Contribution ID: **56** Type: **Poster**

Emergent network motifs under increasing cognitive load

Tuesday, 16 September 2025 16:15 (1 minute)

Biological neural networks can efficiently solve cognitive tasks with different levels of complexity. However, we still lack understanding of how structural and functional features of these networks are affected by increasing the complexity of the goal function. This raises the following fundamental questions: What structural/functional network motifs drive success? How do these motifs change as cognitive demands increase? Can we predict or even engineer success by tuning these features? We address these questions by investigating the emergence of minimal, overrepresented neural network motifs in Artificial Neural Networks (ANNs) evolved via NeuroEvolution of Augmenting Topologies (NEAT). As the proxy for increasing cognitive load we use increasing velocity intervals in a modified version of the classic Atari game Pong. Using a fitness function that involves tracking, prediction and minimal complexity, we evolved three ensembles of ANNs with a goal to successfully play Pong with the varied maximum velocity of the Pong ball (Low, Medium and High velocity constraints). We found that the number of successful ANNs for the Medium ensemble was approximately two times larger than the number of successful ANNs for the Low and the High ensembles. The visual inspection of the High-Low ANNs solving the task confirmed the presence of repetitive exploitative behaviors whereas Medium ANNs consistently tracked the ball. Taking the intersection of all successful ANNs across the interpolation analysis and re-testing them produced nearly perfect solutions that work across the tractable spectrum. By combining Uniform Manifold Approximation and Projection (UMAP) and Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN), the structural feature vectors of the ANNs were identified and correlated with the success criteria across a broad interval of velocities. By linking neural topology evolution to computational complexity theory, this study offers an insight for understanding how structure emerges to meet the demands of increasing cognitive load.

Primary author: VIDAL FRANCO, Pablo (Institute of Theoretical Physics, Jagiellonian University, Krakow, Poland)

Co-author: ZAGÓRSKI, Marcin (Institute of Theoretical Physics and Mark Kac Center for Complex Systems Research, Jagiellonian University, Krakow, Poland)

Presenter: VIDAL FRANCO, Pablo (Institute of Theoretical Physics, Jagiellonian University, Krakow, Poland)

Session Classification: Coffee and Poster Session