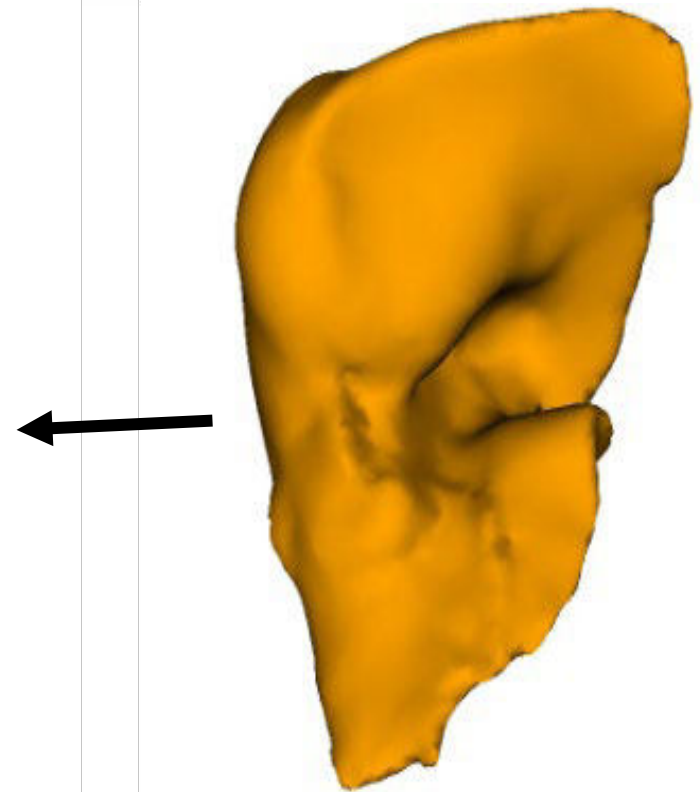
Example: 3D medical image segmentation



Automatic segmentation



Evaluation



Reference segmentation

Juxtaposition and Superposition

Strengths and weaknesses

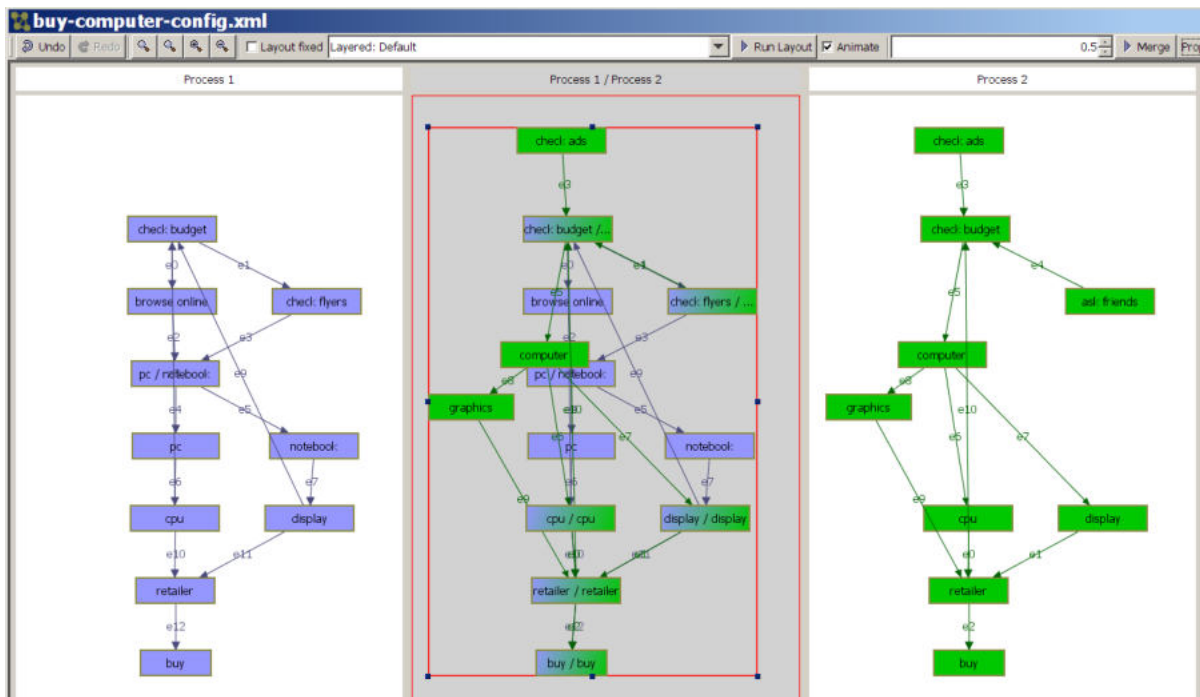
Task: Graph structure - existence

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

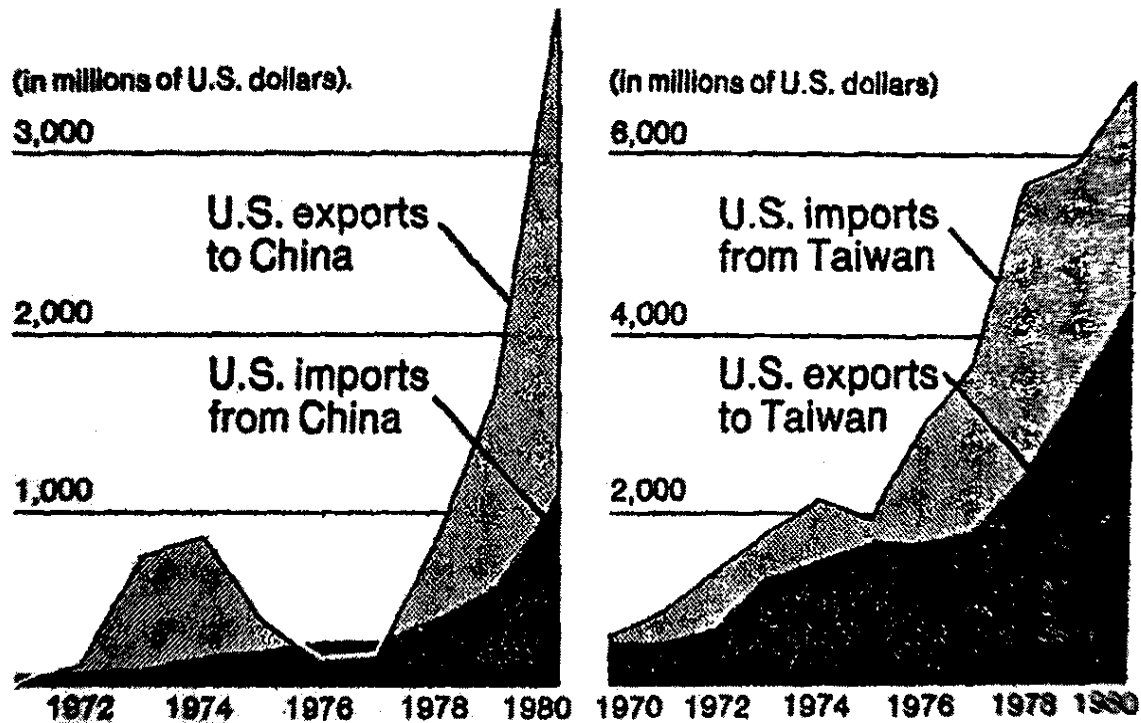


Reference: Andrews: comparison of graphs

Juxta- and Superposition

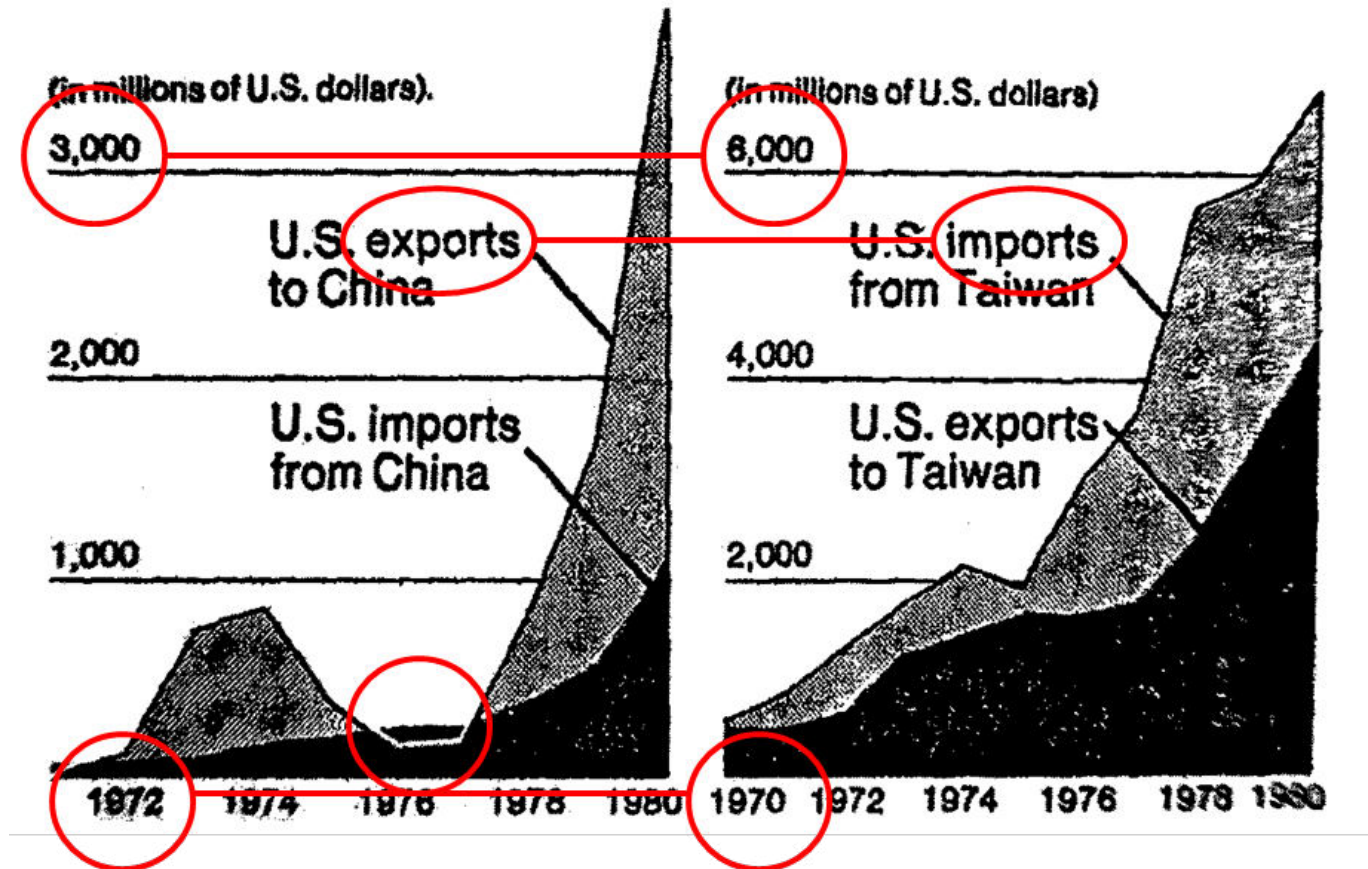
Example: Juxtaposition and superposition challenges

U.S. trade with China and Taiwan



Juxta- and Superposition

Example: U.S. trade with China and Taiwan





Comparison with attributes

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



Comparison with attributes

Comparison Input			Only structure	With attributes
	Juxtaposition			
		Superposition	Simple	
	Transparent			

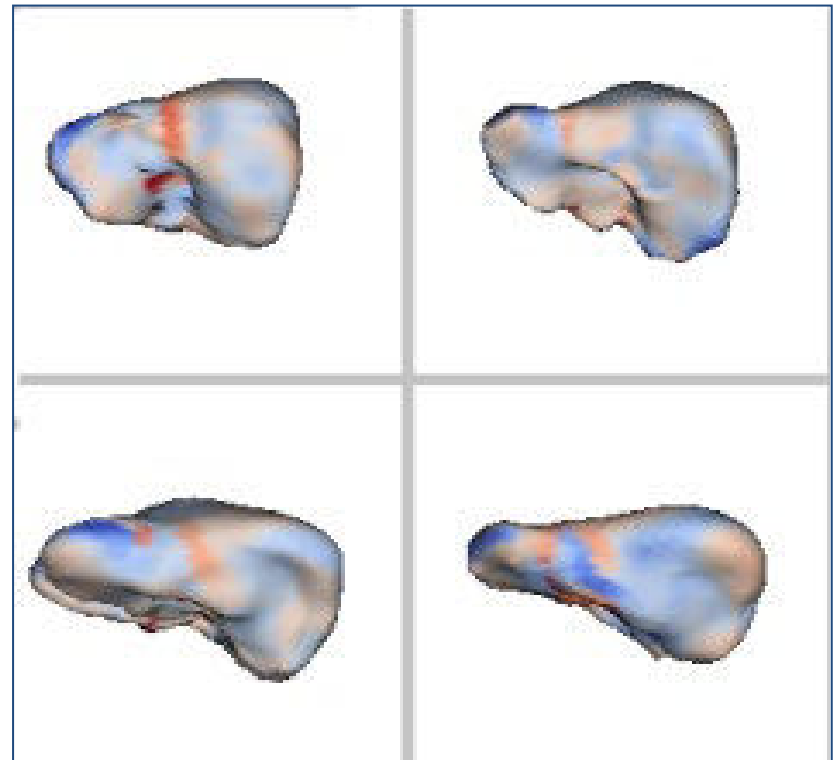


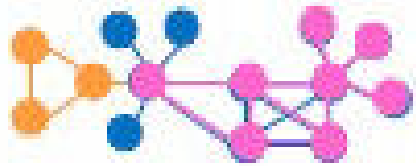
Comparison with attributes

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

Example: Comparison of segmentation quality values:

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





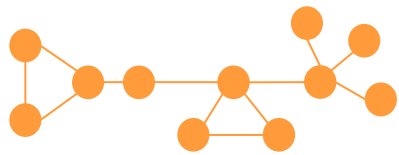
Explicit Encoding

- Shows the items **WITH HIGHLIGHT OF COMMONALITIES OR DIFFERENCES**
- Requires correspondence
- Requires algorithmic pre-processing (→ Part 2)
- Requires task knowledge (→ Part 1)

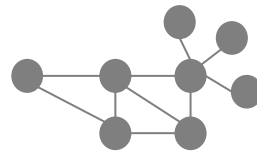
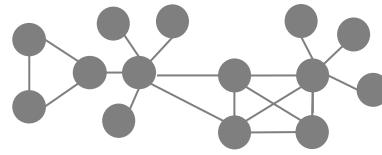
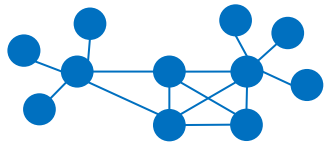
Explicit Encoding: Variants

Examples of explicit encoding variants

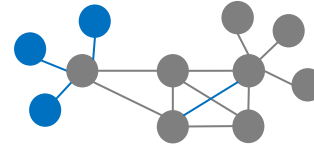
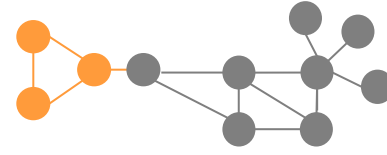
Source → Results:



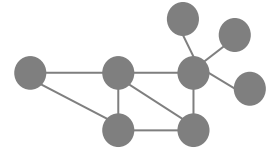
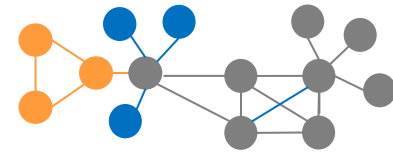
Vs.



