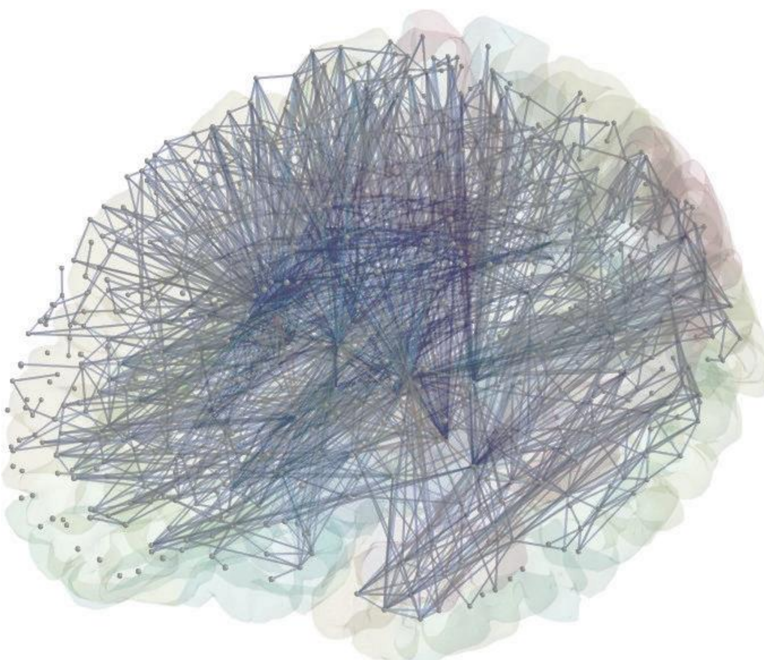
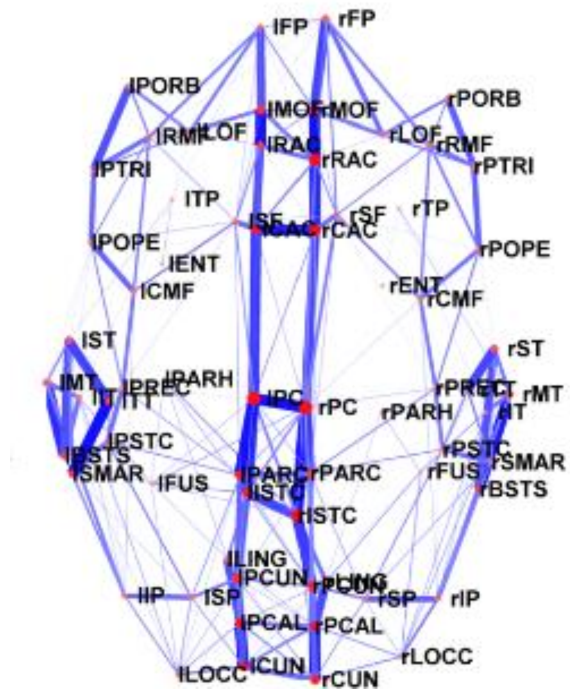
Basak Alper, UCSB, Aviz INRIA
Benjamin Bach, Aviz INRIA
Nathalie Henry-Riche, Microsoft Research Redmond
Tobias Isenberg, Aviz INRIA
Jean-Daniel Fekete, Aviz INRIA

Weighted Graph Comparison Techniques for Brain Connectivity Analysis

Study of Brain Connectivity





Brain connectivity data in the form of weighted graphs visualized as node-link diagrams within spatial context of brain

Methodology and Outline

1. Identify high level neuro-scientific tasks in brain connectivity analysis
2. Explore design space for augmented matrix and node-link visualizations supporting comparison of two weighted graphs
3. Controlled Study

