CS 4884: Projects

T. M. Murali

February 18, 2020

Project 1: Small-Worldness of Fly Connectome

A Connectome of the Adult *Drosophila* Central Brain

C. Shan Xu, Michal Januszewski, Zhiyuan Lu, Shin-ya Takemura, Kenneth J. Hayworth, Gary Huang, Kazunori Shinomiya, Jeremy Maitin-Shepard, David Ackerman, Stuart Berg, Tim Blakely, John Bogovic, Jody Clements, Tom Dolafi, Philip Hubbard, Dagmar Kainmueller, William Katz, Takashi Kawase, Khaled A. Khairy, Laramie Leavitt, Peter H. Li, Larry Lindsey, Nicole Neubarth, Donald J. Olbris, Hideo Otsuna, Eric T. Troutman, Lowell Umayam, Ting Zhao, Masayoshi Ito, Jens Goldammer, Tanya Wolff, Robert Svirskas, Philipp Schlegel, Erika R. Neace, Christopher J. Knecht Jr., Chelsea X. Alvarado, Dennis A. Bailey, Samantha Ballinger, Jolanta A Borycz, Brandon S. Canino, Natasha Cheatham, Michael Cook, Marisa Dreher, Octave Duclos, Bryon Eubanks, Kelli Fairbanks, Samantha Finley, Nora Forknall, Audrey Francis, Gary Patrick Hopkins, Emily M. Joyce, SungJin Kim, Nicole A. Kirk, Julie Kovalyak, Shirley A. Lauchie, Alanna Lohff, Charli Maldonado, Emily A. Manley, Sari McLin, Caroline Mooney, Miatta Ndama, Omotara Ogundeyi, Nneoma Okeoma, Christopher Ordish, Nicholas Padilla, Christopher Patrick, Tyler Paterson, Elliott E. Phillips, Emily M. Phillips, Neha Rampally, Caitlin Ribeiro, Madelaine K Robertson, Jon Thomson Rymer, Sean M. Ryan, Megan Sammons, Anne K. Scott, Ashley L. Scott, Aya Shinomiya, Claire Smith, Kelsey Smith, Natalie L. Smith, Margaret A. Sobeski, Alia Suleiman, Jackie Swift, Satoko Takemura, Iris Talebi, Dorota Tarnogorska, Emily Tenshaw, Temour Tokhi, John J. Walsh, Tansy Yang, Jane Anne Horne, Feng Li, Ruchi Parekh, Patricia K. Rivlin, Vivek Jayaraman, Kei Ito, Stephan Saalfeld, Reed George, Ian Meinertzhagen, Gerald M. Rubin, Harald F. Hess, Louis K. Scheffer, Viren Jain, Stephen M. Plaza

doi: https://doi.org/10.1101/2020.01.21.911859

- Goal: Determine if this network has the small-world property.
- Challenge: network has 25K nodes and 3M edges

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- Goal: Determine if this network has the small-world property.
- Challenge: network has 25K nodes and 3M edges $\Rightarrow$ need to compute 625M shortest paths.
- Devise sampling strategies to estimate average shortest path length efficiently.
- Do the same for clustering coefficient.
- How will you know that your estimates are accurate?

Project 2: Clustering in Fly Connectome

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- Goal: Determine clusters in this network and connect them to functional regions in the fly brain.
- Challenge: network has 25K nodes and 3M edges

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- Goal: Determine clusters in this network and connect them to functional regions in the fly brain.
- Challenge: network has 25K nodes and 3M edges $\Rightarrow$ clustering algorithms are likely to be slow.

Project 3: Routing in Connectomes 1

- How are signals propagated efficiently in brain networks?
- Does the brain use Dijkstra's algorithm?

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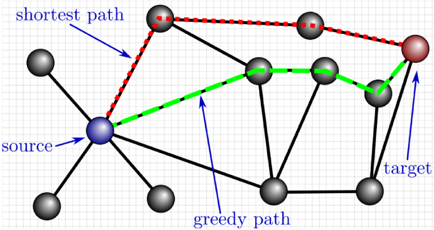
- How are signals propagated efficiently in brain networks?
- Does the brain use Dijkstra's algorithm?
- How does the brain route signals given a node's limited knowledge of entire network?

