Massive Diffusion MRI Graph Structure Preserves Spatial Information

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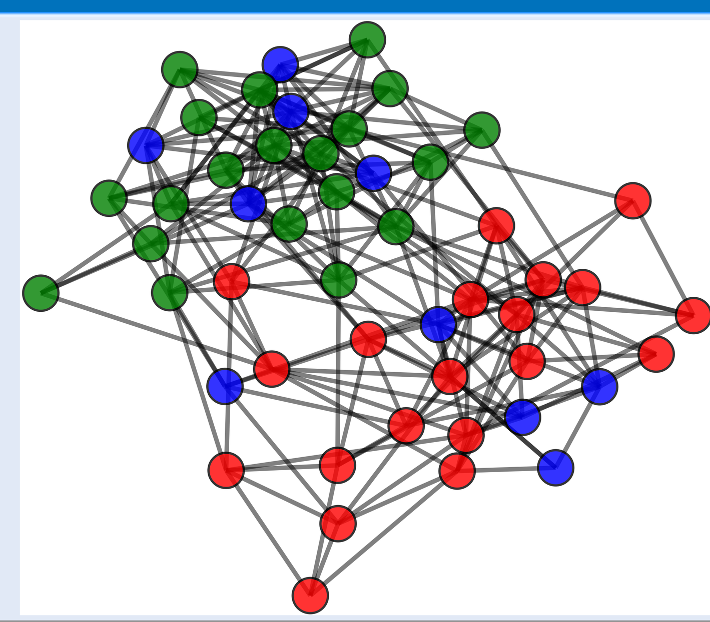
The Problem

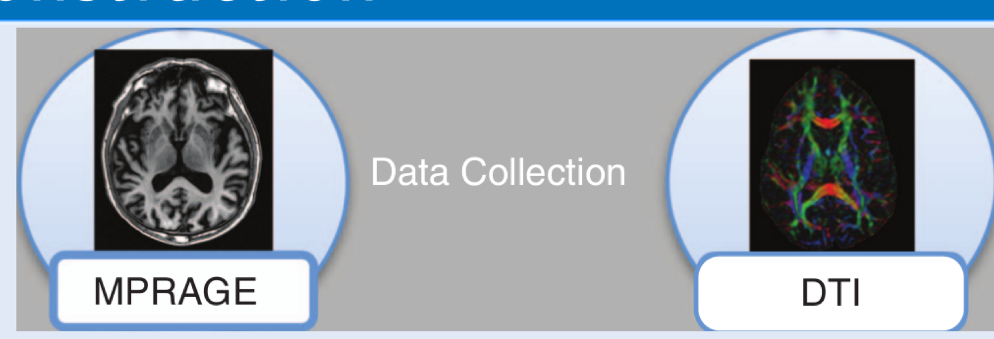
Suppose we create a graph that estimates the underlying connectivity of the brain based on the neurons and synapses between them. How can we determine whether the graph is a *good* estimate?

What is a graph?

- nodes (such as neurons or voxels in an MRI image),
- edges (synapses or fibers connecting voxels), and
- colors (indicating properties of each node).



Graph Construction



- MR Connectome Automated Pipeline [Gray et al., 2012] pre-processing, registration, ROI labeling, and tractography.
- Edge between two voxels/nodes *if and only if* there is a fiber tract connecting those two voxels. Each fiber becomes a *clique* in the graph.
- Nodes are colored according to neuroanatomic ROIs derived from Desykan Atlas.

