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Abstract

The role of network topology on the dynamics in simulations that are executed on the network is a central question in the field of network science. However, we show that the influence of the topology is affected by the global dynamical simulation parameters. To investigate this impact of the parameter settings, multiple simulation runs are executed with different settings. Moreover, since the outcome of a single simulation run also depends on the randomly chosen start configuration, multiple runs with the same settings are carried out, as well. We present an visual approach to analyze the role of topology in such an ensemble of simulation ensembles. We use the dynamics of an excitable network implemented in the form of a coupled ordinary differential equation (ODE) following the FitzHugh-Nagumo model and modular network topologies.

Motivation

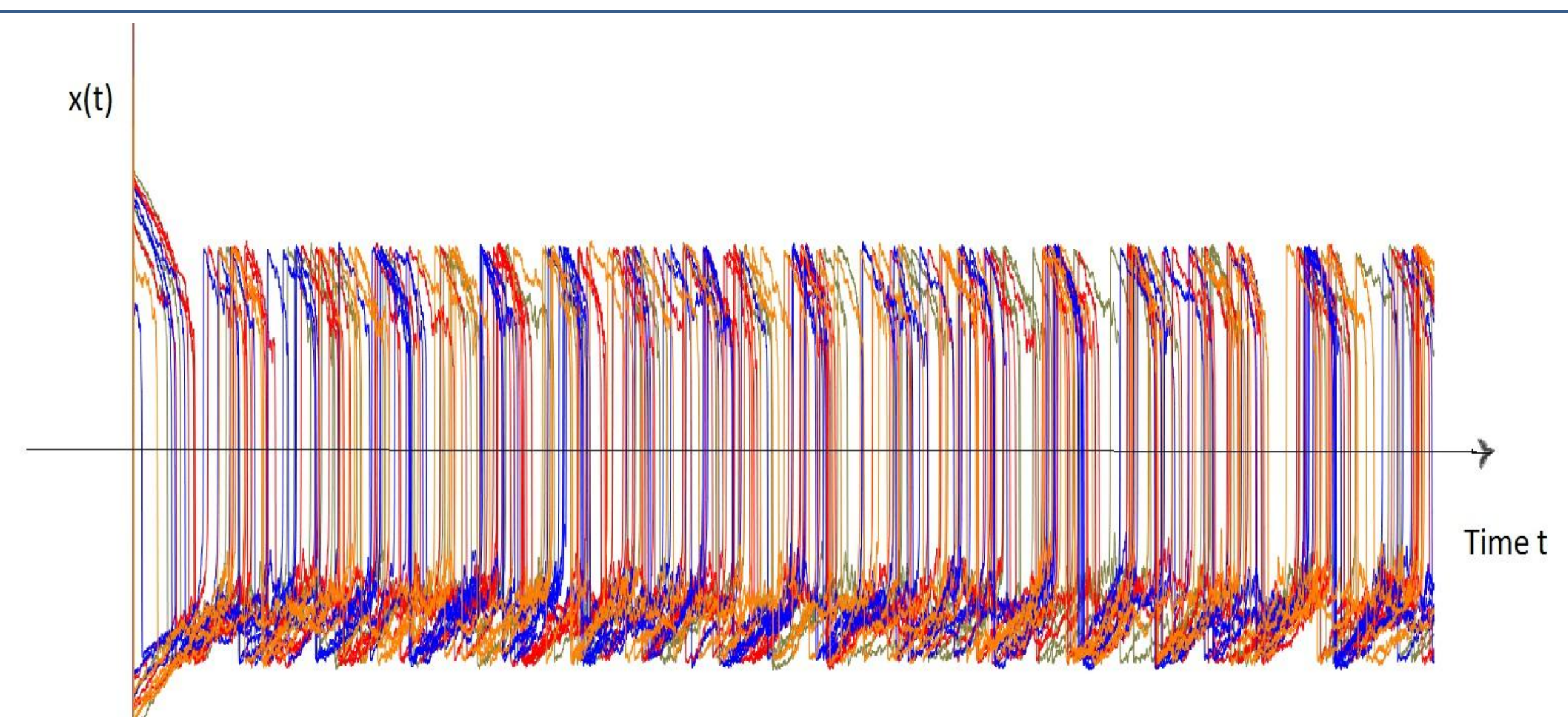
- How topology influences the dynamics is a central question in network science
- Parameters setting determines this influence
- Analyzing effect of parameters has been intensively studied for discrete models at global topological scale
- For continuous models this has not been addressed
- We address it with a visual analytics approach
- We apply it to excitable network dynamics based on the FitzHugh-Nagumo (FHN) model in modular networks in observing co-activation pattern