Navigable maps of structural brain networks across species

Antoine Allard, M. Ángeles Serrano

Version 2 Published: February 3, 2020 • https://doi.org/10.1371/journal.pcbi.1007584



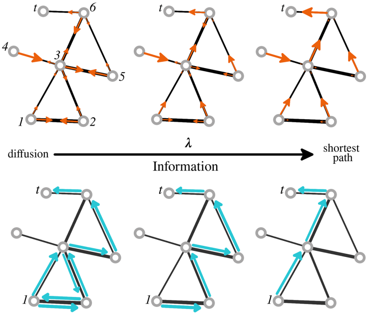
Project 4: Routing in Connectomes 2

- Local-global strategy: combine diffusion and shortest-path approaches to routing.
- Changing one parameter smoothly transitions from one extereme to another.

A spectrum of routing strategies for brain networks

Andrea Avena-Koenigsberger, Xiaoran Yan, Artemy Kolchinsky, Martijn P. van den Heuvel, Patric Hagmann, Olaf Sporns

Version 2 Published: March 8, 2019 • https://doi.org/10.1371/journal.pcbi.1006833



Project 5: Rentian Scaling

- Brain networks are (believed to be) modular.
- How are connections between modules distributed within a network?

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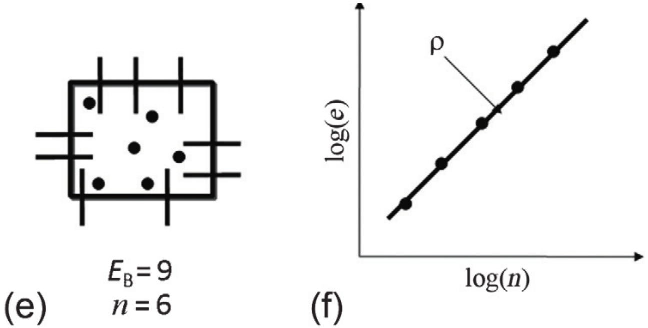
- Brain networks are (believed to be) modular.
- How are connections between modules distributed within a network?
- Rentian scaling: Power-law relationship between number of nodes in a module and number of edges leaving module.
- Goal: Determine the Rentian scaling laws for different brain networks.
- Challenge: implement algorithms for topological/geometric Rential scaling.



Project 6: A Mouse Connectome

- Organizing principles for the cerebral cortex network of commissural and association connections: publication and analysis of a comprehensive connectome of the mouse brain, collected from findings in over 185 publications that appeared in the literature since 1974.
- Goal: Analyze the structural properties of this connectome.
  - Small-worldness
  - Efficiency
  - Clustering
- Additional challenge: correlate this network with the mouse connectome created independently by the Allen Institute for Brain Science.

Project 7: Generative Models of Connectomes

- Connectomes arise from experimental observations of the brains of different organisms.
- What types of evolutionary processes in nature can generate the types of connectomes that exist in organisms?
- Several mathematical models that have been proposed for connectomes.
- Goal: 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 modularity.
  - Resolving Structural Variability in Network Models and the Brain
  - Box 10.1: Growth Connectomics: Generative Models for Brain Networks
- Important question: should models incorporate geometric constraints imposed by the structure of the brain?

Project 8: Genetic Model of the Connectome

Neuron

VIEWPOINT | VOLUME 105, ISSUE 3, P435-445.E5, FEBRUARY 05, 2020

A Genetic Model of the Connectome

Dániel L. Barabási • Albert-László Barabási [5] • Show footnotes

Published: December 02, 2019 • DOI: https://doi.org/10.1016/j.neuron.2019.10.031 •

- Why do connectomes of individuals of the same species show considerable architectural and wiring similarity?
- How is neuronal connectivity encoded at the protein level?

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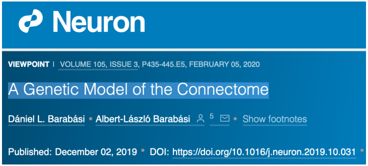

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- Why do connectomes of individuals of the same species show considerable architectural and wiring similarity?
- How is neuronal connectivity encoded at the protein level?
- Hypothesis: genetic identity of neurons guides synapse formation.
- Predict the existence of specific biclique motifs in the connectome.