Math Matters

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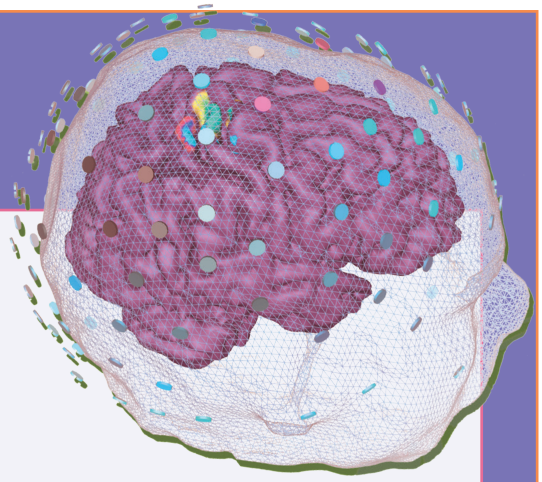
The math behind...
Brain Connectivity



Technical terms used:

Neuron, synapse, connectome, graph, vertex, edge, hub, module, efficiency

Uses and applications:

Maps of brain connectivity can be used to understand how the brain works, diagnose disorders, and study the effects of drugs and treatments.

How it works:

The brain is composed of billions of connected cells, called neurons. The interactions between these cells are responsible for all of our thoughts, memories, and personalities. When there are problems with the connections between neurons, diseases can result. How does this happen, and is it possible to understand how a brain works from studying its connections?

To answer this, neuroscientists have been making maps of brain connections – called connectomes – using techniques such as MRI. The resulting maps are far too complicated to interpret by eye, and require other analytic techniques. To study connectomes, a type of mathematics called graph theory is used, which allows us to use formulae to describe and investigate the properties of networks.

Using graph theory, scientists are beginning to find patterns in how neurons connect to one another that are helping them learn how the brain processes information. For example, graph theoretic analysis has revealed that brains contain special "hubs" with many connections that seem to be responsible for the efficient communication between spatially separated regions. It is these hubs that are most affected by diseases such as Huntington's and Alzheimer's.

The study of brain connectivity is still an emerging field with many unsolved problems. Although much remains to be discovered, the mathematics of graph theory has already proven itself a powerful and invaluable tool in developing our understanding, and might someday help us find better treatments for brain disorders and psychiatric conditions.

Interesting facts:

The human brain has as many neurons as stars in the Milky Way galaxy, about 100 billion; as such, it has so far only been possible to create partial maps of the human brain. The only animal to have had its entire connectome mapped is a small worm called C. elegans, with just 302 neurons. It is hoped that we will soon achieve the same for larger animals, and someday humans too.

References:

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J. D. Medaglia, D. S. Bassett, Network Analyses and Nervous System Disorders. arXiv:1701.01101 (2017).

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