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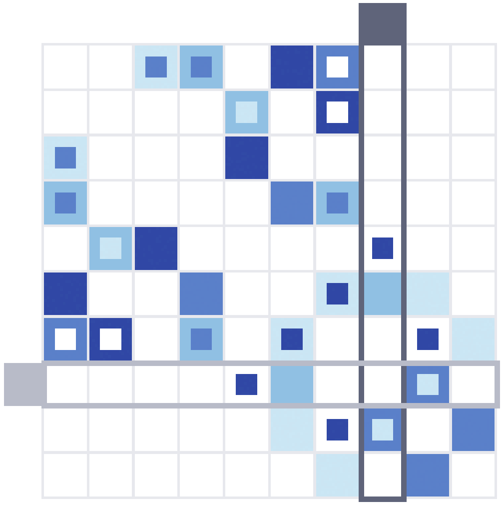
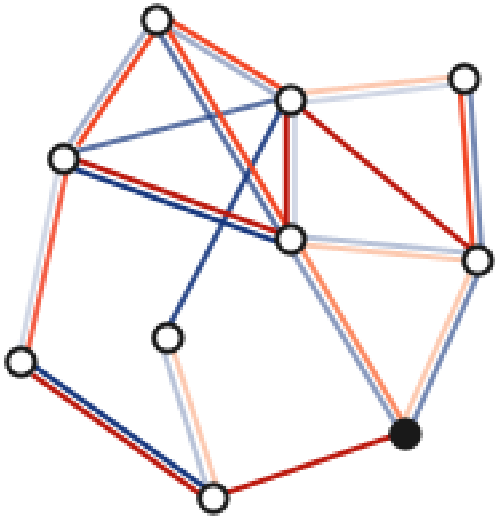
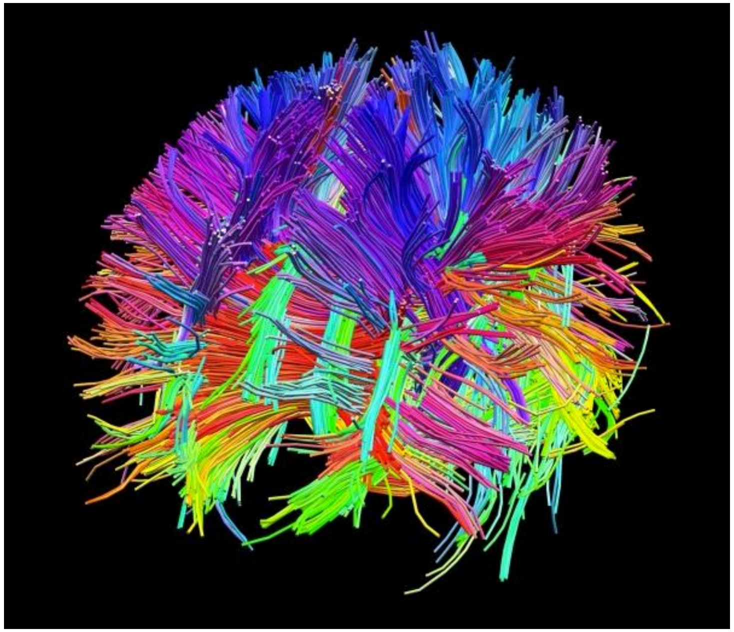