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



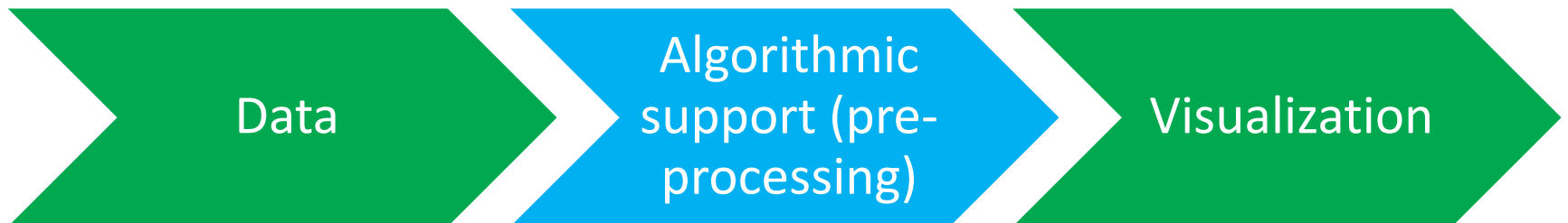
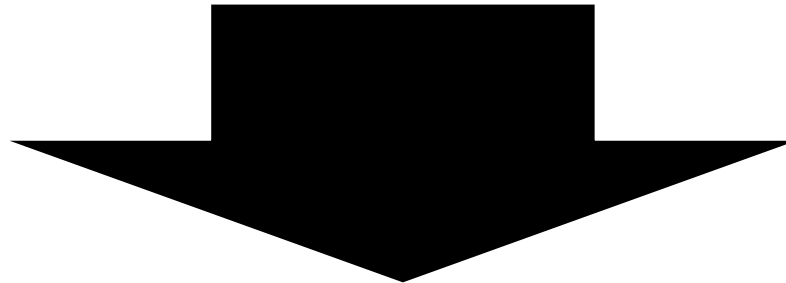
b) Juxtaposition +
Explicit Encoding:
Additive (Intersections
added)



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

ALGORITHMIC SUPPORT FOR VISUAL COMPARISON

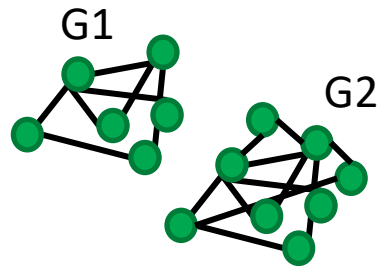
Algorithmic Support



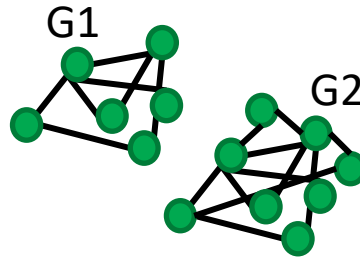
Motivation

- 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

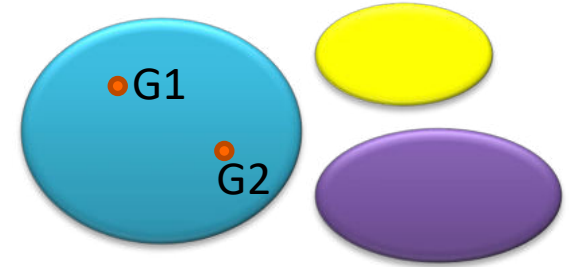


Visualization of the data with no further visual aid

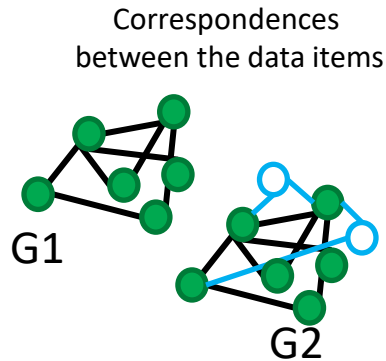


Sim. Measure – graph edit distance: 6

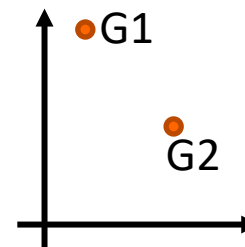
Similarity measures



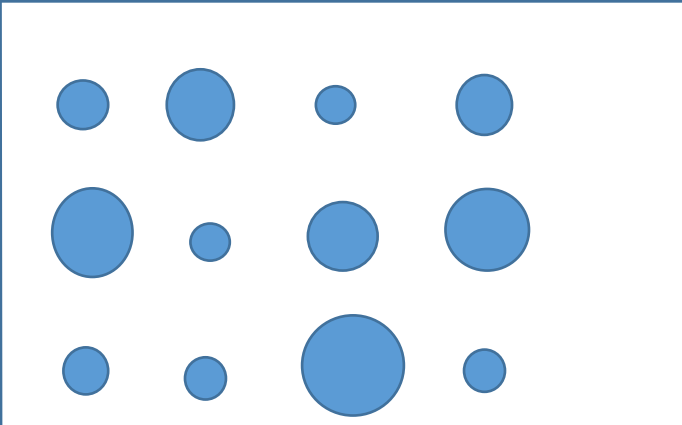
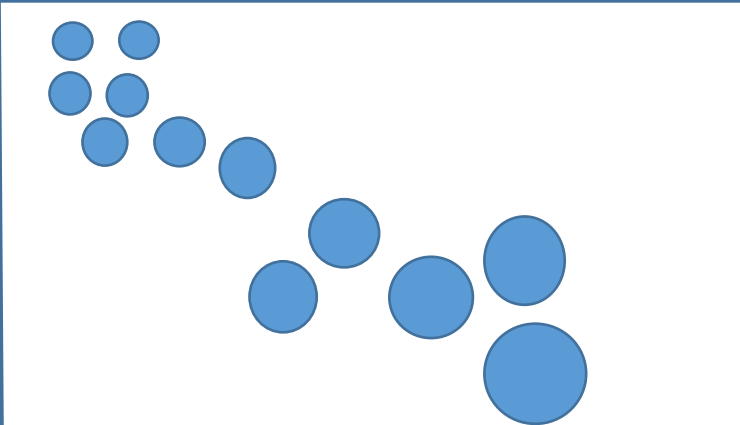
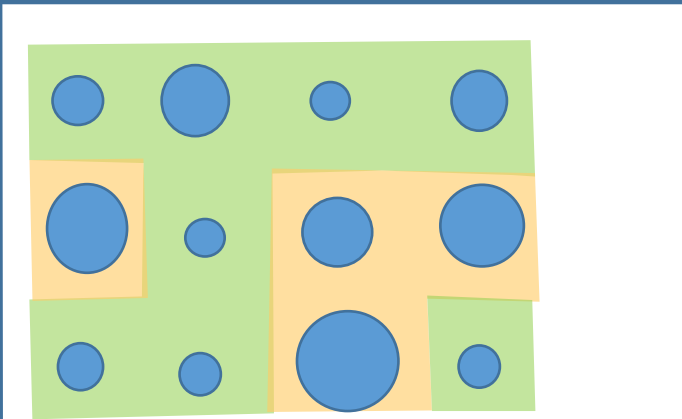
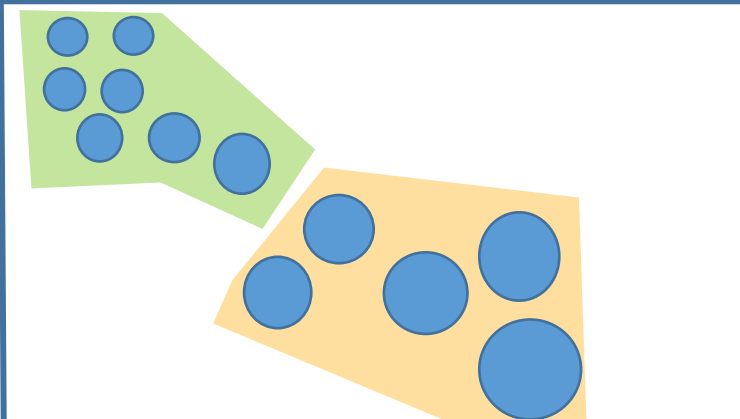
Postprocessing of the similarity measures – e.g., clustering (SOM)



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



Value of Algorithmic Support: Visual Clustering

	Original comparative view (objects positioned in a grid)	Algorithmically-supported comparative view (objects positioned according to their similarity)
Comparison input		
Result clusters		

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

The Comparison Visualization

Comparison Types

WHAT?

HOW?

1-to-1
comparison

1-to-many
comparison

many-to-many
comparison

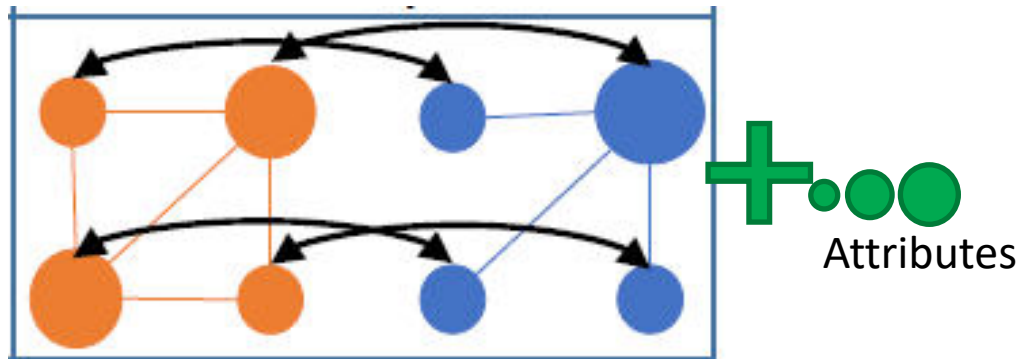


Structure
Attributes?

