Network Boxplots: A Method to Visualize Network Ensembles

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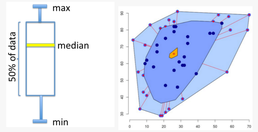
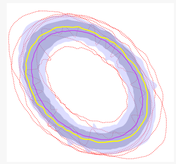
1. INTRODUCTION

- Network (or graph) is defined as G(V,E,W).
- Ensembles of *aligned* networks are common in many areas.
- Need to convey salient features of the network ensemble.
- Goals : 1) *Compare* ensemble to individual.
  2) *Compare* two ensembles.
- Questions when comparing: Is there a difference? Direction of difference? Significant?

2. BACKGROUND

- Tukey Boxplot (Points in 1-D)
- Bagplot (Points in 2-D) [1]
- Functional Boxplot (Functions)[2]
- Contour Boxplot (Contours)[3]
- Curve Boxplot (Multivariate curves)[4]
- Path Boxplot (Paths on a network)





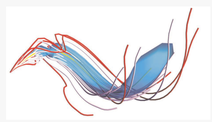


Fig. A classic boxplot for univariate data (*top left*). Bagplot for bivariate data(*top right*). Contour boxplot (*bottom left*). Curve boxplot (*bottom right*)

3. COMPUTING RANK STATISTICS

- Step 1: Convert network ensemble to function ensemble.

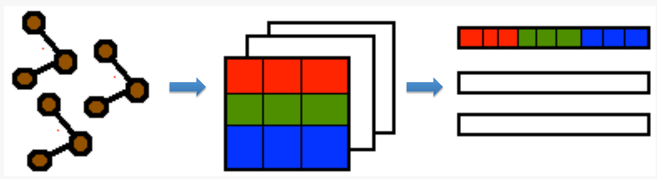


Fig. Network ensemble (left), adjacency matrix ensemble(center) and vector ensemble(right).

- Step 2: Perform functional band depth analysis[5]

$$\mathrm{fBD} = \mathrm{Prob}(f \in \mathrm{Band}(f_1, \ldots, f_j))$$

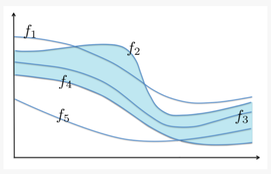
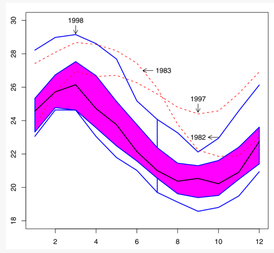
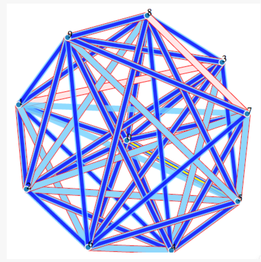


Fig. A functional band (*left*) and functional boxplot(*right*).



4. NETWORK BOXPLOT: UNWEIGHTED NETWORKS



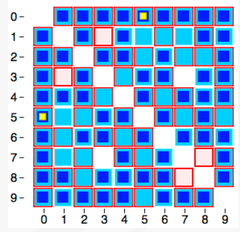


Fig. Network boxplot for synthetic (Erdos Renyi) network ensemble in two visualization schemes. Node link diagram (*left*) and adjacency matrix(*right*).

5. NETWORK BOXPLOT: WEIGHTED NETWORKS

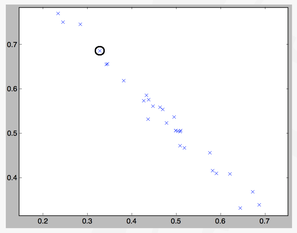
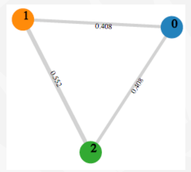
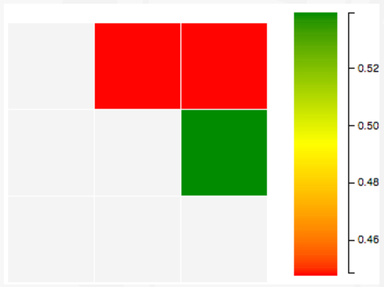
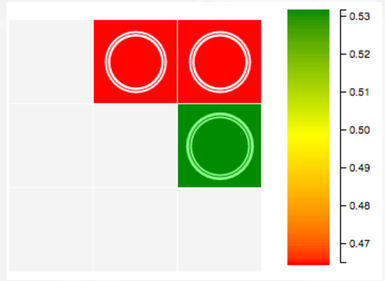


Fig. Samples from 2D normal distribution (*left*). Representative graph from ensemble (*right*).