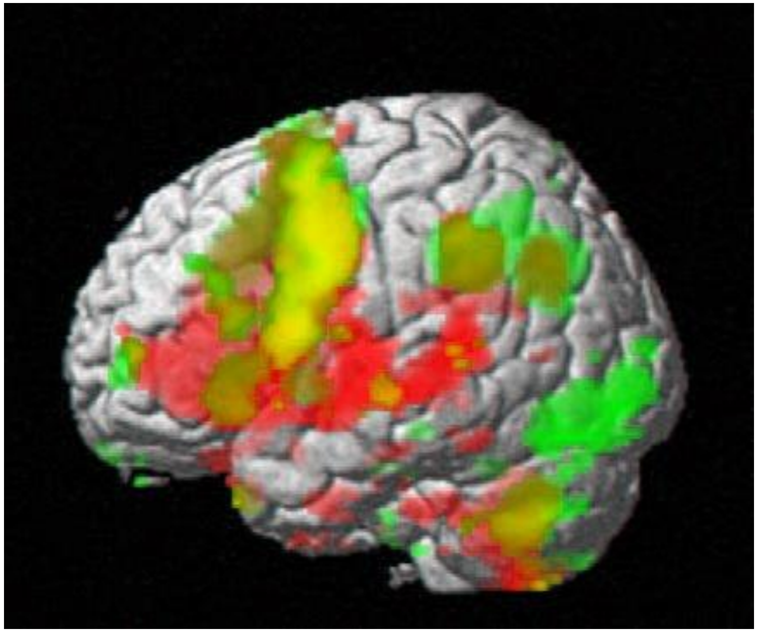
1

Brain Connectivity Task Analysis

Brain Connectivity

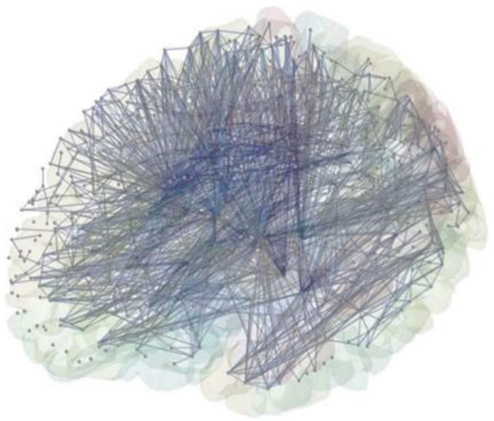


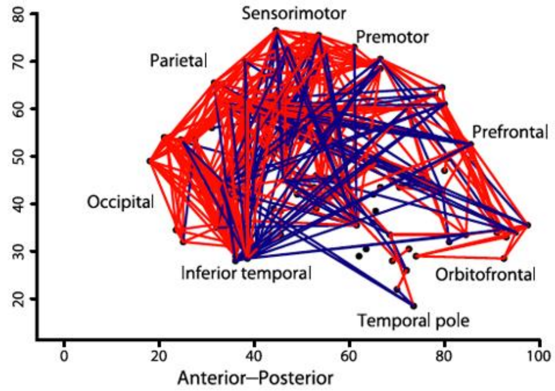
Anatomical Connectivity

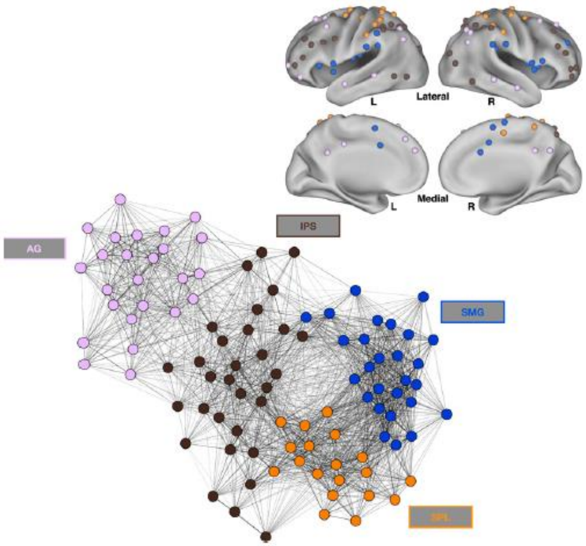


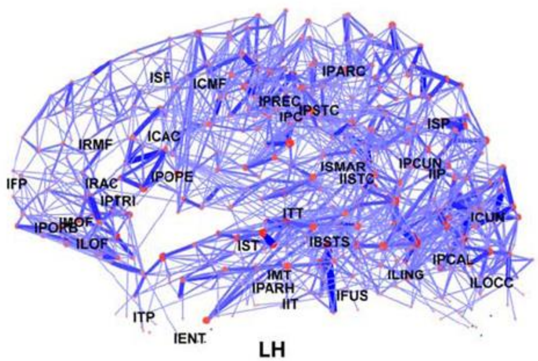
Functional Connectivity

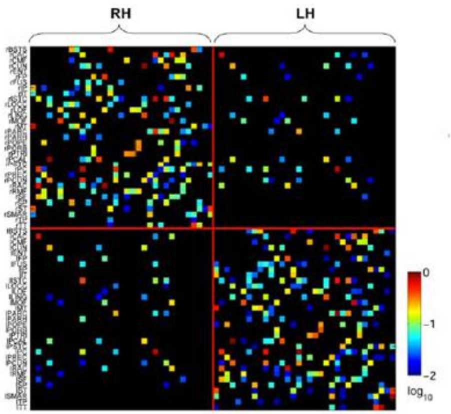
Brain Connectivity Visualization











Brain Connectivity Analysis

High Level Neuro-Scientific Tasks

- Cognitive functionality
- Alterations over time
- Anomalous patterns
- Characterization of an individual's connectivity
- Correlations between functional and anatomical connectivity

Brain Connectivity Analysis

- Several brain connectivity data can be expressed in the form of weighted graphs.

- Several high level neuro-scientific investigations can benefit from visual comparison of these weighted graphs.