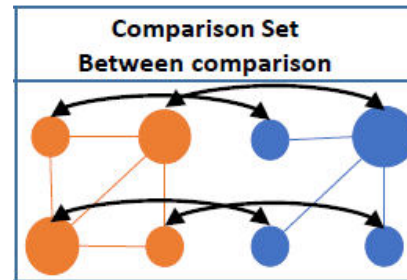


**Level of
algorithmic
support**

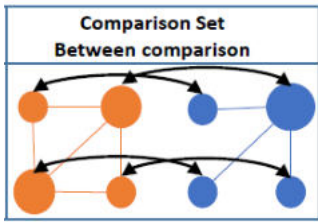
PART I: 1-TO-1 COMPARISON



Speaker: Kathrin Ballweg



STRUCTURAL COMPARISON



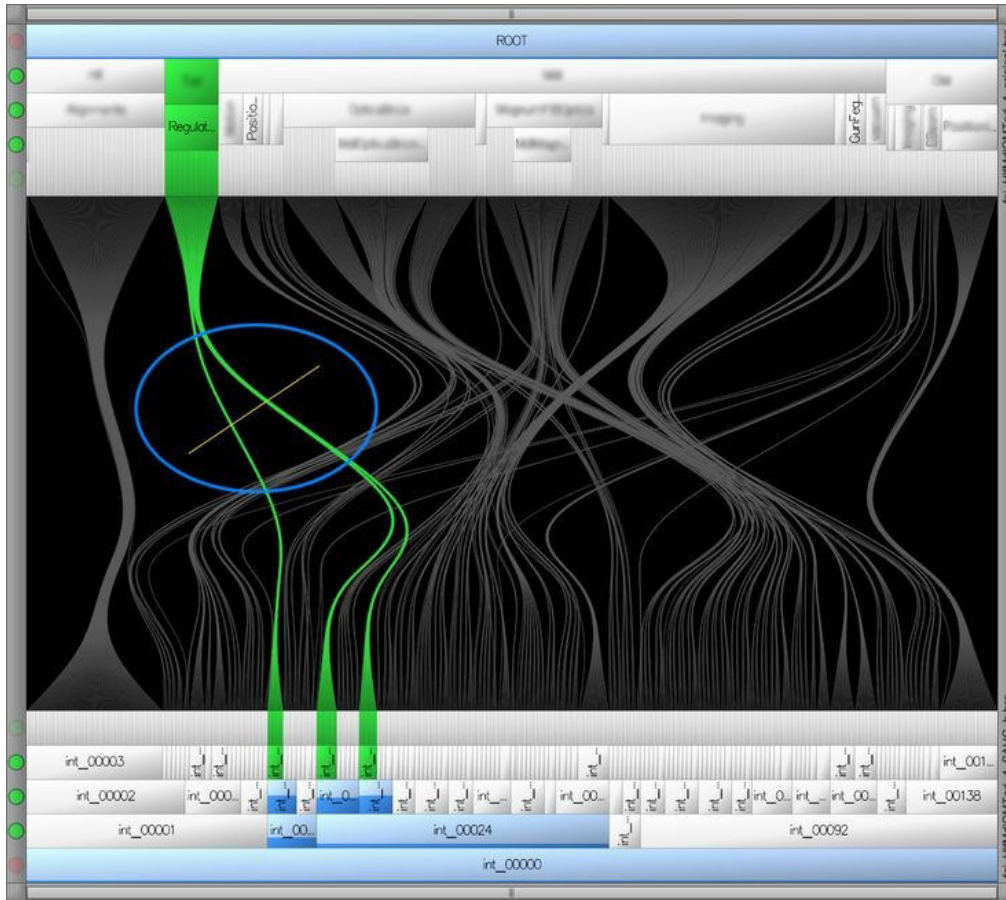
J

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

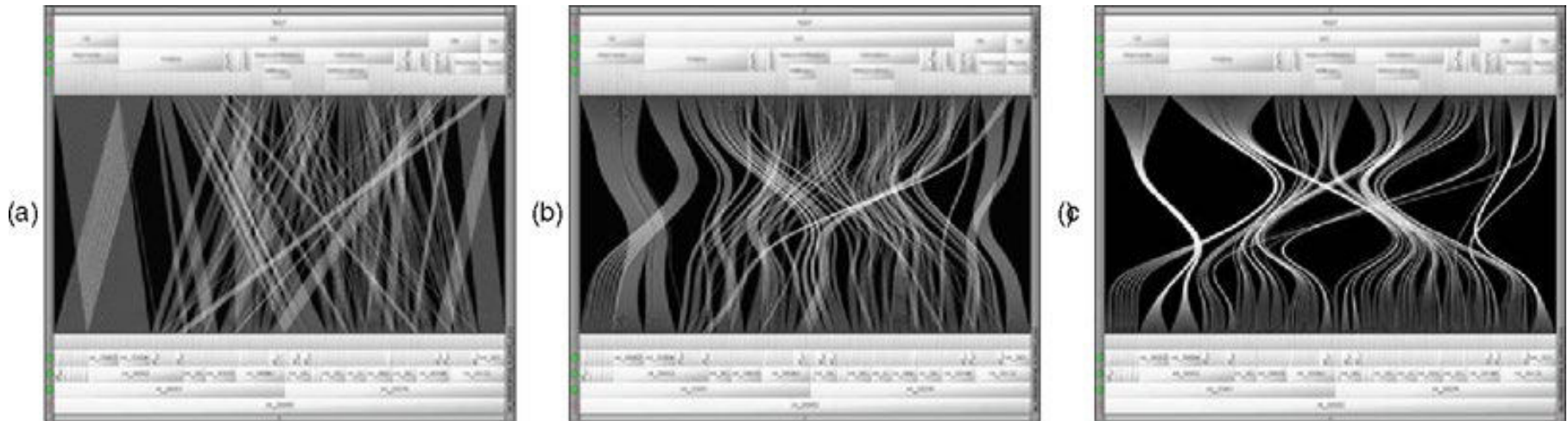


Data: software structure

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

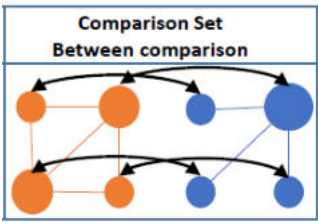


Linking of matches: Clutter reduction by edge bundling



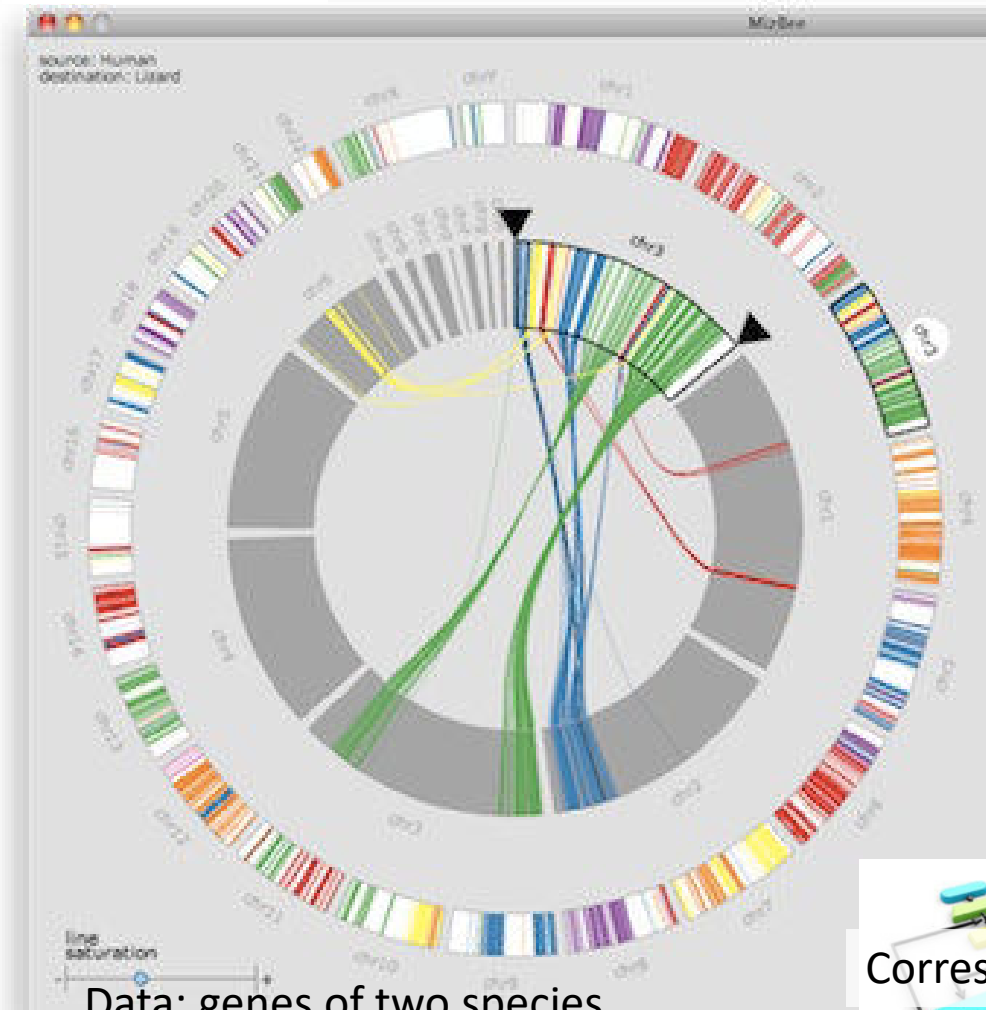
Data: software structure

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



Linking & coloring matches

J



Task: Match of genes between two species – gene differences

Characteristics:

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

Specifics:

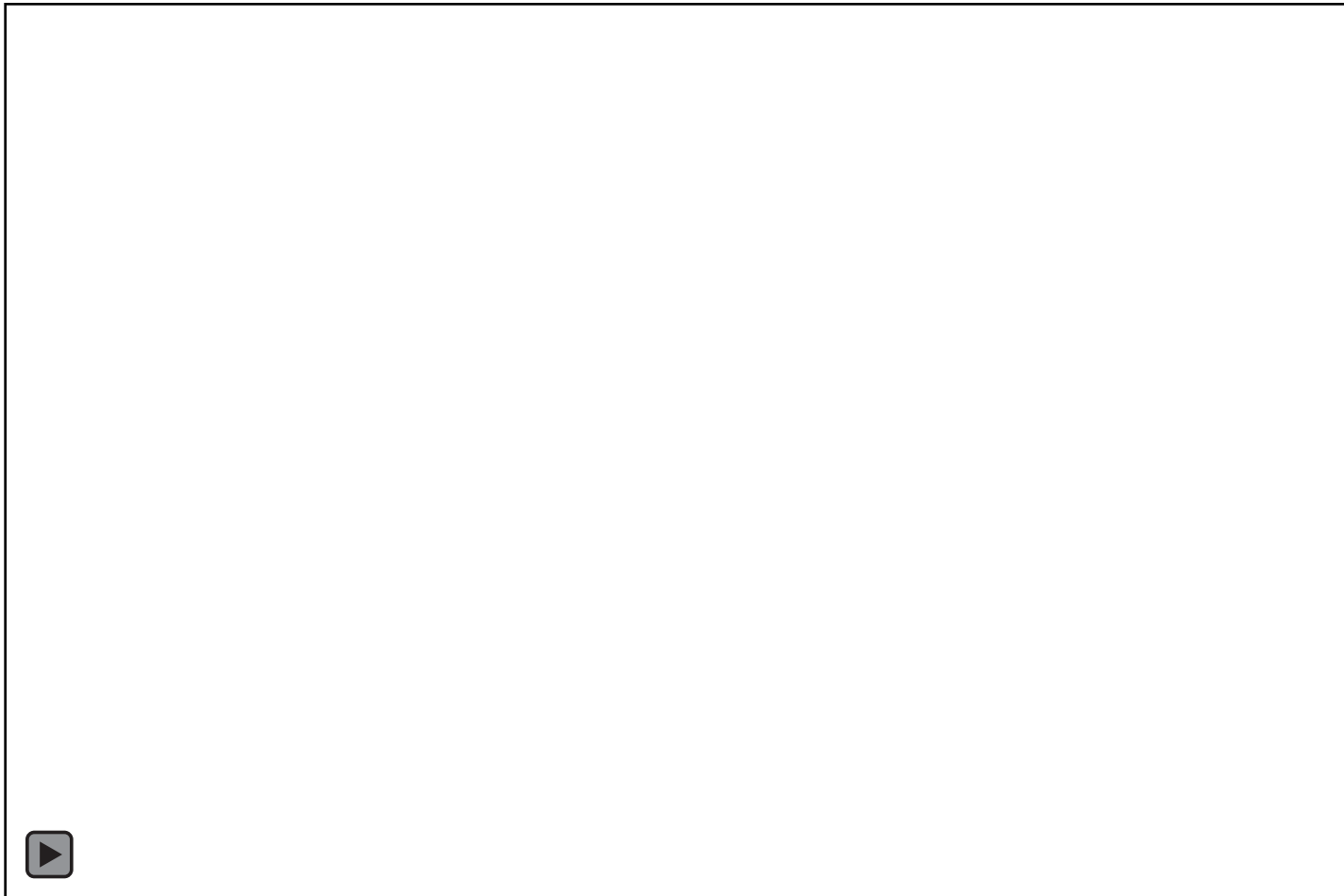
- Requires interaction: selecting the chromosome to be matched
- uses several views (see video)

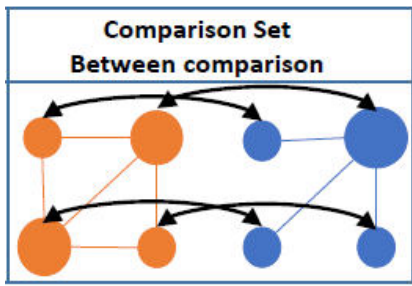
[VIDEO](#)



Data: genes of two species
Reference: Munzner MizBee

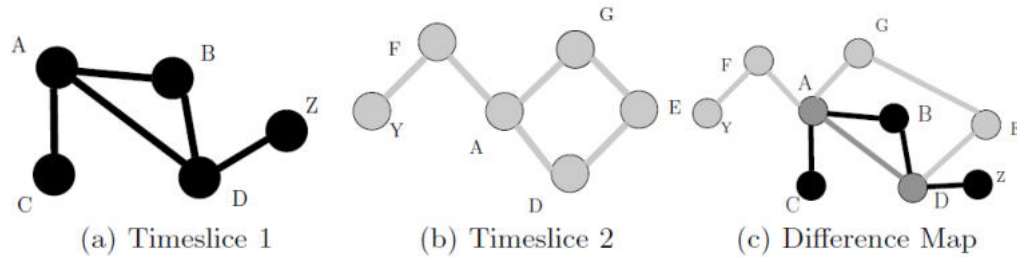
Mizbee: Video





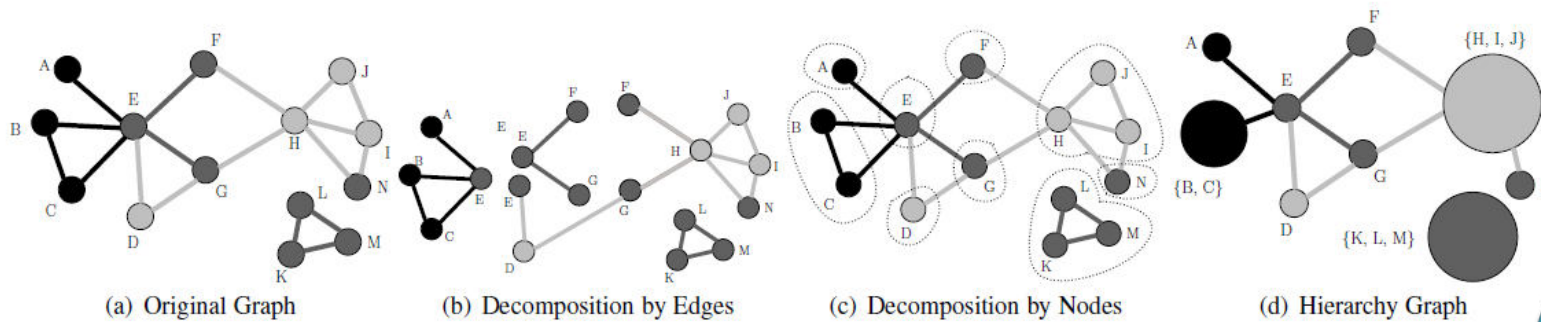
S+E

Difference-based Aggregation: Scalability

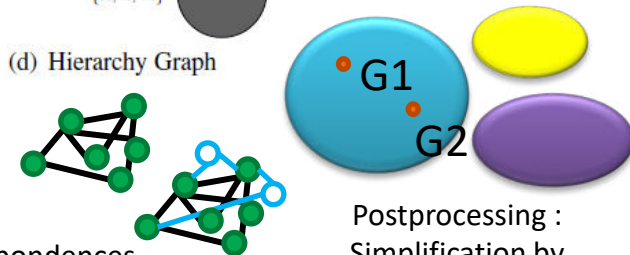


Task: Difference between large graphs

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



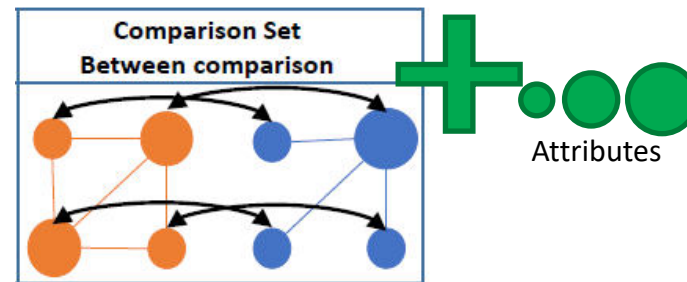
G2



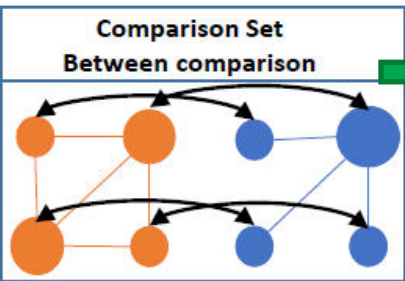
Reference: Structural Differences Between Two Graphs through Hierarchies

Correspondences between the data items

Postprocessing: Simplification by aggregation



STRUCTURE AND ATTRIBUTES



J & S & E

Visual encoding of differences

Comparing 2012 vs 2011 Using budget in thousands of dollars

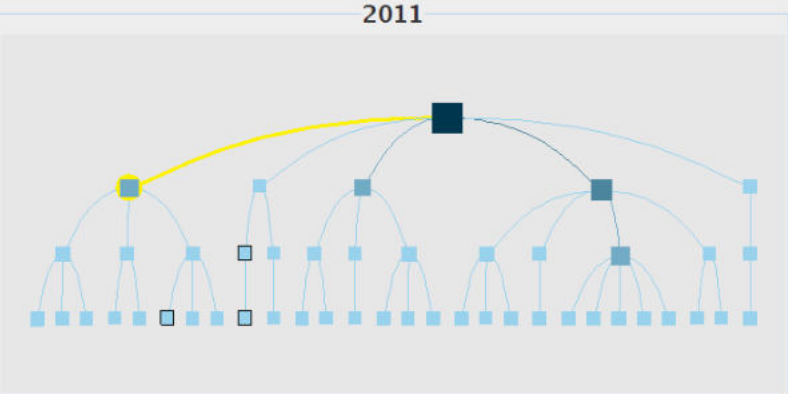
Size by: Budget

Border by: Topological Difference

Only on this tree

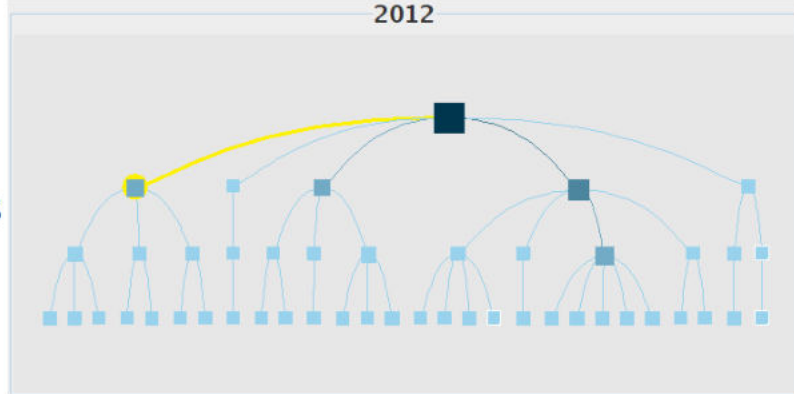
Color by: Budget

\$3,280 to \$4,100
\$2,460 to \$3,280
\$1,640 to \$2,460
\$820 to \$1,640
\$0 to \$820



