MSc in Computational Cognitive Neuroscience

Goldsmiths UNIVERSITY OF LONDON

Developing a neuropercolation of a small cellular network to explore universal cognitive patterns.

Leah Greenaway & Tim Blackwell

Background

Neuropercolation theory is a mathematical approach to describing and modelling phase transitions and criticality in the brain, particularly in large-scale cortical networks. In this theory, phase transitions refer to the change in the dynamics of neural activity as the parameters of the model pass a threshold, for example the change from a subcritical state to a supercritical state. Criticality in the brain is the state of the system when it is at the brink of a phase transition between order and randomness. Kozma (2015), summarizes the theory of neuropercolation in modelling the brain, stating that it combines various mathematical concepts. These concepts combined allow for the modelling of complex neural systems with a novel, underutilized method.

They propose that neuropercolation theory could be used to interpret rapid transitions, as it combines several other theories which individually could explain parts of phase transitions in the brain. The current research project investigates how far the boundaries of the model can be pushed, and whether it is achievable to reproduce transient behaviour observed in brain imaging.

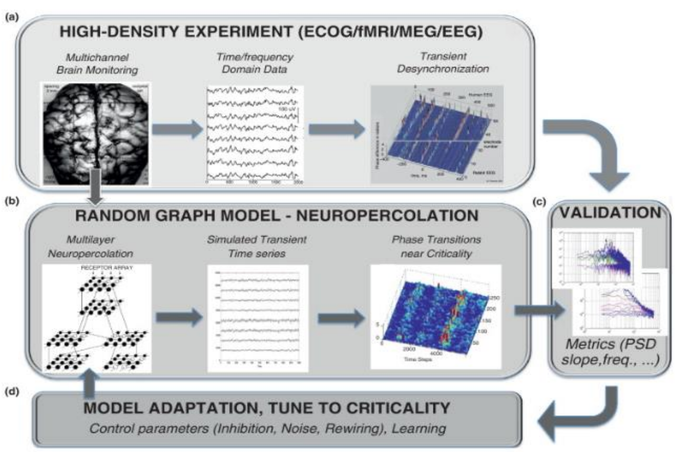

Figure 1 (Kozma, 2015) Comparison of brain imaging data and simulated neuropercolation results.

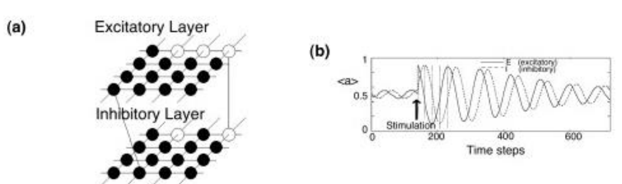

Figure 3 (Kozma, 2015) Hierarchy of neuropercolation model with example of time series graph.

Research questions

- To what extent can the parameters of a neuropercolation model be pushed to reproduce transient behaviour?
- Is there a way to improve on the drawbacks of the current modelling technique?
- Are there any emergent properties observed in the neuropercolation model?

Hypothesis

It is hypothesised that a neuropercolation model of a small cellular network will produce output patterns which are comparable to transient behaviour in the human brain. It is hypothesised that the cellular network will artificially and randomly replicate pre-existing patterns in the brain and be an appropriate model for a biological cellular network.

Methodology

An original model of a group of neurons experiencing criticality will be developed in MATLAB, neuropercolation rules will be applied to the model and the resulting time series graphs will be analysed. The time series graphs will show phase transitions in the model, and they will be compared using statistical techniques such as ARIMA and the Augmented Dickey Fuller test.

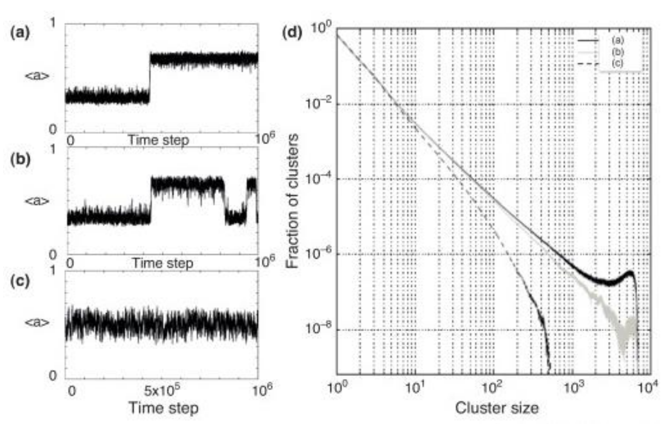

Figure 2 (Kozma, 2015) Example of time series graphs in neuropercolation.

Summary

The current project aims to develop a neuropercolation of a group of neurons, comparing the resulting time series to evaluate the biological replicability capabilities of the modelling technique.

Kozma, R., Puljic, M. (2015). Random graph theory and neuropercolation for modelling brain oscillations at criticality. *Current opinion in neurobiology, 31,* 181-188.