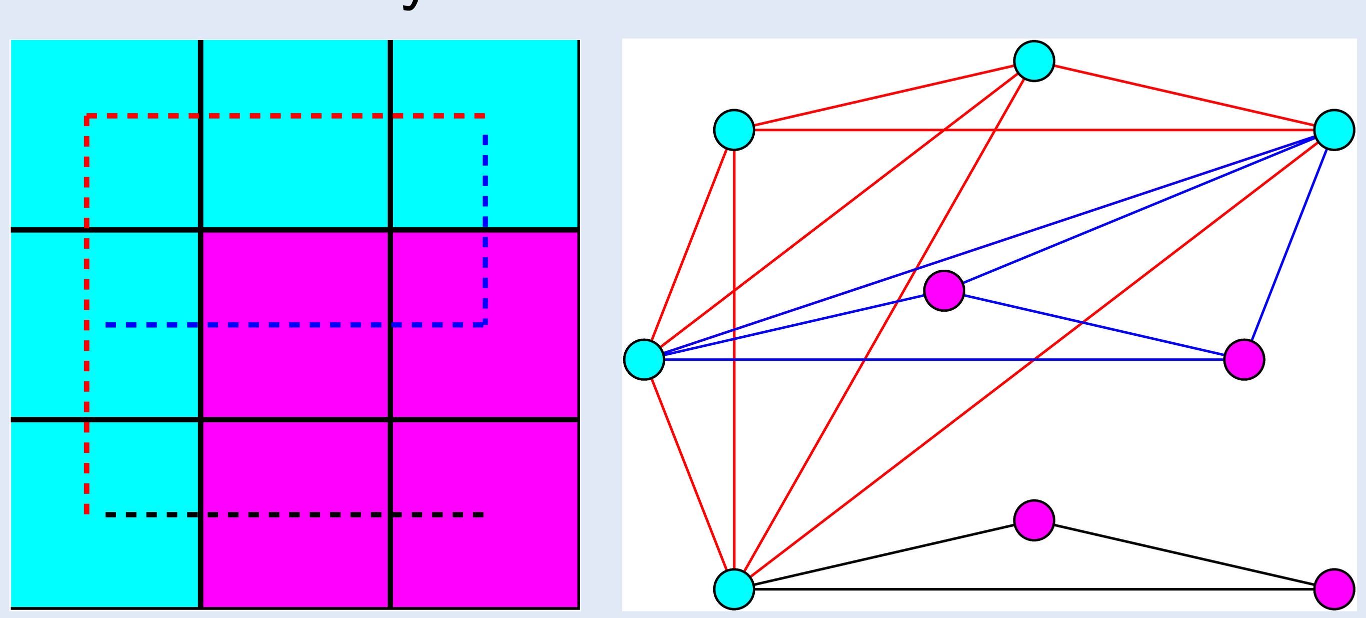
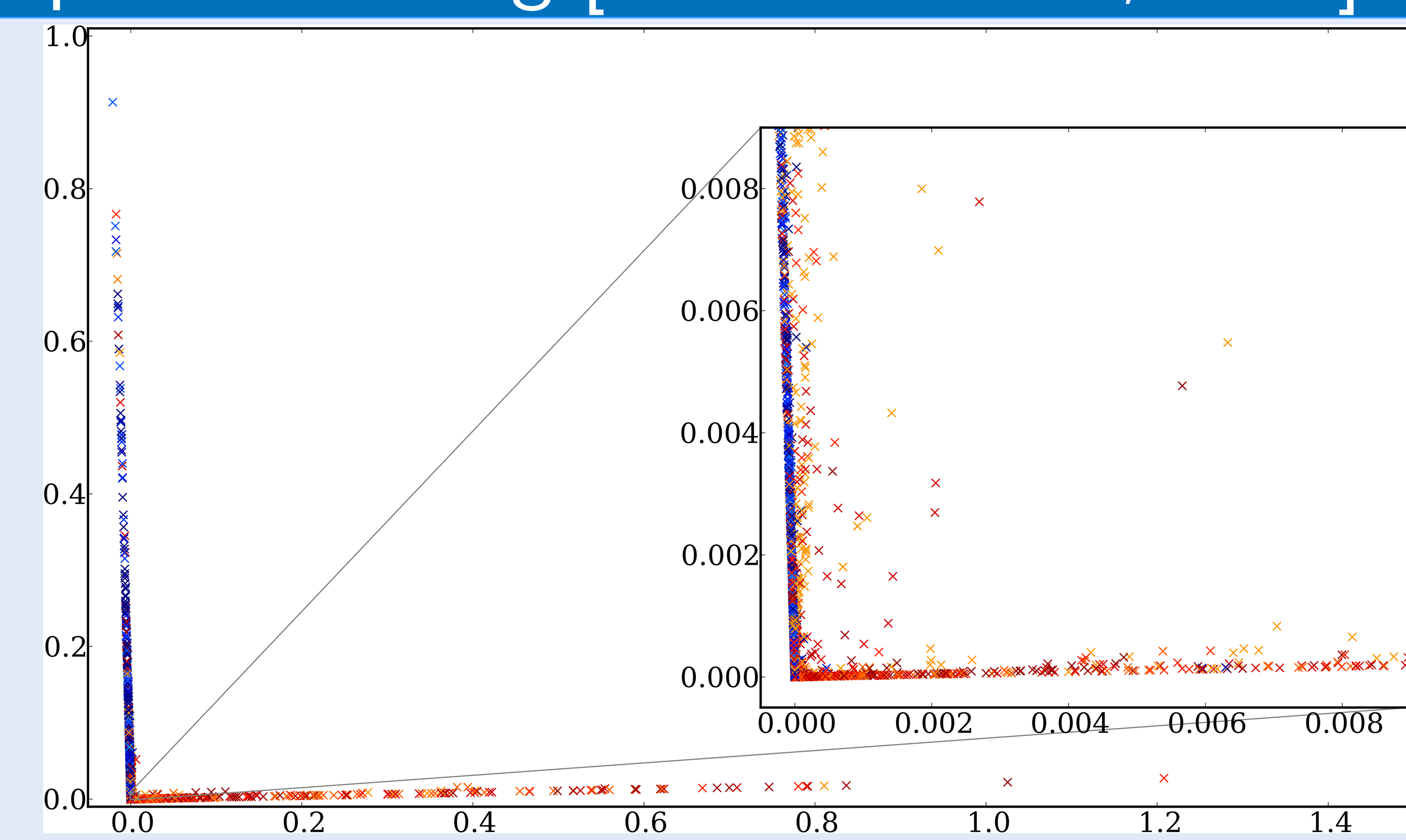