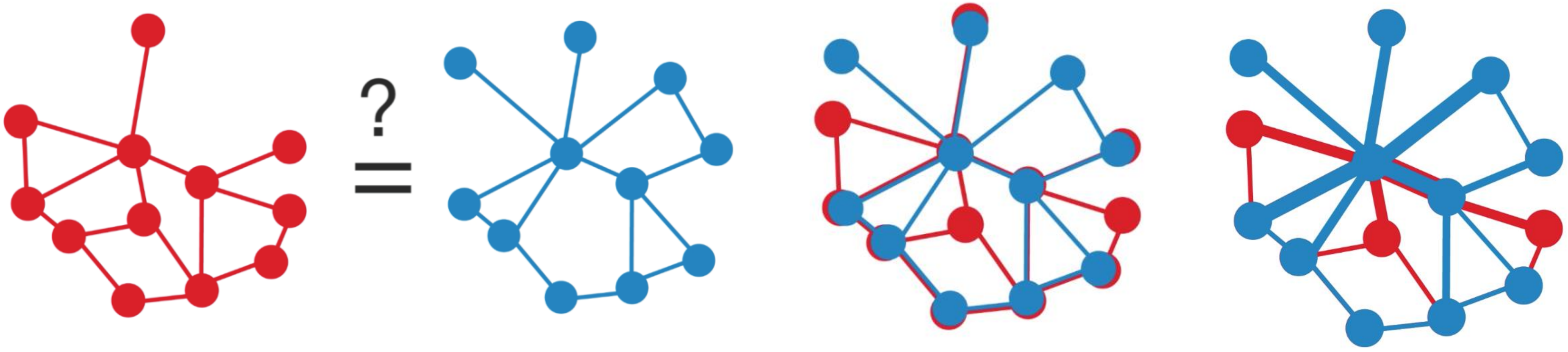
2

Design Space Exploration

Weighted Graph Comparison

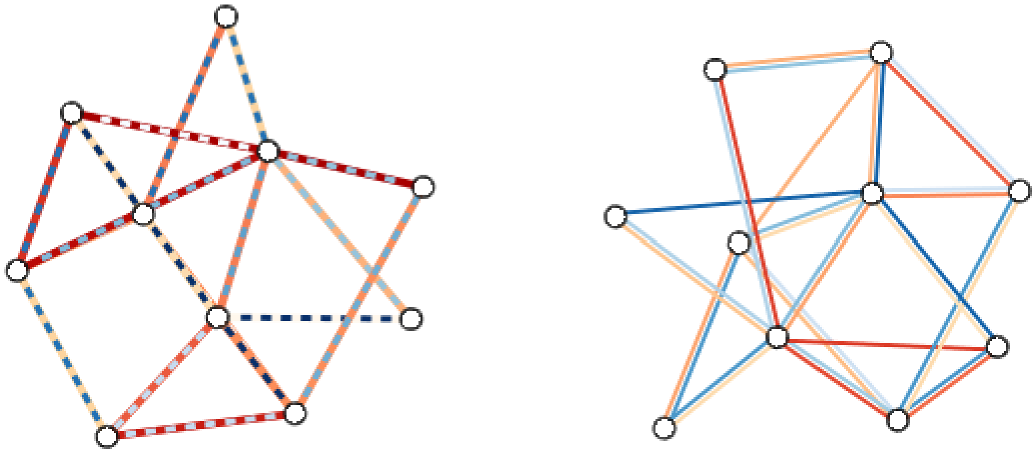
How to support visual graph comparisons?

- 2D instead of 3D
- Non-spatial instead of within the spatial context of brain
- Superimposed instead of juxtaposed



Weighted Graph Comparison

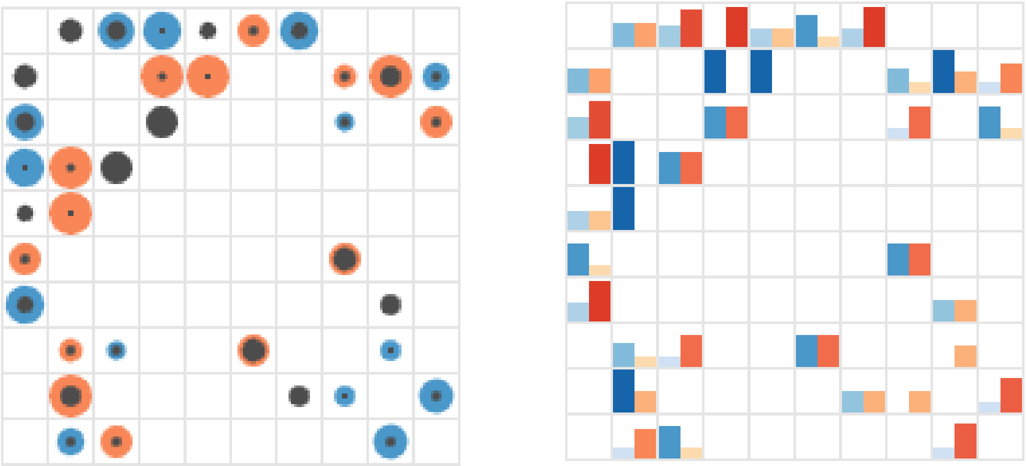
Alternative visualizations for node-link representations encoding edge weights in two graphs:



Superimposed versus side-by-side edge encodings

Weighted Graph Comparison

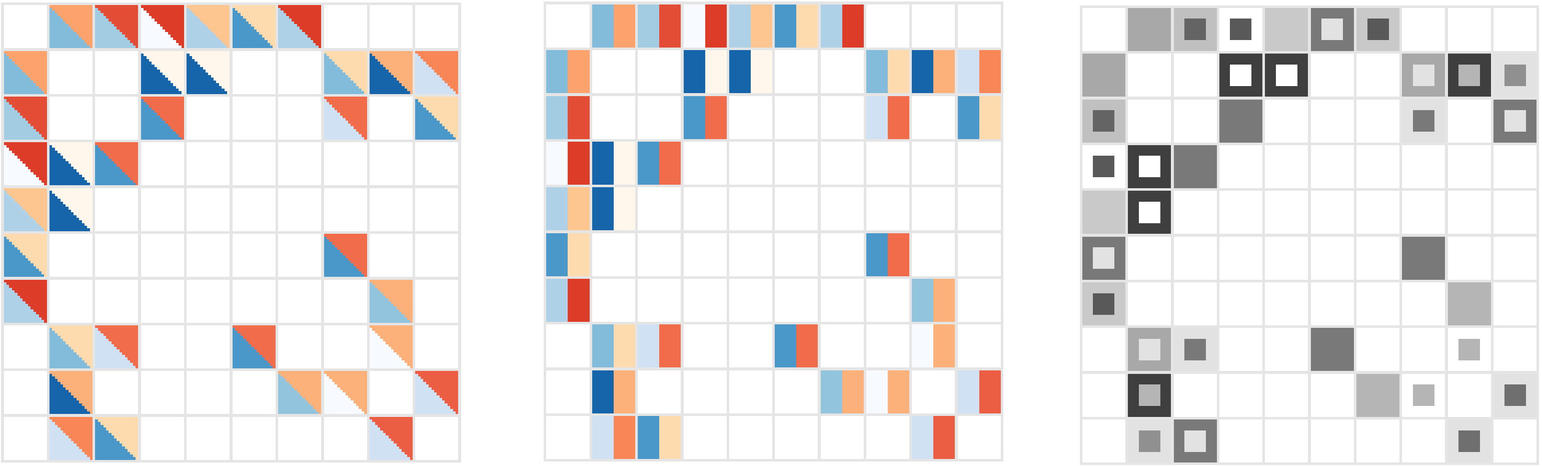
Alternative visualizations for matrix representations encoding edge weights in two graphs:



Using scaled glyphs within each matrix cell

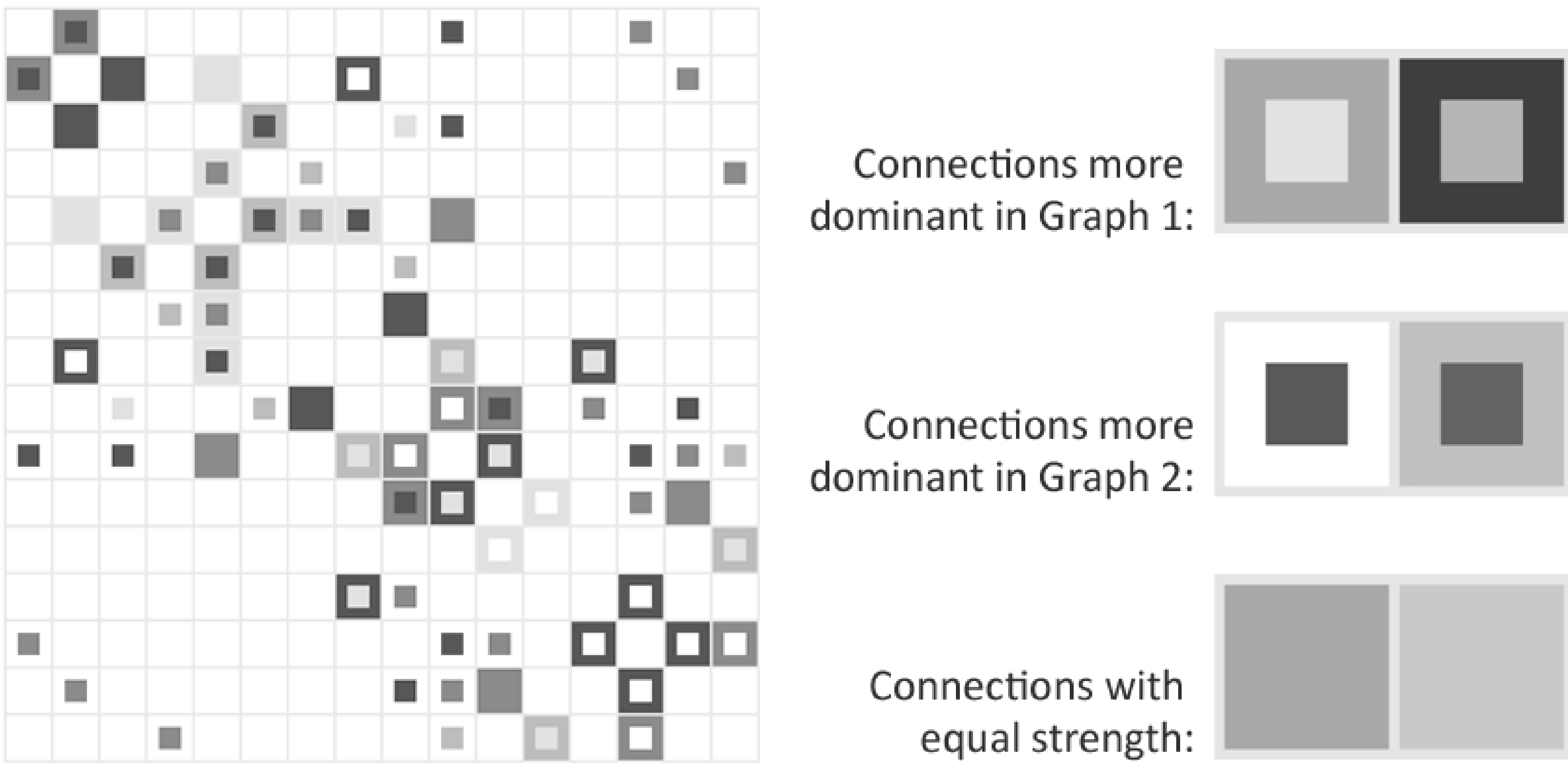
Weighted Graph Comparison

Alternative visualizations for matrix representations encoding edge weights in two graphs:



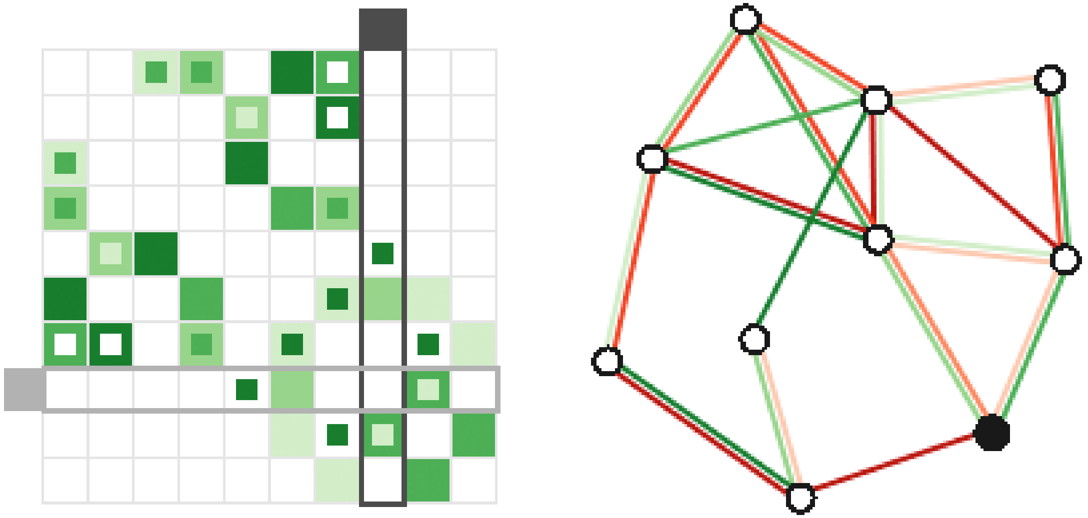
Alternatives for dividing the matrix cell

Edge Weight Encodings in Matrix



3 Controlled Study

Techniques



Generic Comparison Tasks

- Assess weight change of a node's connections (Trend)
  – Given one highlighted node, does the overall edge weight to all of its neighbors decrease or increase from G1 to G2?
- Assess connectivity of common neighbors (Connectivity)
  – Given two highlighted nodes, how many of their common neighbors in G1 are still common neighbors in G2?
- Identify the region with most changes (Region)
  – Identify the region showing the most variation between G2 and G1?

Experiment Design

A within subject design of:

2 Techniques (Matrix, Node-Link) x

3 Tasks (Trend, Connectivity, Region) x

2 Data Sizes (40, 80 nodes) x

2 Edge Densities (5%, 10% edge density) x

4 repeats

= 96 trials per participant

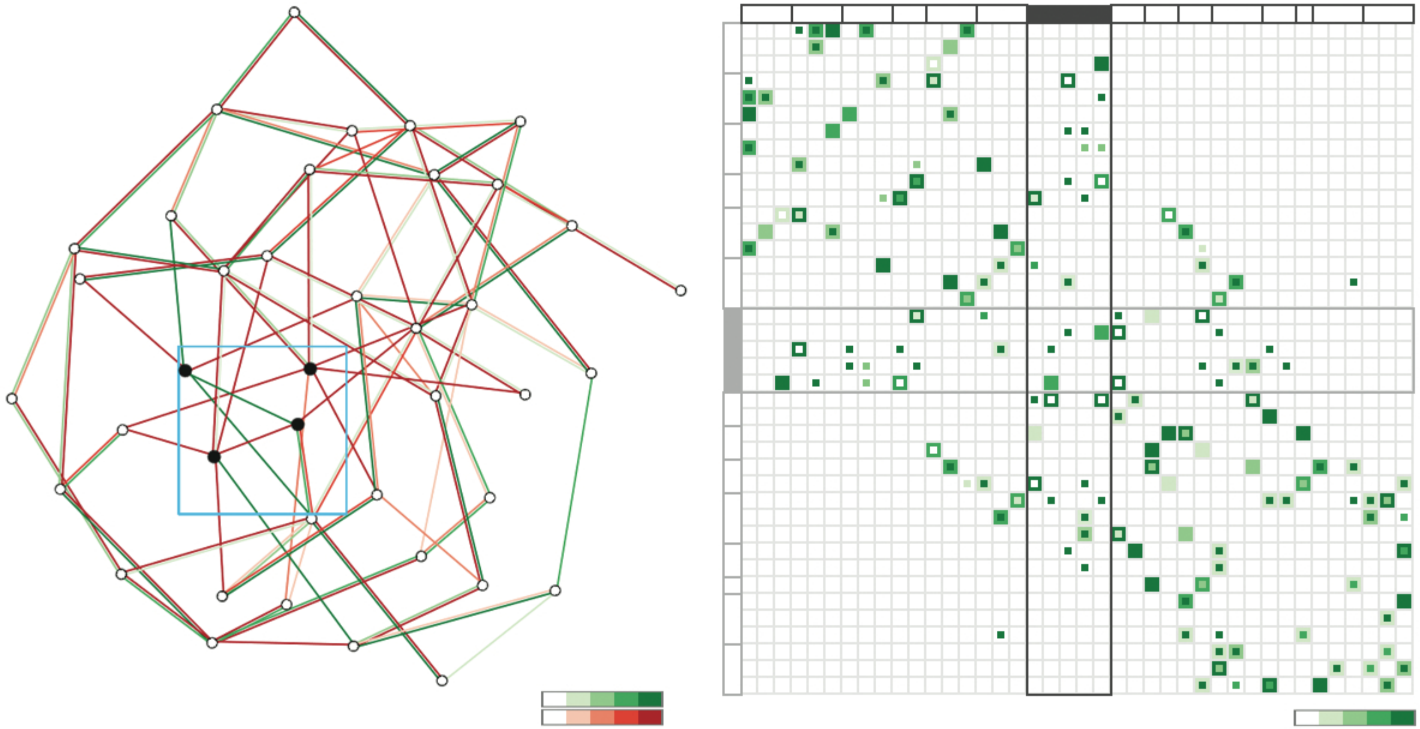
Experiment Design

We generated a synthetic graph per:
2 Data Sizes x 2 Edge Densities x 4 repeats

11 subjects

~45 minutes

Visual Stimuli



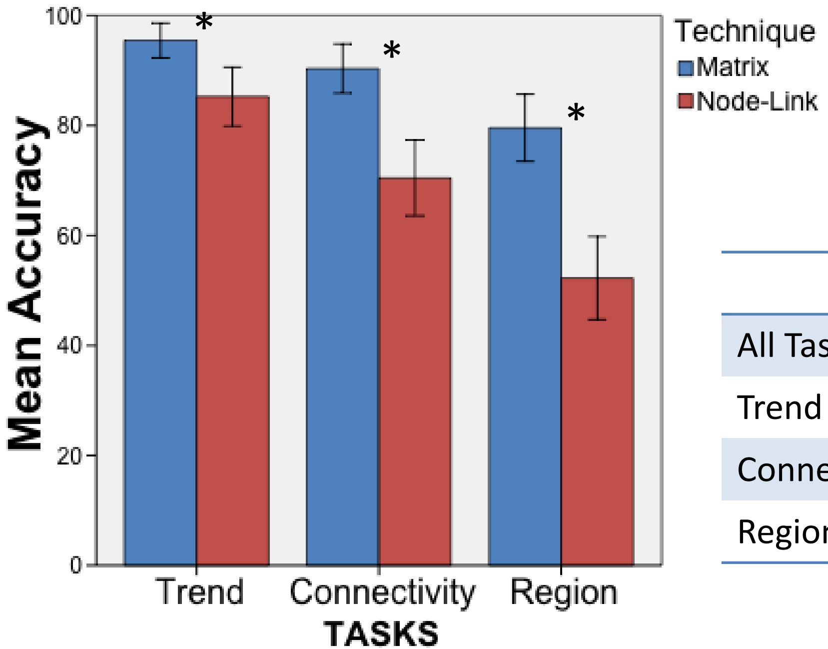
Visual stimuli images used in the Region task
for the Node-Link and Matrix techniques

Controlled Study

Hypotheses:

- (H1) Matrix > Node-Link for dense datasets in Trend task.
- (H2) Matrix ~ Node-Link in Connectivity task.
- (H3) Matrix > Node-Link in Region task.
- (H4) Node-Link decrease in performance for dense datasets.