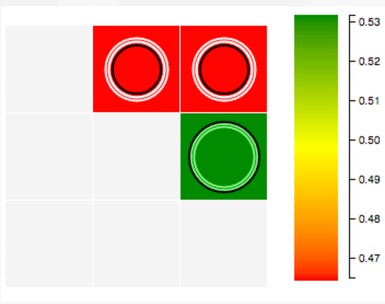


Fig. Mean adjacency matrix heatmap (*top left*). Network boxplot (*top right*). Network boxplot with highlighted outlier(*bottom right*).

6. COMPARING NETWORK ENSEMBLES

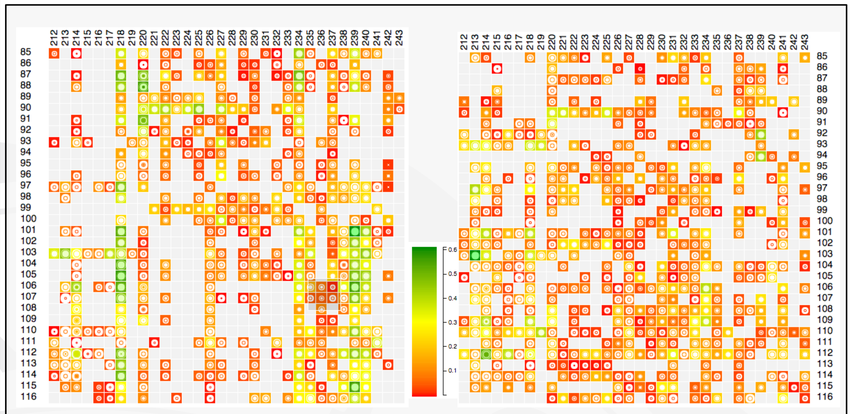
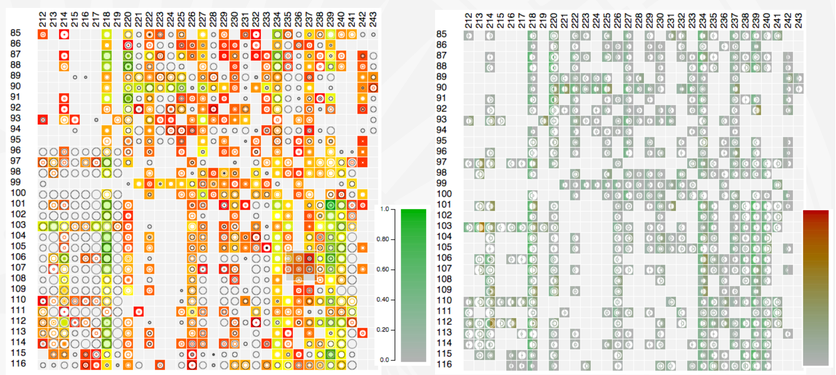


Fig. Network boxplot for fMRI data of healthy population(*top left*) and autistic population(*top right*). Population-individual comparison(*bottom left*). Alternative visualization scheme for difference visualization (*bottom right*).



7. FUTURE WORK

- User study.
- Node aggregation and node reordering.

REFERENCES

- [1] Rousseeuw et al. 1999
- [2] Sun et al. 2011
- [3] Whitaker et al. IEEE Visualization 2013
- [4] Mirzargar et al. IEEE Visualization 2014
- [5] Pintado Lopez et al. 2009

ACKNOWLEDGEMENTS

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