Graph Cellular Automata and Beyond: Applications in Network Neuroscience

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Abstract

Classical cellular automata on lattices are minimal models of emergent complexity; replacing the lattice by an arbitrary graph yields a *graph cellular automaton* (GCA), in which the topology of the network becomes part of the dynamics. In this talk we first review GCA on digraphs, where the splitting of a vertex neighborhood into in- and out-neighborhoods allows local rules to distinguish causal directionality. We introduce in-/out-neighborhood densities and three families of update rules (density-based, node-weight, and arc-weight thresholds). Since a GCA is an intrinsically pairwise model, we then go beyond it and propose a formal framework for *simplicial cellular automata* (SCA), whose cells are the directed simplices of a directed flag complex and whose neighborhoods are given by directed q-nearness and directed q-stars. The resulting rule families are built in analogy with the GCA ones. Finally, we present a *brain-inspired* GCA whose underlying digraphs are information partial directed coherence (iPDC) networks estimated from scalp EEG of patients with left temporal lobe epilepsy (Siena Scalp EEG Database). The complexity of the emergent dynamics is quantified by average cell entropy, average mutual information and average Hamming distance, and compared across the pre-ictal, ictal and post-ictal phases in different frequency bands.

Keywords: Simplicial Complexes; Directed Flag Complexes; Graph Cellular Automata; Information Partial Directed Coherence; Brain Connectivity Networks; Epilepsy.

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