Figure: Left: A 3×3 image with 3 different fibers. The pixels are either cyan or magenta and the fibers are shown in red, blue and black. Right: The corresponding graph which is constructed as described above. The node colors correspond to pixel colors and the edge colors correspond fiber colors.

Data

- 50 DTMRI images and MPRAGE images.
- Main analysis on 1 brain: size is $149 \times 185 \times 149$ voxels
  1. Start a fiber tract at each voxel [Mori et al., 1999]
  2. Build graph as described
  3. Keep largest connected component ($\approx 500K$ nodes)
  4. Embed the Graph ...

Graph Embedding [Sussman et al., 2012]



Embedding of Brain Graph: Each point represents a node in the graph, ie voxel in image. (Red = right brain, blue = left brain)

- Convert the graph, (ie nodes and edges) into points.
- Each point represents a node in the graph.
- Uses spectral statistics of adjacency matrix.
- Note: Can choose # of dimensions (above $d = 2$).

DTMRI Image ⇒ Fibers ⇒ Graph ⇒ Point Cloud

Classification Framework

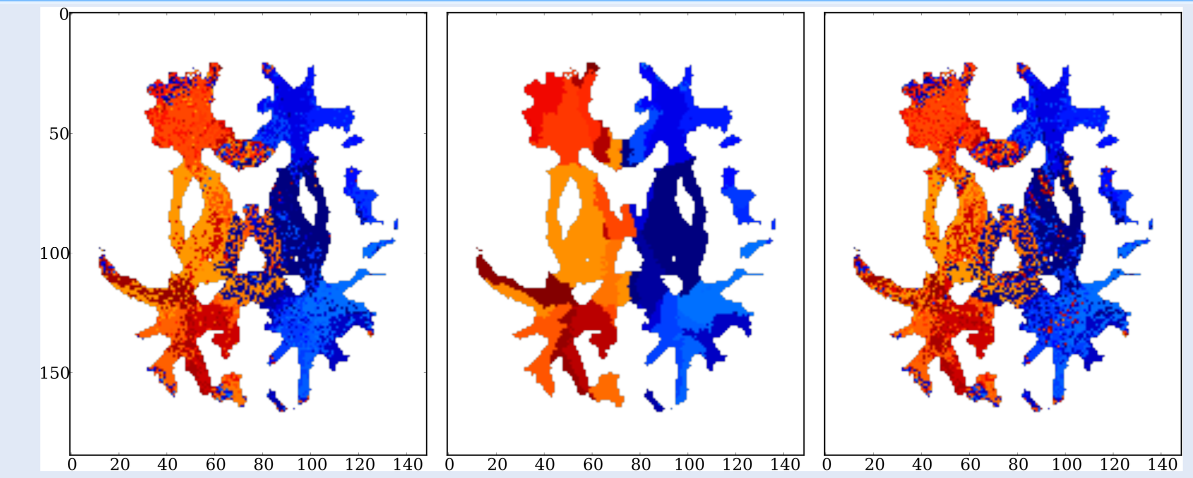
Each voxels/node/point is labelled with an ROI (ie color of the node).