Study Results: Accuracy

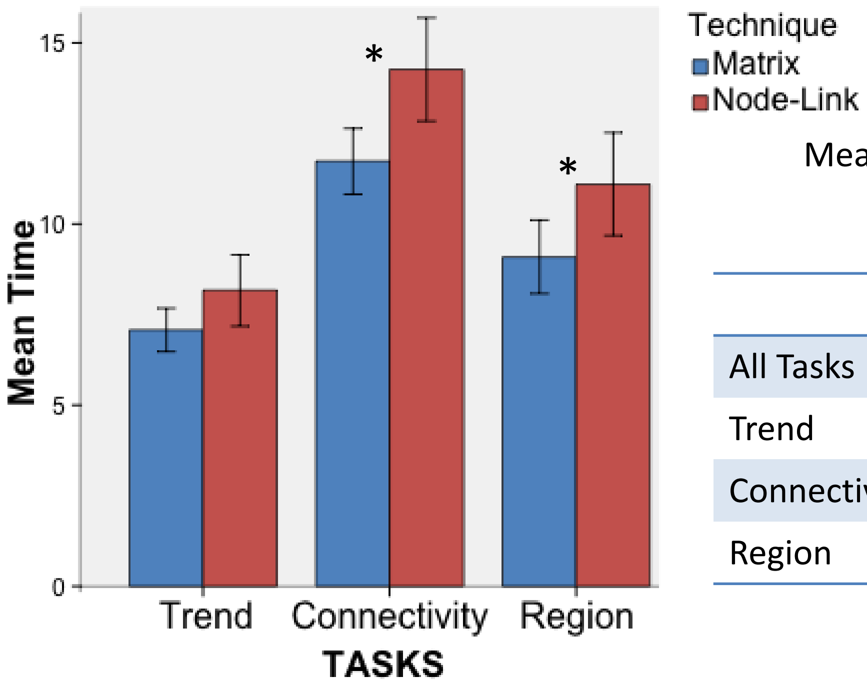


Mean accuracy in percentage
(Error bars indicate +- SE)

Means of accuracy in percentage
Standard Error is shown in parenthesis

	Matrix	Node-Link	p-value
All Tasks	88.5 (0.9)	69.3 (2.0)	< .001
Trend	95.5 (1.2)	85.2 (4.3)	<.05
Connectivity	90.3 (1.0)	70.5 (2.5)	< .0001
Region	79.6 (2.1)	52.3 (4.5)	<.0001

Study Results: Time



Mean time in seconds
(Error bars indicate +- SE)

Means of completion time in seconds (excluding errors)
Standard Error is shown in parenthesis

	Matrix	Node-Link	p-value
All Tasks	9.3 (0.3)	11.0 (0.4)	< .001
Trend	7.1 (0.3)	8.2 (0.5)	Not significant
Connectivity	11.7 (0.5)	14.3 (0.7)	< .0001
Region	9.1 (0.5)	11.1 (0.7)	<.01

Study Results Discussion

- Our hypotheses H1 and H3 verified:
  - Matrix > Node-Link (accuracy and time) for both Trend and Region tasks.

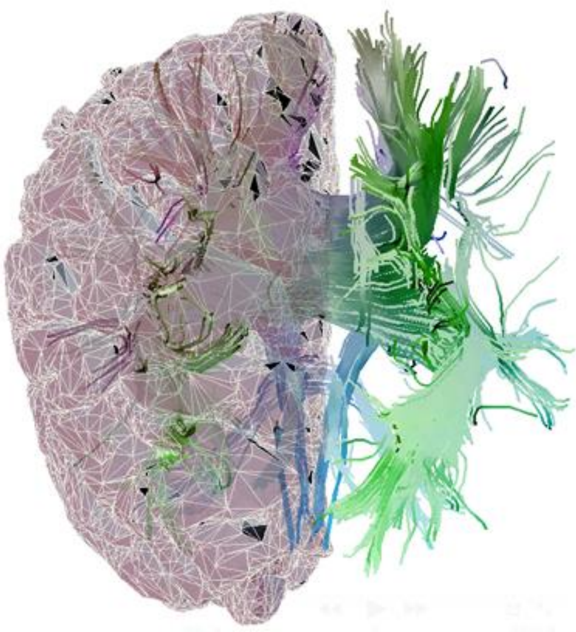
- Our hypothesis H2 not verified:
  - Matrix > Node-Link (accuracy and time) for the Connectivity task.

- Our hypothesis H4 verified:
  - Node-Link accuracy performance decreases with increase in size as well as density.

4 Conclusions

Implications for Design

Integration of spatial and abstract representations.



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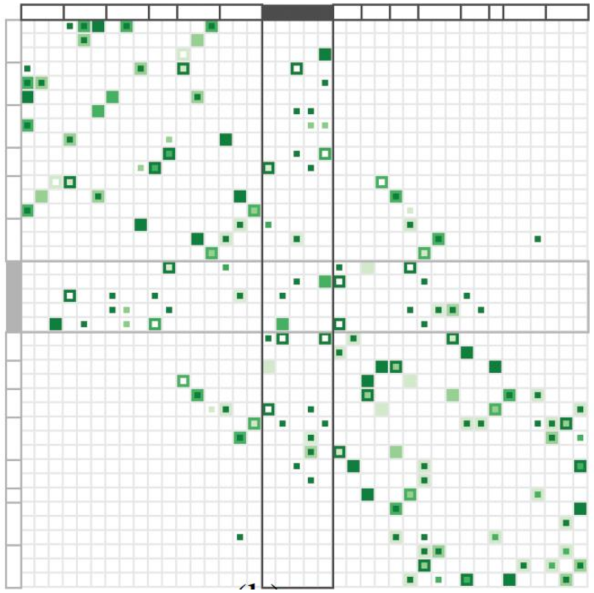

Conclusion

- We propose a novel matrix representation that supports comparison of two weighted graphs.
- Brain connectivity visualization tools can significantly benefit from supporting visual weighted graph comparisons.
- Applications to other domains such as gene correlation, protein co-activation networks as well as computer or social networks are possible.

Acknowledgements

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