46 visible nodes

VS



47 visible nodes

Absolute Differences 2012-2011

Size by: Percentual Difference

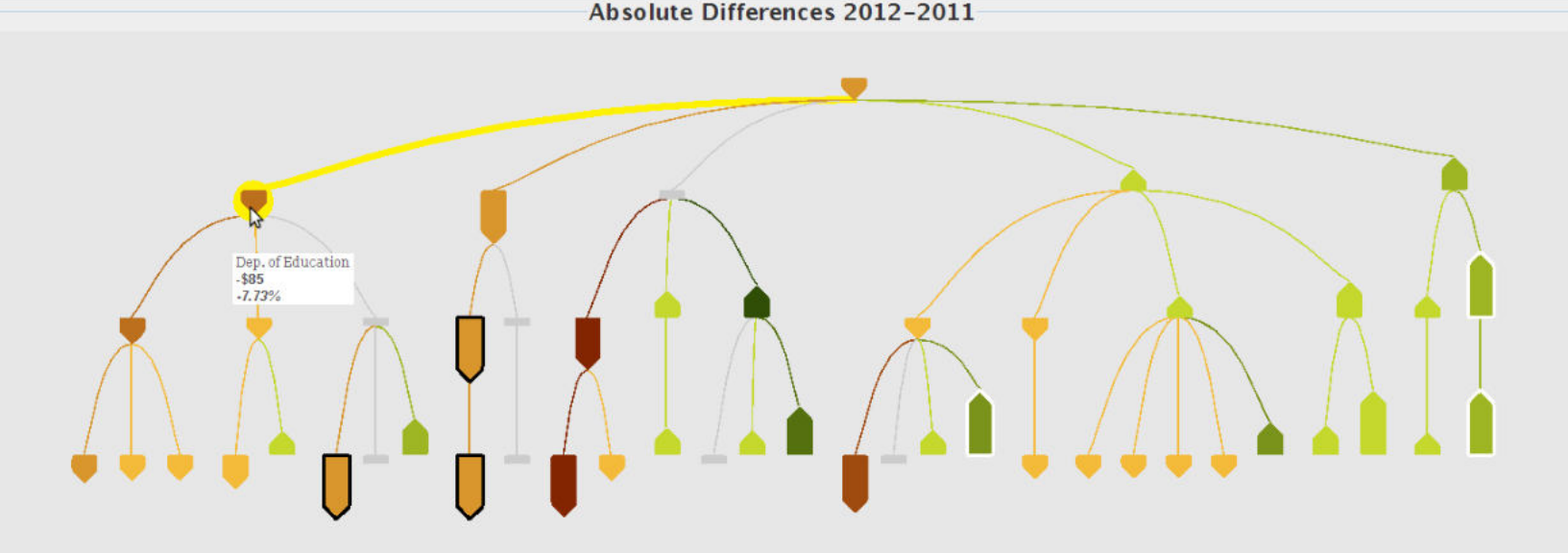
Border by: Topological Difference

Only on 2011

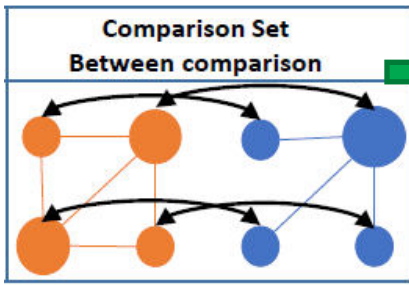
Only on 2012

Color by: Absolute Difference

\$120 to \$150
\$90 to \$120
\$60 to \$90
\$30 to \$60
\$0 to \$30
\$0
-\$0 to -\$30
-\$30 to -\$60
-\$60 to -\$90
-\$90 to -\$120
-\$120 to -\$150



50 visible nodes



J & S & E

Visual encoding of differences

Task:

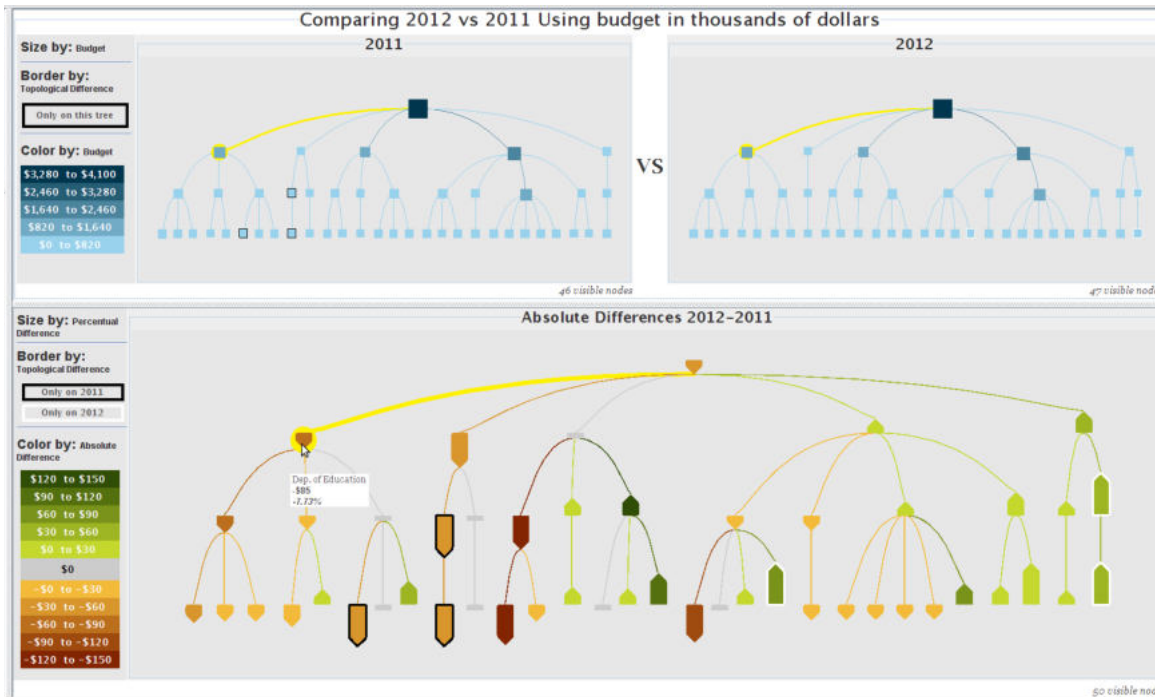
- Graph structure & attribute

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



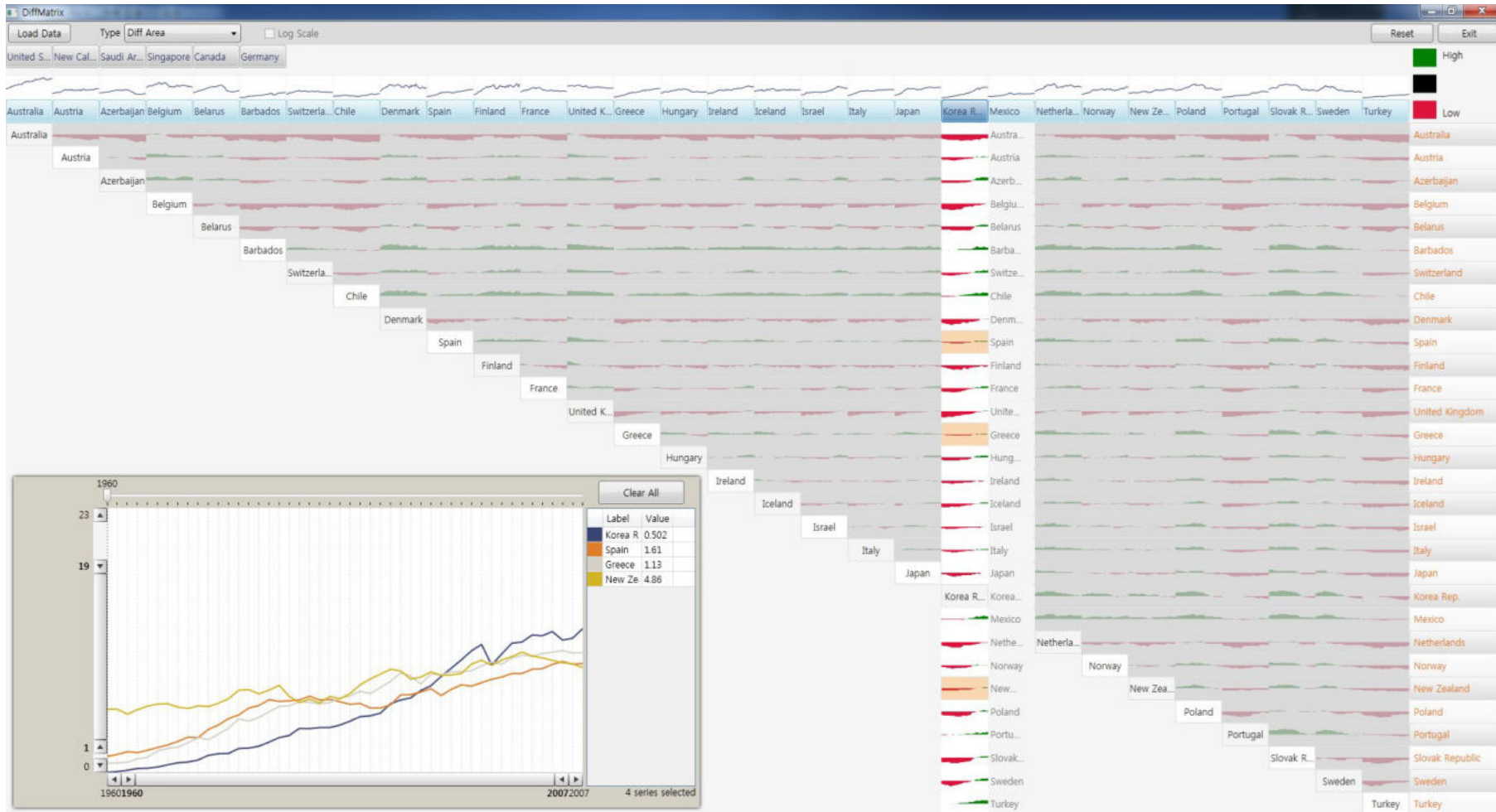
ig Two Trees

Reference: Interactive Visualizat
With Structure and Node Value

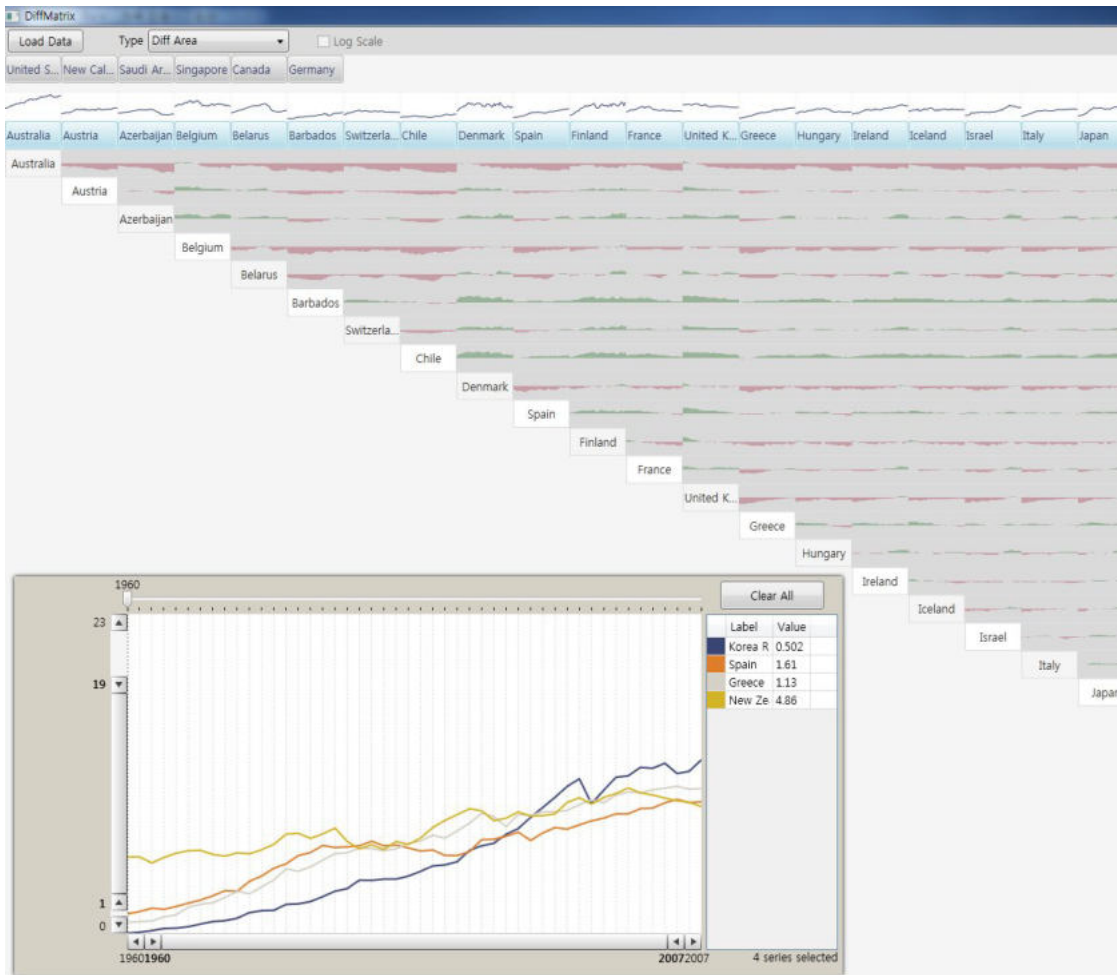
SPECIAL CASES

N times 1-to-1 Comparison

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



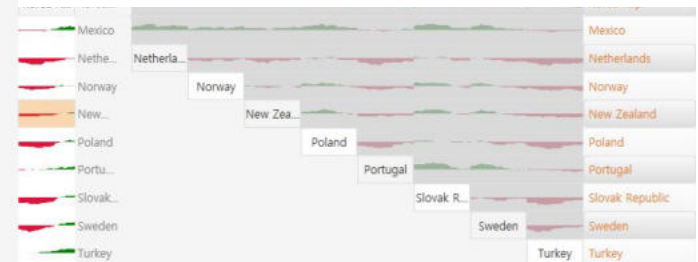
Time Series: N times 1-to-1 Matrix-based View



Task: Pairwise Comparison of many time series

Characteristics:

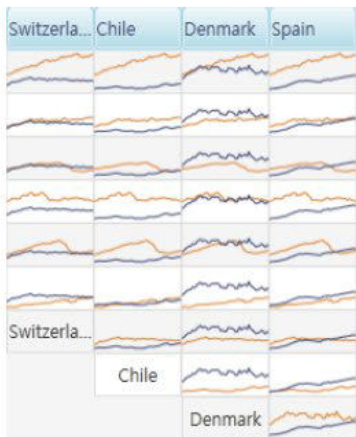
- Matrix view leads to small space for pairwise comparison views
- design evaluation
- additional detailed view needed for **selected** pairs (manual inspection required)



Data: Economic time series for countries

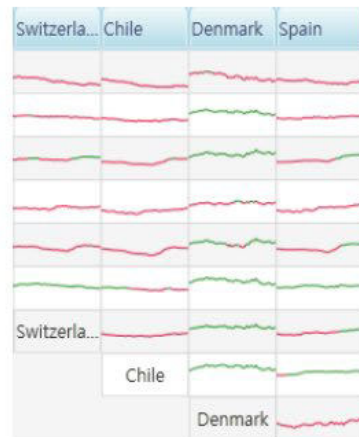
Time Series Comparison Visual Designs: Evaluation

Superposition



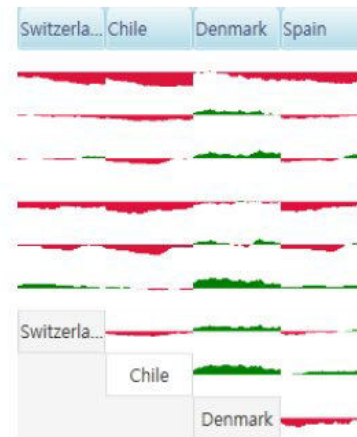
(a) Dual lines

Explicit encoding 1



(b) Diff line

Explicit encoding 2



(c) Diff area

Explicit encoding 3



(d) Diff heatmap

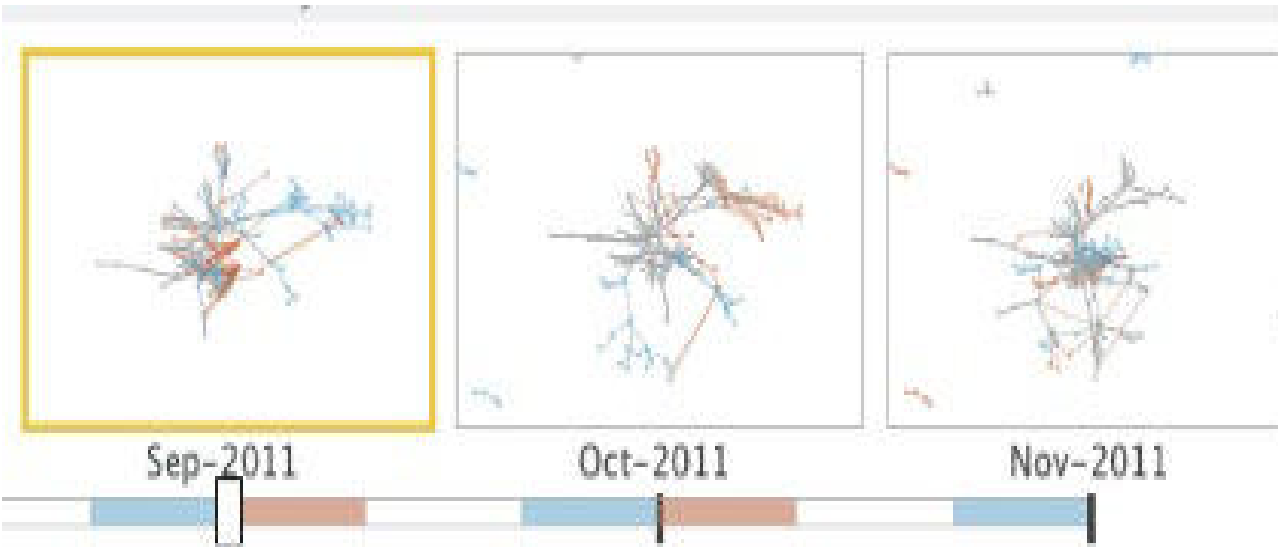
Figure 2: Four visual representations for each cell in the matrix to help users see the difference between two time series.

Result: Diff area works best in this case

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



N times 1-to-1 Comparison

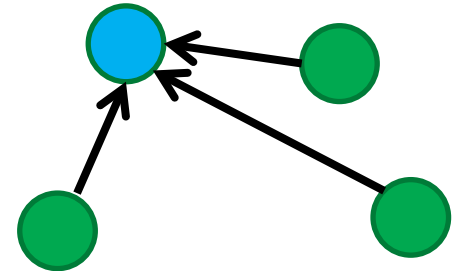


J & S & E



Reference: Bach et al. GraphDiaries

Defined Reference Object



PART II: 1-TO-MANY COMPARISON

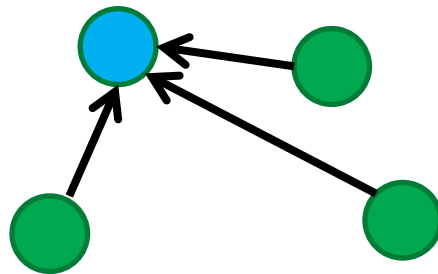
Speaker: Kathrin Ballweg

1: many Comparison

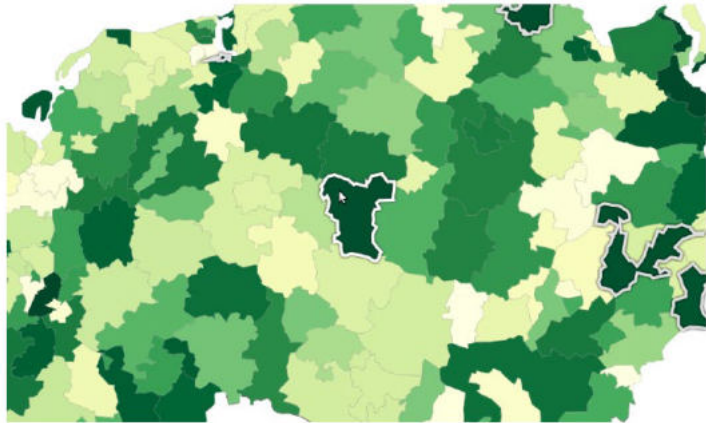
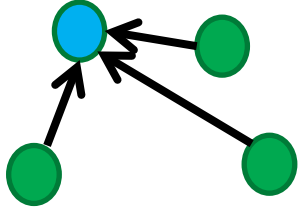
Definition:

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

Defined Reference Object



Defined Reference Object



(a) Zoomed-in view.



(b) The CompaRing with indicator arcs.

Reference: Tominski, CompaRing

Juxtaposition: Interactive Support

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

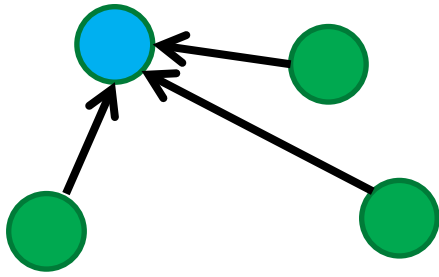
Characteristics:

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

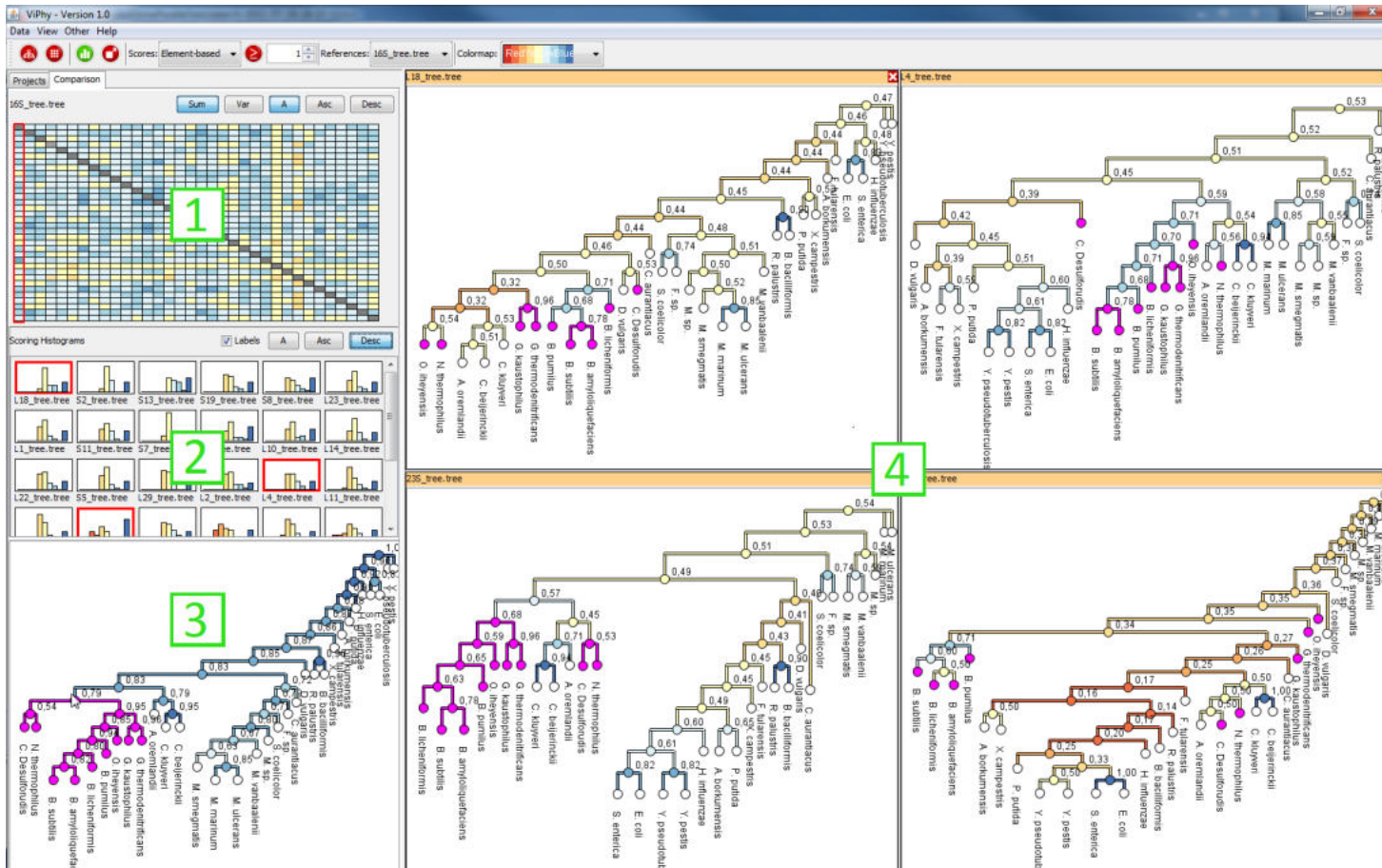
Specifics:

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

Defined Reference Object

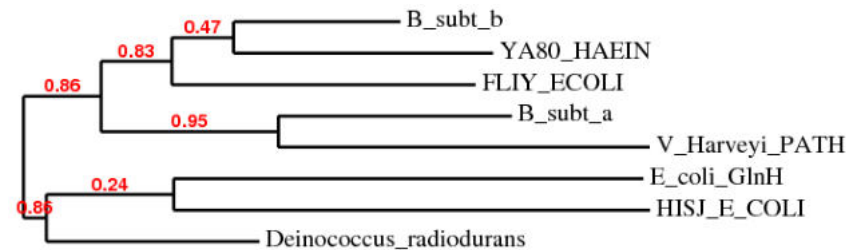
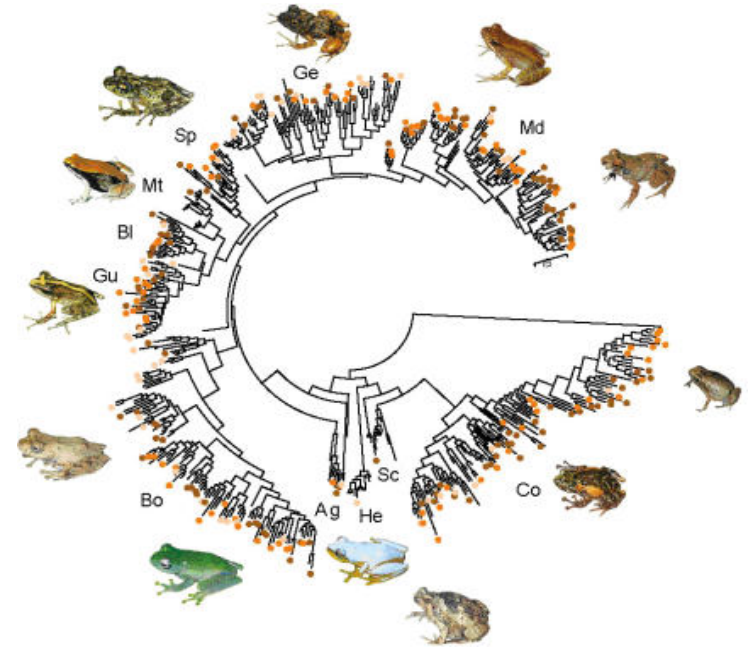