> Suppose we hide the ROI labels, can we recover them using the graph structure alone?

- We perform a 5-fold cross validation, 20% of the points for testing, use 80% for training.
- For each test point find nearest neighbor among
  - (Full) all training points OR
  - (No Clique) training points not on same fiber as test voxel, ie not adjacent to test node.

No Clique emphasizes *secondary* graph structure.

Results



Example Slice: Colors indicate ROI. Left and right show predicted ROI using Full and No Clique 5-fold cross validation classification procedure, respectively. Center is the true ROI labelling.

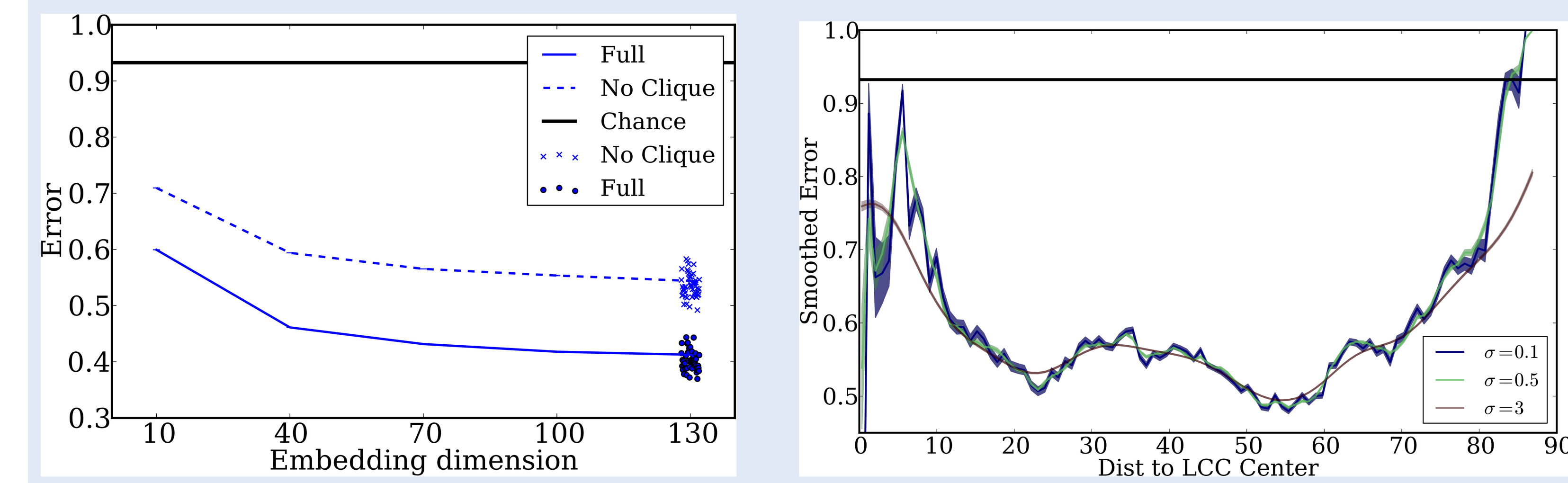


Figure: (Left) Classification error rate for single subject. The chance line indicates the error rate if there was no relationship between ROI and the graph. Dots indicate error rate for 49 other subjects. Conclude ROI and graph structure are related. (Right) Smoothed Error rate as a function of the distance to center of the largest connected component in voxel space.

Conclusion

- Amongt the first voxel-level graphs from DTMRI.
- Voxel-level DTMRI graphs retain spatial information.
- Signal is retained even after removing some of the clique structure which biases the error rate.
- High error rates occur in locations well explained by our understanding of the brain and DTMRI.

Future Work

- Show that ROI boundaries correspond in some way to notional graph boundaries.
- Use framework to evaluate ROIs based on the brain graph structure.

References

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