CS 4884: Projects

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March 7, 2019
Plan after Spring Break

- Schedule meetings with project groups during class time in my office.
- Number of meetings will depend on number of groups.
- Poster preparation for VTURCS Symposium on April 30.
Schedule of Meetings

- Each group meets me for 60–90 minutes three times.
  - Goal is to discuss details of project.
  - Come prepared with a plan to each meeting (you will have to prepare for the meeting):
    - Read your paper or book section. Find other relevant papers.
    - Create a detailed outline of your work and individual responsibilities.
    - Present the results you have obtained since the last meeting.
    - Ask me questions, especially about challenges you are facing.

- Office hours for these meetings:
  - Start Thursday, May 21, 2019
  - 3:30pm–5pm on Tuesdays
  - 1pm–2:30pm on Thursdays,
  - 3:30pm–5pm on Thursdays,
  - and by appointment.
How are signals propagated efficiently in brain networks?

Algorithms such as Dijkstra’s require complete knowledge of all the nodes and edges in a graph.

A node in the brain is likely to have information only on neighbours.

How can we define an efficient routing protocol in this scenario?
Project: Navigation Routing: Idea

- Paper: *Navigation of brain networks*.
- Use a simple propagation rule that is based on local knowledge of the distance between cortical regions.

\[ E_{R}(A, H) = 0.75 \]

\[ E_{R}(B, F) = 0 \]

\[ E_{R}(E, C) = 1 \]

\[ E_{R}(s, t) = 0.75 \]
Project: Navigation Routing: Goals

- Implement navigation routing.
- Compare it to other shortest path algorithms, including Dijkstra’s algorithm and the A* algorithm.
- Is the Bellman-Ford algorithm useful here? How can we use it as an alternative to navigation routing.
- Develop methods to compare its performance to all the other algorithms.
- Replicate the results in Figures 1-3 and, if possible, Figure 4 in the paper.
How are different components of the brain network important for different cognitive control?

How do these components shift between cognitively demanding states?

How can we compute the components from connectomes?
Project: Functional Subgraphs: Idea

- Paper: Subgraphs of functional brain networks identify dynamical constraints of cognitive control
- Use quantitative, matrix techniques to determine how the brain is able to accomplish multiple tasks.

\[
W \times H \approx V
\]

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Project: Functional Subgraphs: Idea

- Paper: Subgraphs of functional brain networks identify dynamical constraints of cognitive control
- Use quantitative, matrix techniques to determine how the brain is able to accomplish multiple tasks.
Project: Functional Subgraphs: Idea

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- Use quantitative, matrix techniques to determine how the brain is able to accomplish multiple tasks.

PCA
Learn about NMF yourself. What are its advantages over other ways of factoring matrices or clustering graphs?

Recreate the results in the paper, especially Figures 3–5 and perhaps Figure 6 as well.

Try methods similar to NMF, e.g., other clustering algorithms, to see if you can get similar results.
Project: Consensus Clustering: Motivation

- How many clustering algorithms do you know?
Project: Consensus Clustering: Motivation

- How many clustering algorithms do you know?
- How many clustering algorithms are there in the literature?
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Community landscapes: an integrative approach to determine overlapping network module hierarchy, identify key nodes and predict network dynamics

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Summary

In this Electronic Supplementary Material (S1) we give a detailed description of the ModuLand network module determination method family. This integrative method is based on the construction of community landscapes from influence functions. In Section IV, we describe three versions of the influence function calculation algorithms, the NodeLand, LinkLand and PerturLand algorithms in detail. As the next step, the combination of influence functions to a community landscape is shown. We demonstrate the wide applicability of the ModuLand method to accommodate previous community detection methods in the examples of the BetweennessCentralityLand (BCLand) and CliqueLand community landscape determination methods resulting in distinct and overlapping network modules, respectively. In Section V, we show the local maxima-based identification of modules as hills of the community landscape. The module membership of network nodes and links is calculated using one of the developed module membership assignment methods, such as the GradientHill, ProportionalHill or TotalHill methods yielding modules of minimal, fair or detailed overlaps, respectively. In Sections VII and VIII, we also show that the ModuLand method family enables a hierarchical analysis of network topology and the construction of a zoom-in network visualization method. Besides the detailed description of the ModuLand method the Electronic Supplementary Material also contains 14 Supplementary Figures and their Supplementary Discussion, as well as a detailed summary of 18 module definitions, 129 different modularization methods, 13 module comparison methods as 5 Supplementary Table, 96 and 956 references.
How many clustering algorithms do you know?
How many clustering algorithms are there in the literature?

Supplementary Figures and their Supplementary Discussion, as well as a detailed summary of 18 module definitions, 129 different modularization methods, 13 module comparison methods as 5 Supplementary Tables and 396 references.
How many clustering algorithms do you know?
How many clustering algorithms are there in the literature?
How do we compare the results of different clustering algorithms? How do we combine them?
Project: Consensus Clustering: Goals

- Read chapter Chapter 9.3: Comparing and Aggregating Network Partitions of the textbook.
- Read other papers on "consensus clustering" published in the literature.
- Decide a set of algorithms to compare after discussion with me.
- Download the code for each algorithm and make sure it runs well. If necessary, you may have to implement some algorithms.
- Develop and implement ideas and methods for comparing modules and partitions computed by different algorithms.
- Implement consensus clustering algorithms.
- Run these algorithms on connectomes and report your results.
Brain networks are modular, where each module is a set of nodes that is highly connected internally.

How are intermodule connections distributed within a network?
**Project: Rentian Scaling: Idea**

- Brain networks are modular, where each module is a set of nodes that are highly connected internally.
- How are intermodule connections distributed within a network?
- Rentian scaling: number of external connections between nodes in different modules is related to the number of nodes inside the modules by a power-law relationship.

![Diagram](image-url)
Project: Rentian Scaling: Goals

- Relevant reading:
  - Efficient Physical Embedding of Topologically Complex Information Processing Networks in Brains and Computer Circuits
  - Evidence of Rentian Scaling of Functional Modules in Diverse Biological Networks
  - Chapter 8.3.3: Rentian scaling

- There are different algorithms for computing modules. How much does the Rentian scaling property (the power in the law) vary depending on the algorithm?

- Does Rentian scaling change from one organism to another?

- There are two different notions of Rentian scale: topological and geometric. There are different ways to compute them. How do these values differ?
Project: Generative Models: Idea

- We have studied and analysed several types of connectomes.
- Each of these connectomes arose from experimental observations of the brains of different organisms.
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What types of (evolutionary) processes in nature can generate connectomes that exist in organisms?
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Project: Generative Models: Goals

- Consider several mathematical models that have been proposed for connectomes.
- Test these models for their ability to generate artificial networks with properties that match those of real connectomes such as the small world property and hierarchical modularity.
- Relevant reading:
  - Resolving Structural Variability in Network Models and the Brain
  - Box 10.1: Growth Connectomics: Generative Models for Brain Networks
- Should models incorporate geometric constraints imposed by the structure of the brain?