Explicite Encoding and Juxtaposition

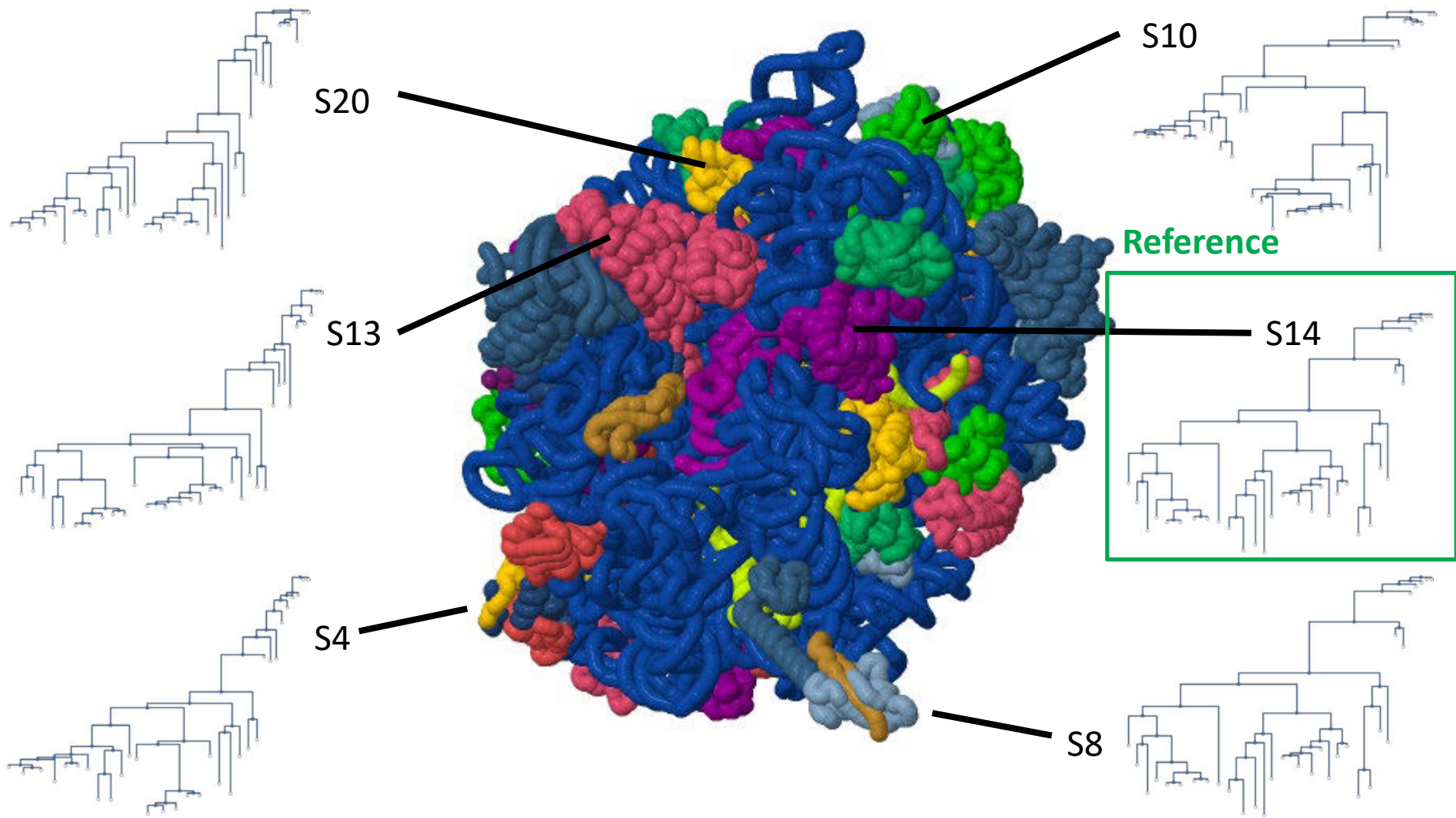


Motivation

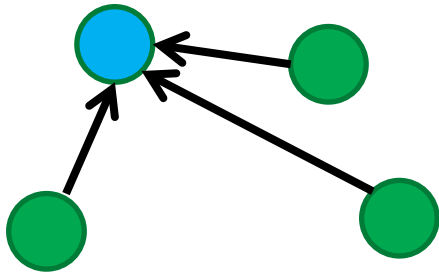
- Analysis phylogenetic trees
- Describe evolutionary relatedness
- Can be calculated based on various sources
- Popular Source: Ribosome
 - Assembles proteins
 - Present in every living organism



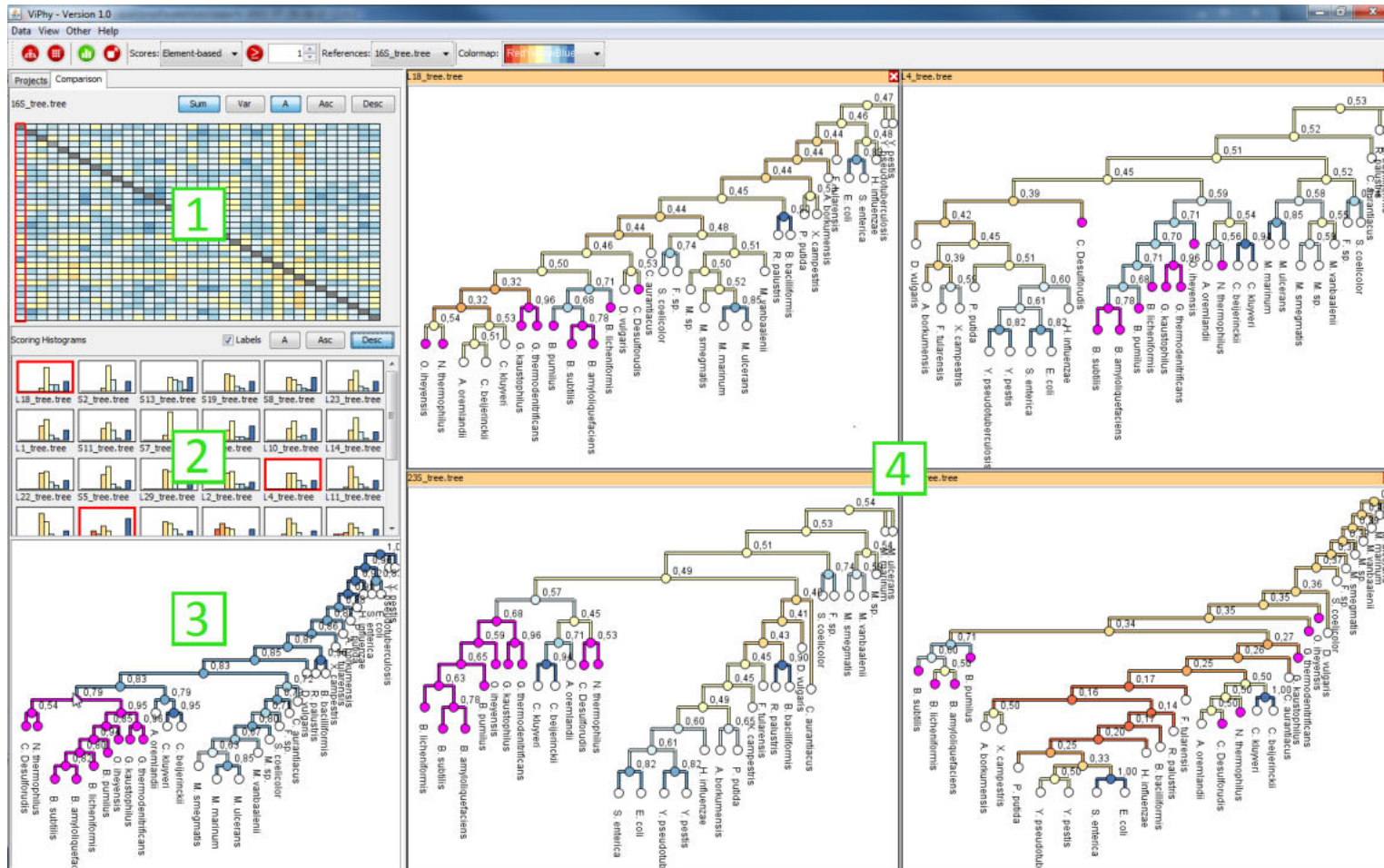
1 reference and 33 other trees



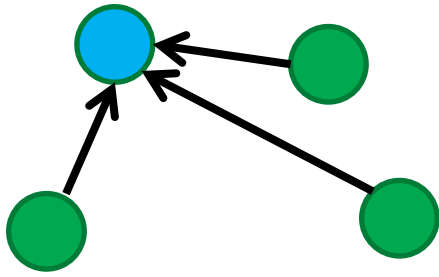
Defined Reference Object



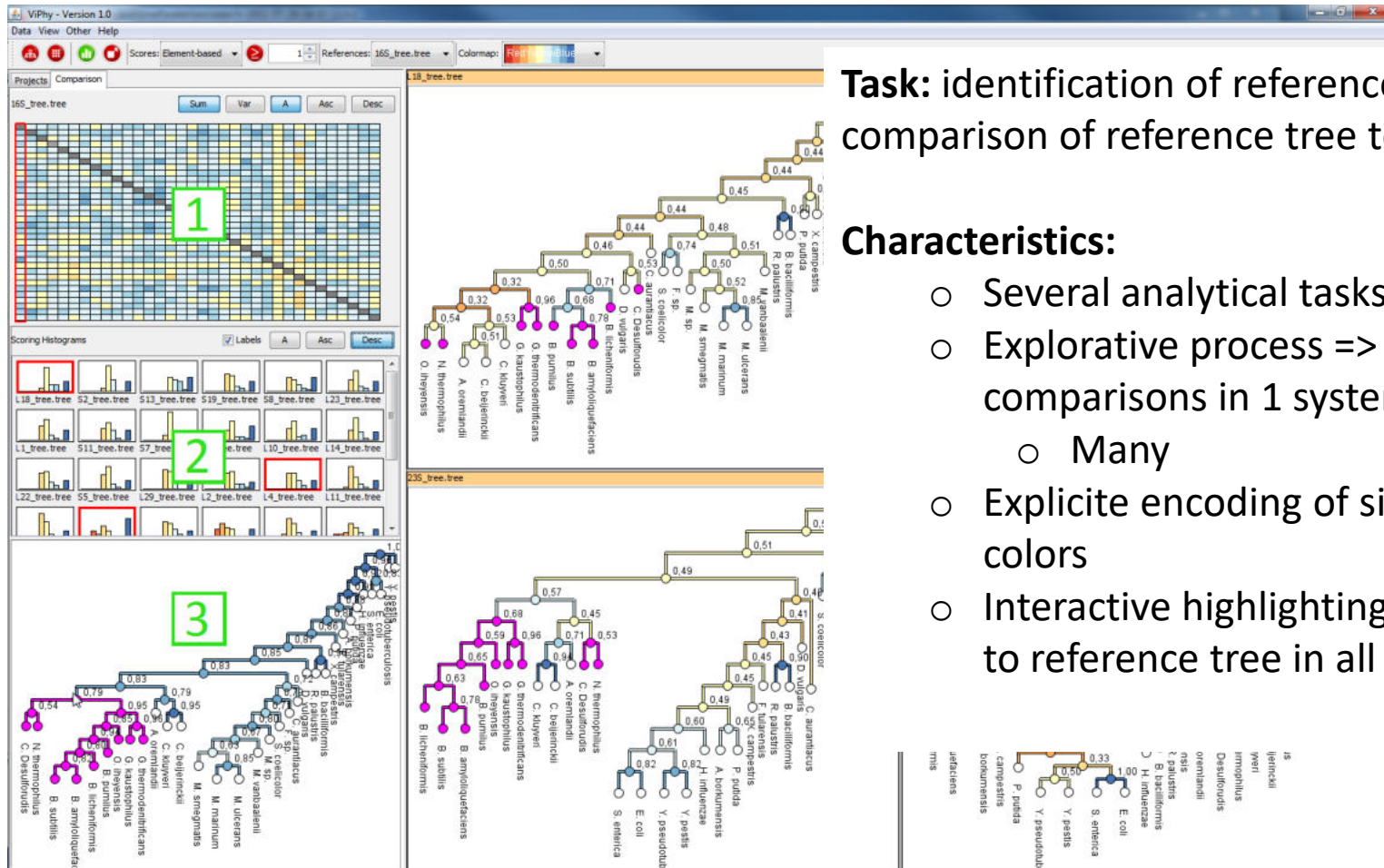
Explicite Encoding and Juxtaposition



ViPhy.org



Explicite Encoding and Juxtaposition



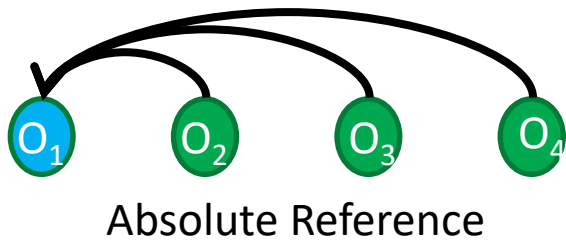
Task: identification of reference tree and comparison of reference tree to many other trees

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 subtrees to reference tree in all other trees

