Quantifying the dynamics of complex neural systems

Ben D. Fulcher[1]*

[1] *School of Physics, The University of Sydney, Camperdown NSW, Australia.*
* ben.fulcher@sydney.edu.au

Many systems in the world around us are complex and evolve through time, and can be measured in the form of multivariate time series, $\mathbf{X}(t)$. Neural datasets are often in this form, and are being measured in increasing volumes, with unprecedented spatial and temporal resolution. How do we find and quantify interesting patterns in these complex, high-dimensional data?

In this lecture I will introduce different ways of thinking about dynamics, and the corresponding tools that exist for analyzing time-series data. In particular, I will introduce the 'highly comparative' methodology that we have developed for quantifying time-series datasets (so called because large numbers of possible analysis methods are compared). This highly comparative approach enables new, systematic ways of analyzing time series, leveraging interdisciplinary literatures in ways that link scientists back to interpretable theory, thereby providing deeper understanding of the observed dynamical structure. The highly comparative approach is implemented in two key software packages: *hctsa* (which implements > 7000 time-series features) [1]; and *pyspi* (which implements ~ 250 statistics of pairwise dependence) [2].

I will overview recent applications of this approach to problems in neuroscience—including to experiments in mouse brain stimulation, and whole-brain resting-state EEG and fMRI—where the approach has uncovered new types of temporal structure in datasets. I will also summarize general issues to consider when analyzing time series, including the importance of preprocessing, and accounting for spatial dependencies in time-series data measured from physical systems.

References

[1] B.D. Fulcher, N. S. Jones, *Cell Systems* **5**(5): 527 (2017).

[2] O.M. Cliff, J.T. Lizier, N. Tsuchiya, B.D. Fulcher, *arXiv*: 2201.11941 (2022).