New tools for time-evolving brain network analysis from Aalto University

In his master’s thesis in Complex Systems, titled ‘Construction and multilayer motif analysis of temporal fMRI brain networks’, Tarmo Nurmi presents a new pipeline tool for building multilayer brain networks with time-evolving brain regions from brain imaging data. The brain networks represent constantly changing patterns of connections between the neurons and regions in the brain: these patterns can be disassembled into smaller constituents (motifs) which give insight into how the human brain functions.

Brain networks are usually defined in terms of static brain regions that don’t change in time. However, current research has indicated that these brain regions are often internally inconsistent and do not always function as coherent units in functional magnetic resonance brain imaging. In his master’s thesis, Tarmo Nurmi creates a tool for constructing less constrained time-evolving multilayer brain networks, where brain regions are defined in a data-driven manner from current imaging data instead of from static precomputed brain atlases. This tool uses a topical mathematical framework called multilayer networks, a generalization of simple networks, that are capable of accommodating temporal information into the networks. The multilayer networks constructed by the tool consist of layers corresponding to intervals in time, and brain regions on a layer can be freely defined using data from the time interval corresponding to that layer. Brain regions defined using time-interval-specific data can be optimized for internal consistency and coherency, essentially ‘personalizing’ the brain networks to a specific imaging subject and task.

The pipeline tool presented in the thesis also finds the sub-network building blocks of these brain networks, which can be compared between subjects and to statistical null models to identify repeating motifs. Some applications are presented as a proof-of-concept for the function of the pipeline. In the thesis work, the pipeline is applied to data from subjects of Finnish and Russian cultural backgrounds listening to a story with cultural elements, in order to find exact points in time where connectivity patterns differ between the groups. The time-point differences are, however, small between the groups. The pipeline is also applied to compare randomly shuffled networks against human brain networks, showing that well-connected sub-networks are more prevalent in human brains than in the randomized reference networks.

Contact information: Tarmo Nurmi, tarmo.nurmi@aalto.fi