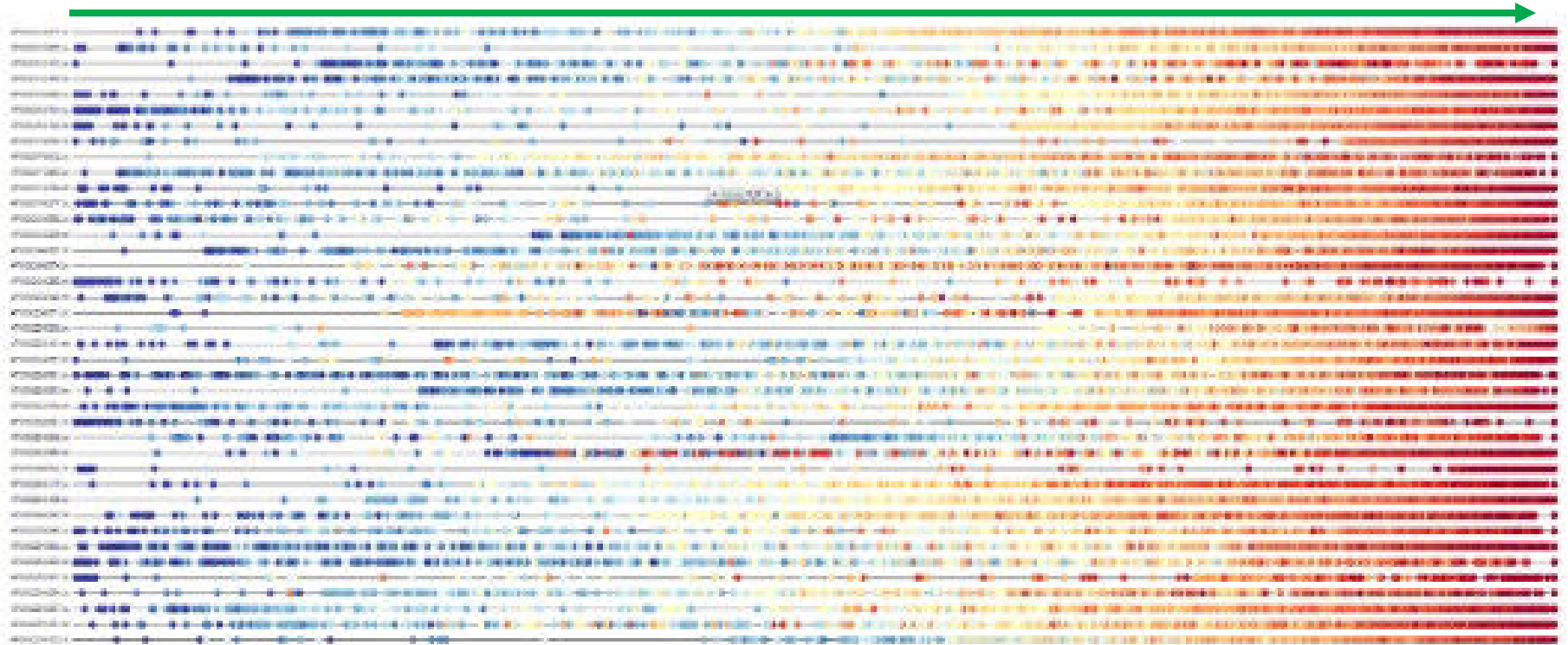
ViPhy.org



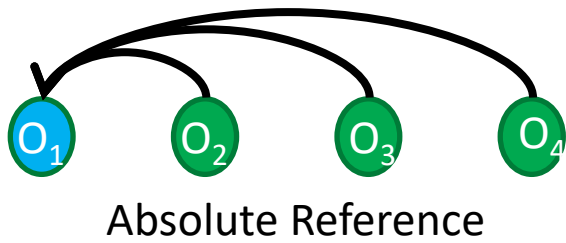


Many times 1:many

Distance to reference

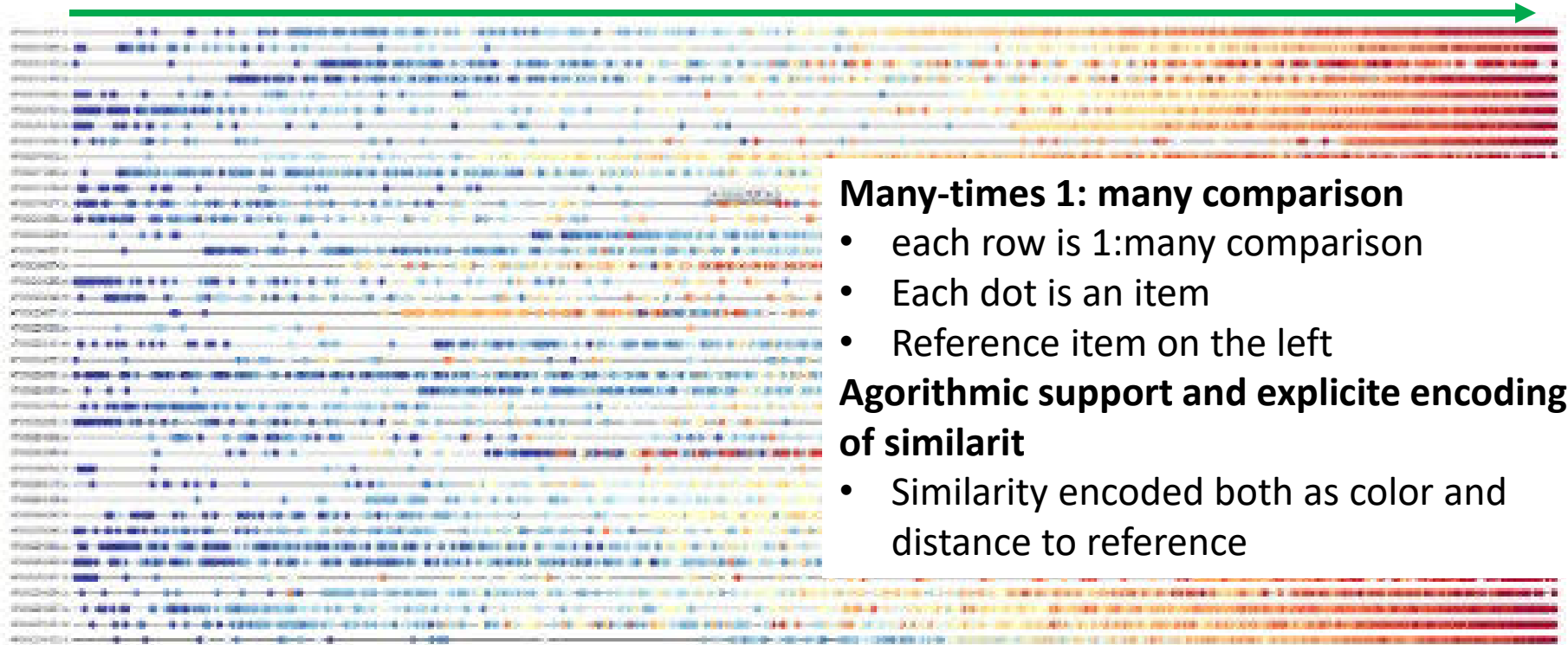


Reference: Gleicher et al.



Many times 1:many

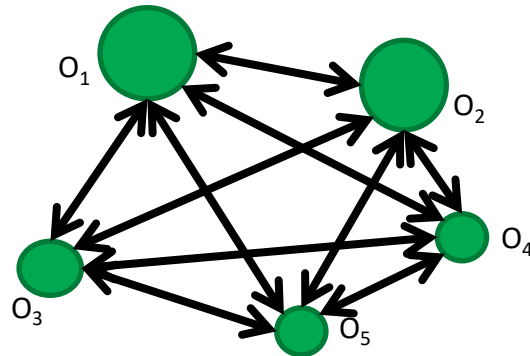
Distance to reference



Data: document topics

Reference: Gleicher et al.

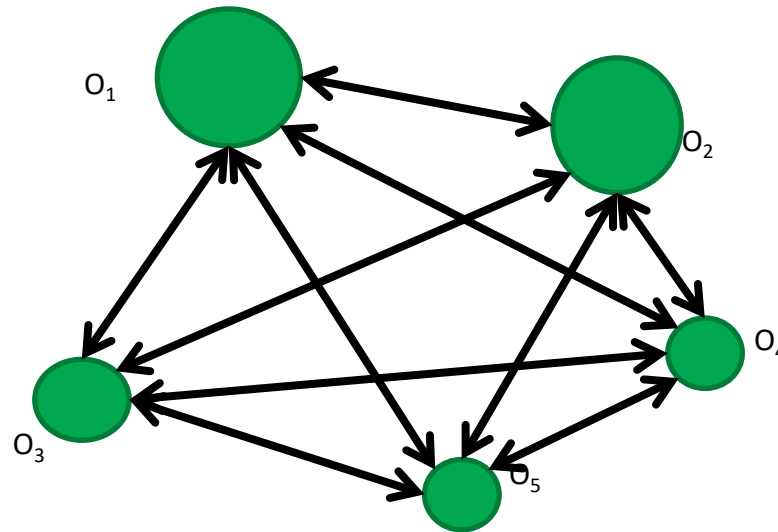
PART III: MANY-TO-MANY COMPARISON



Speaker: Kathrin Ballweg

Definition

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



Challenge: Scalability

Number of compared items

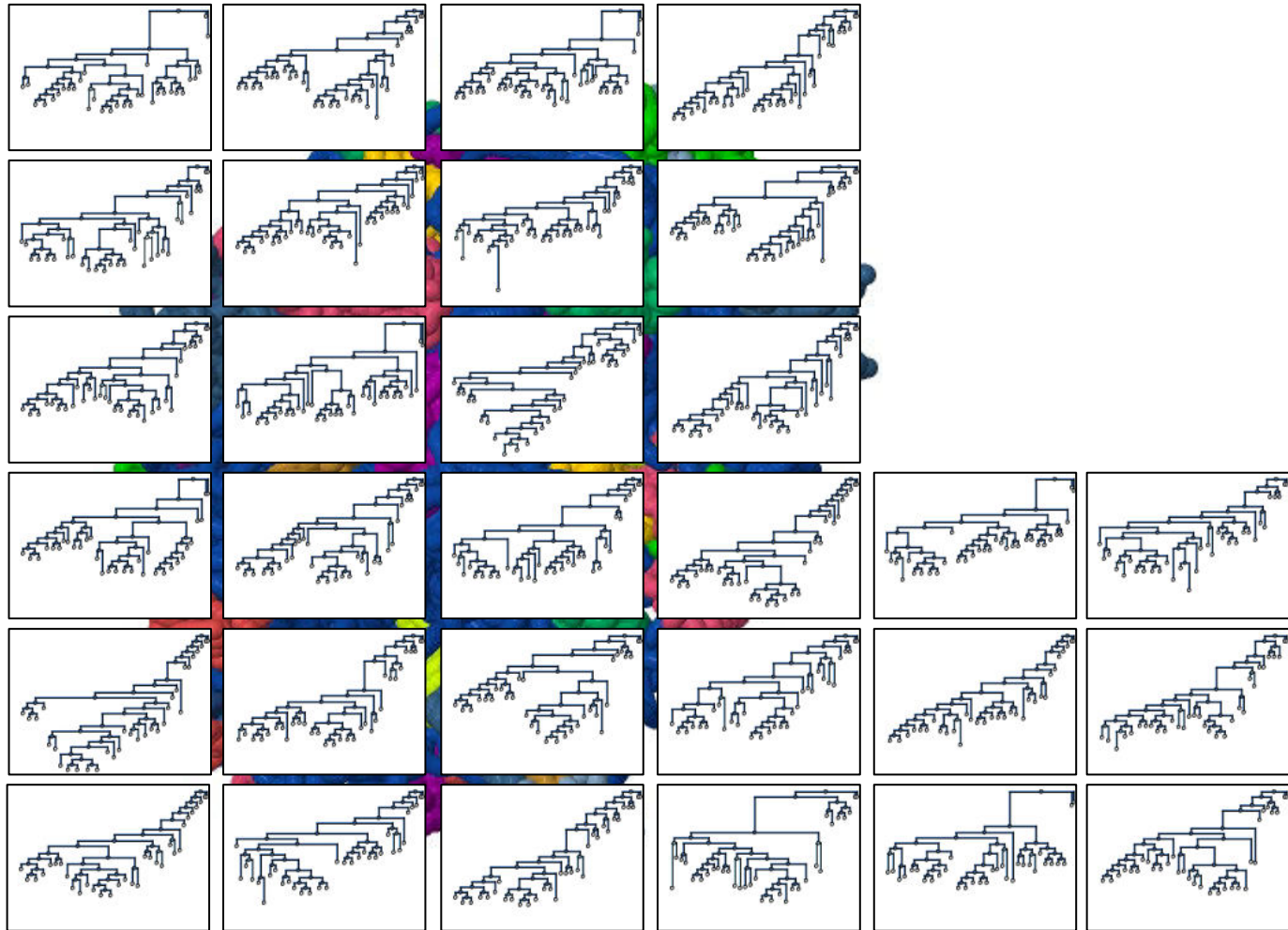
Juxtaposition:

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

Dataset

Juxtaposition

Phylogenetic trees:
34 trees
32 organisms each



Challenge: Scalability

Number of compared items

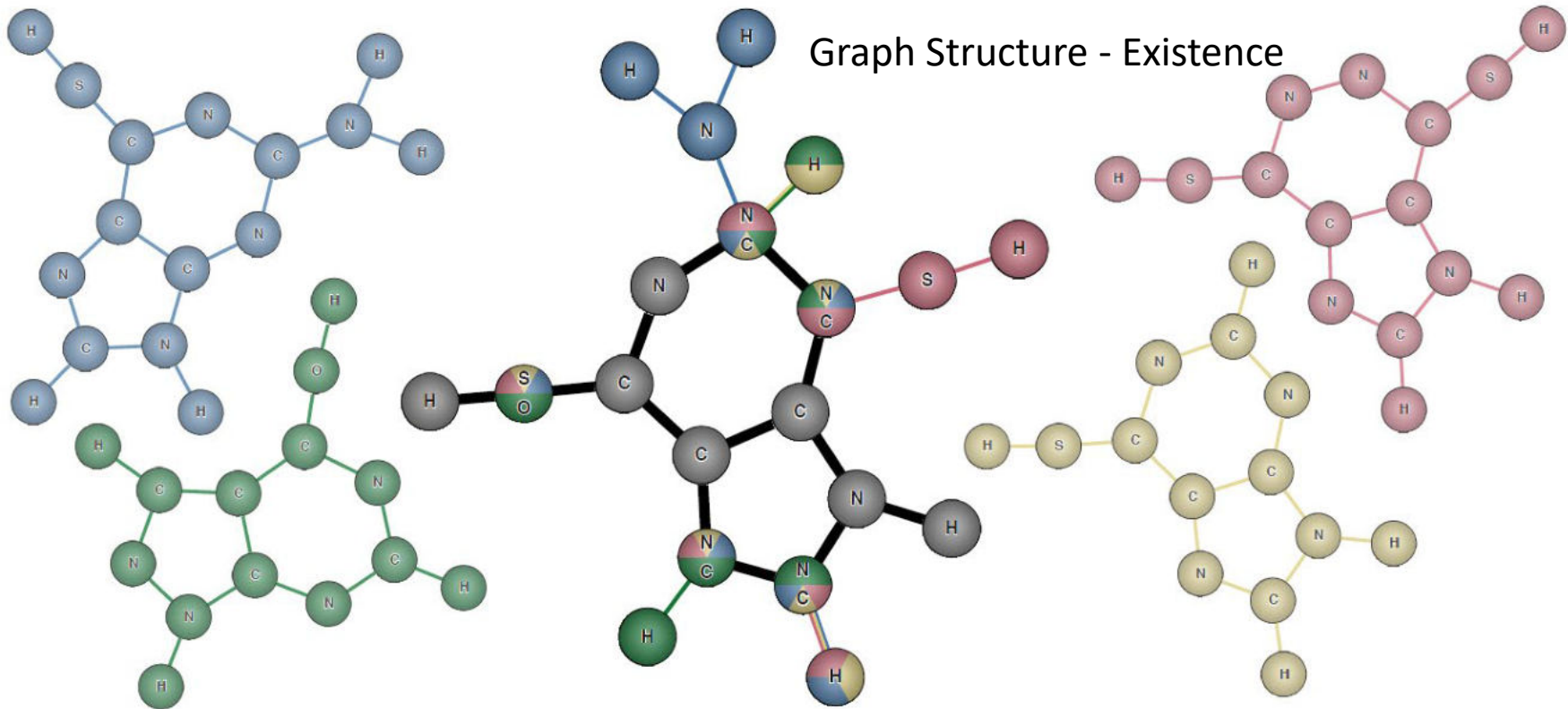
Juxtaposition:

- 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

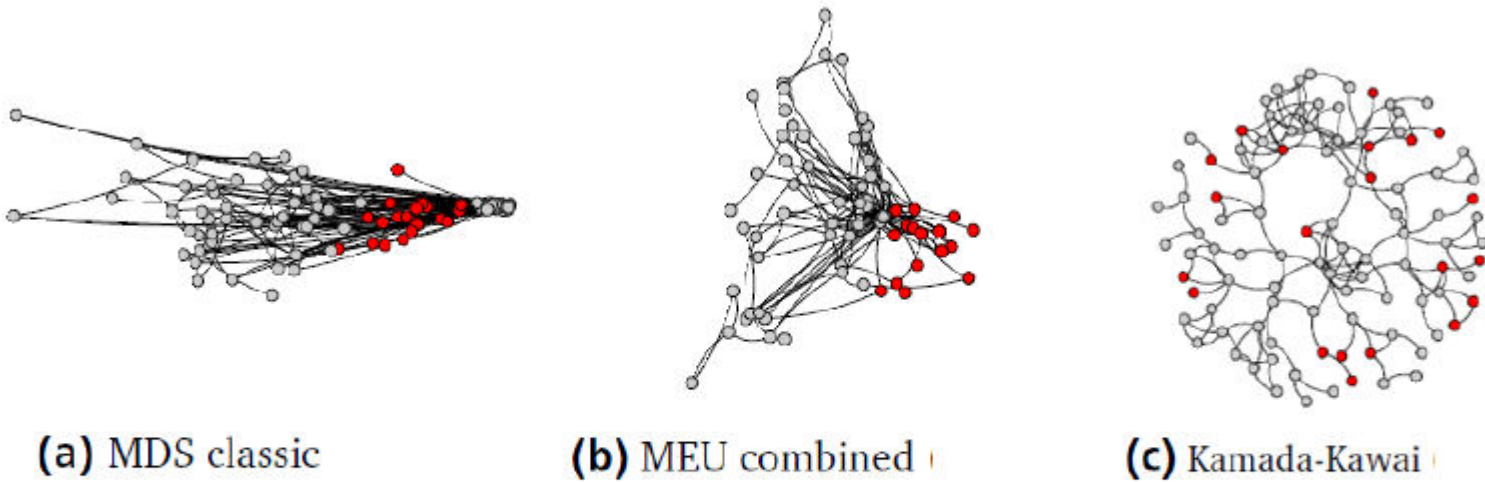
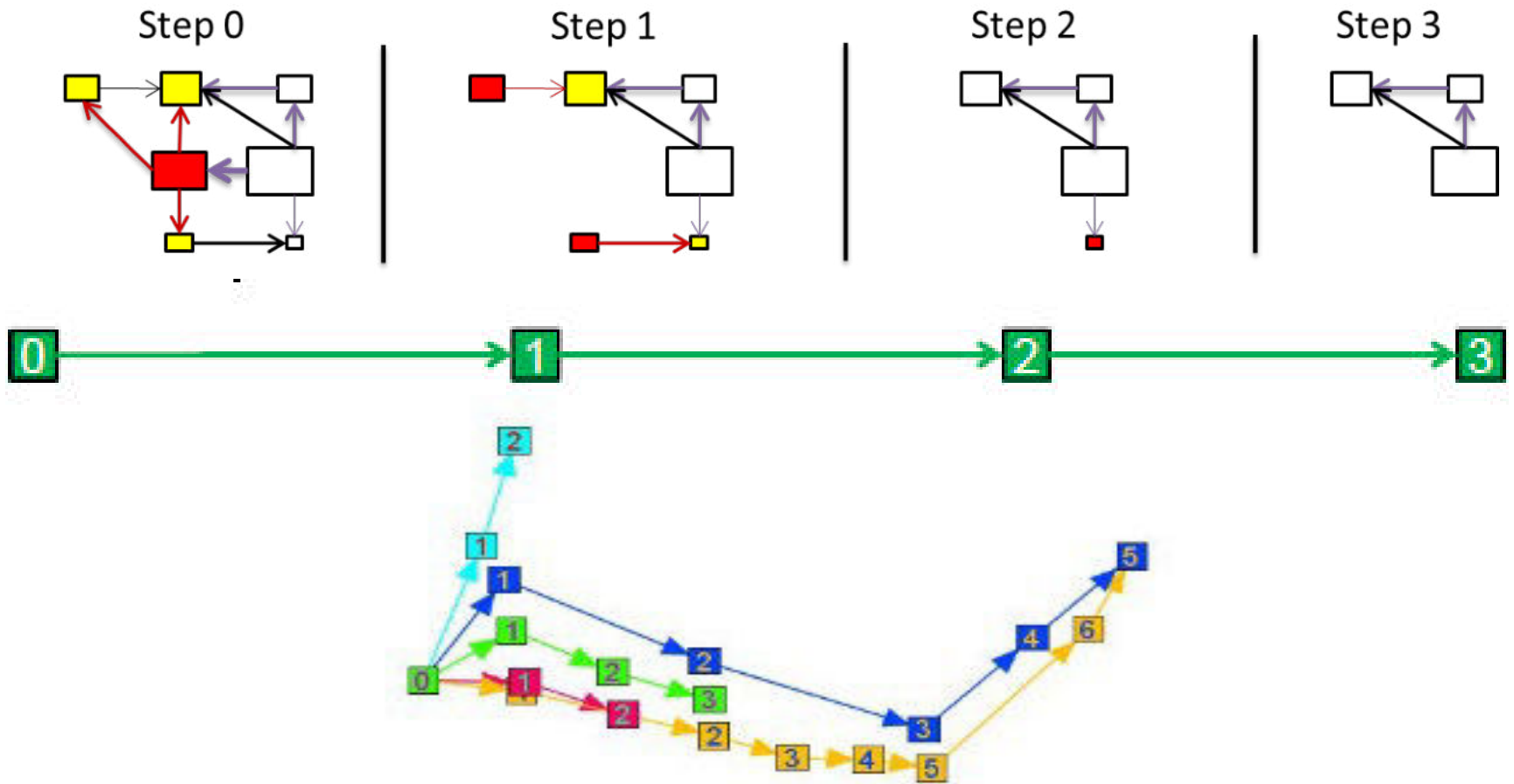
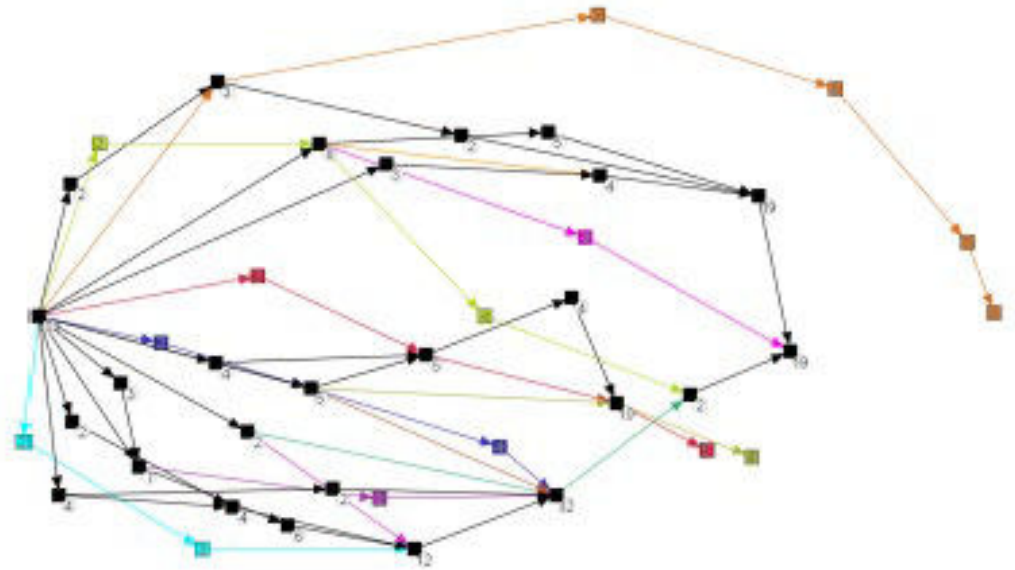
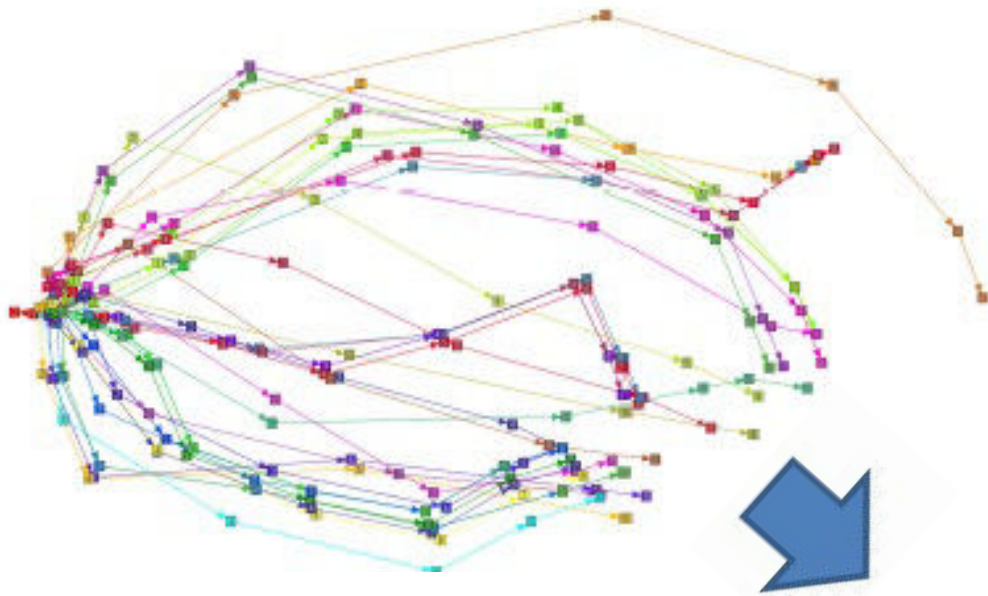


Fig. 7. Influence of the comparison specification on the graph layout when comparing similarity of nodes. Source: [84].

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 Comparison of Cascade Simulations





FURTHER READING



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

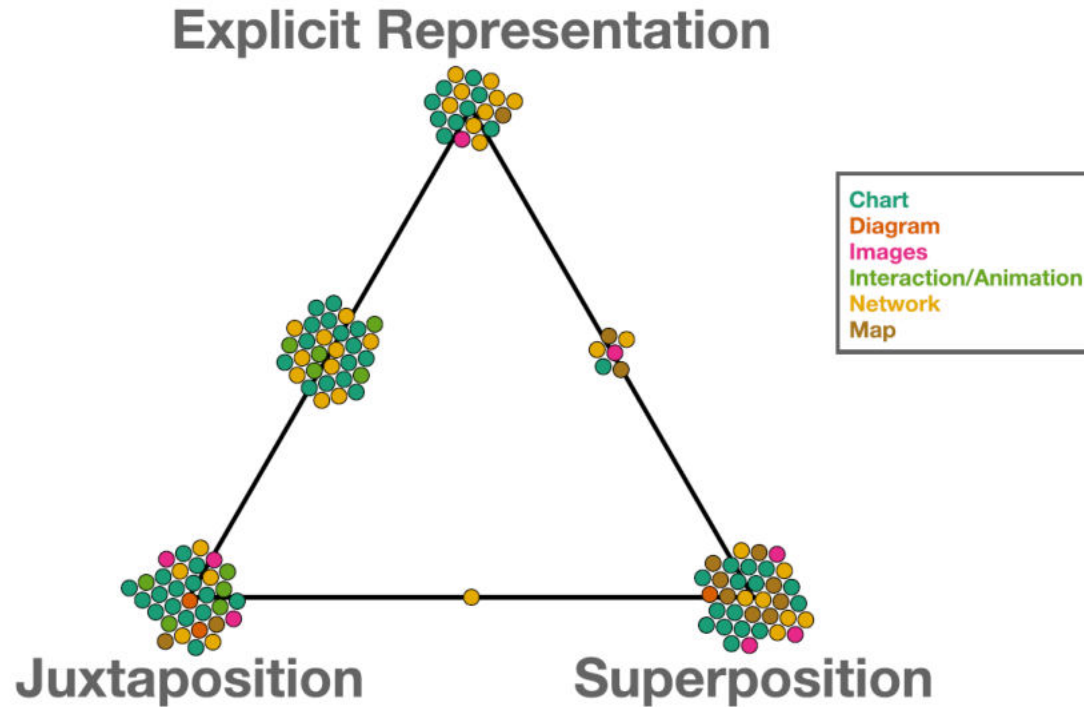


Figure 3: The design space provides three primary categories (juxtaposition, superposition, and explicit representation) with the three intermediary categories. The visualization is taken from our database of systems that we have researched. Our database includes

“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)

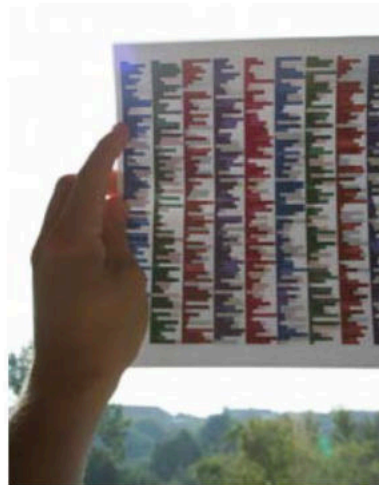
Naturally inspired interaction

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

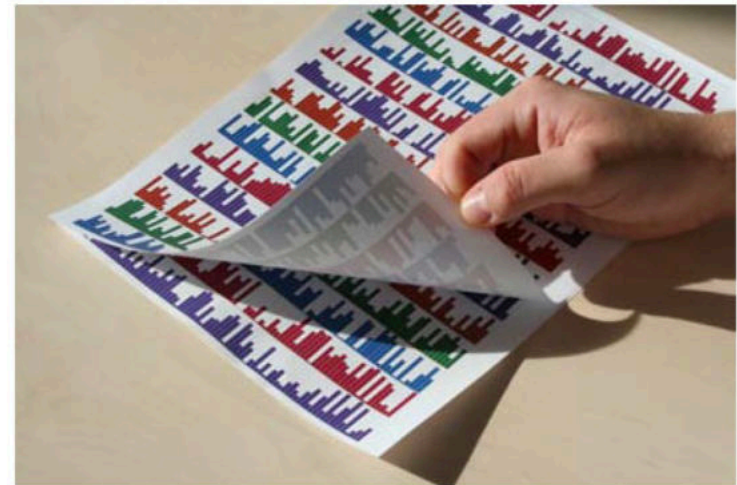
Interactions – Tominski et al 2



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

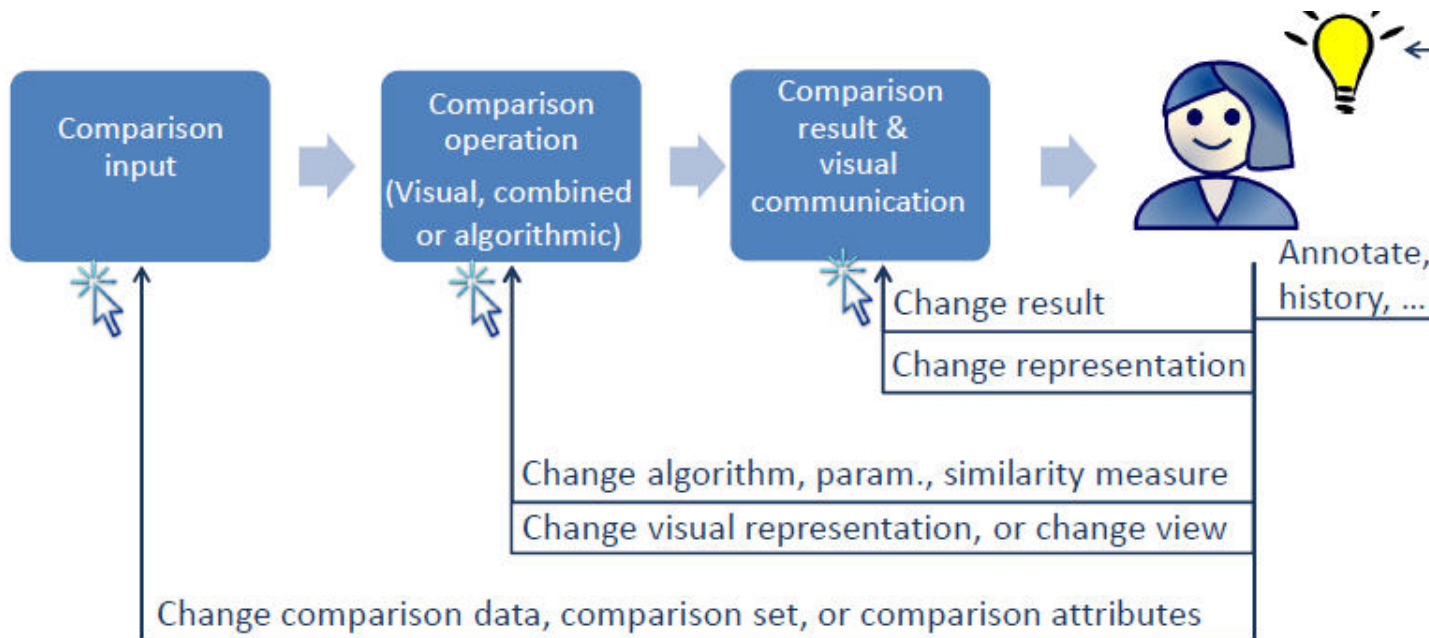


Figure 2.46.: Types of interactions in visual comparison workflows.