Simulation of FHN model

- The FHN model is described in the form of an ordinary differential equation (ODE):

$$\begin{cases} \tau_x \frac{dx(t)}{dt} = \gamma x(t) - \frac{x^3(t)}{3} - y(t) + kDx(t) + \sigma v_x(t), \\ \tau_y \frac{dy(t)}{dt} = \beta y(t) + x(t) + \alpha + \sigma v_y(t). \end{cases}$$

- We perform multiple simulation runs for different noise settings
- For each noise setting we perform multiple runs with different random initial configurations

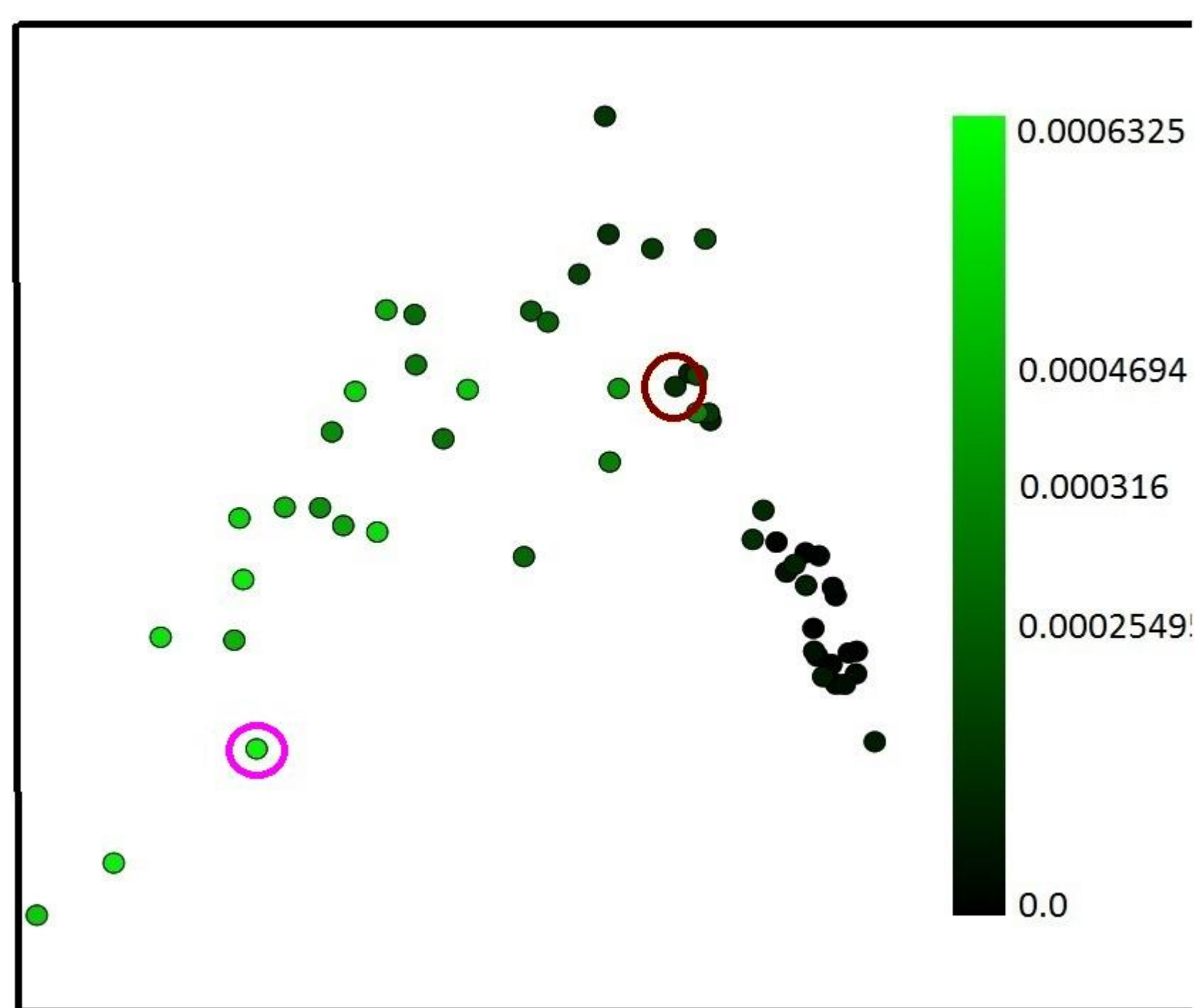


Time series of all nodes in one simulation run (colored by modular topological structure)

Similarity measurement

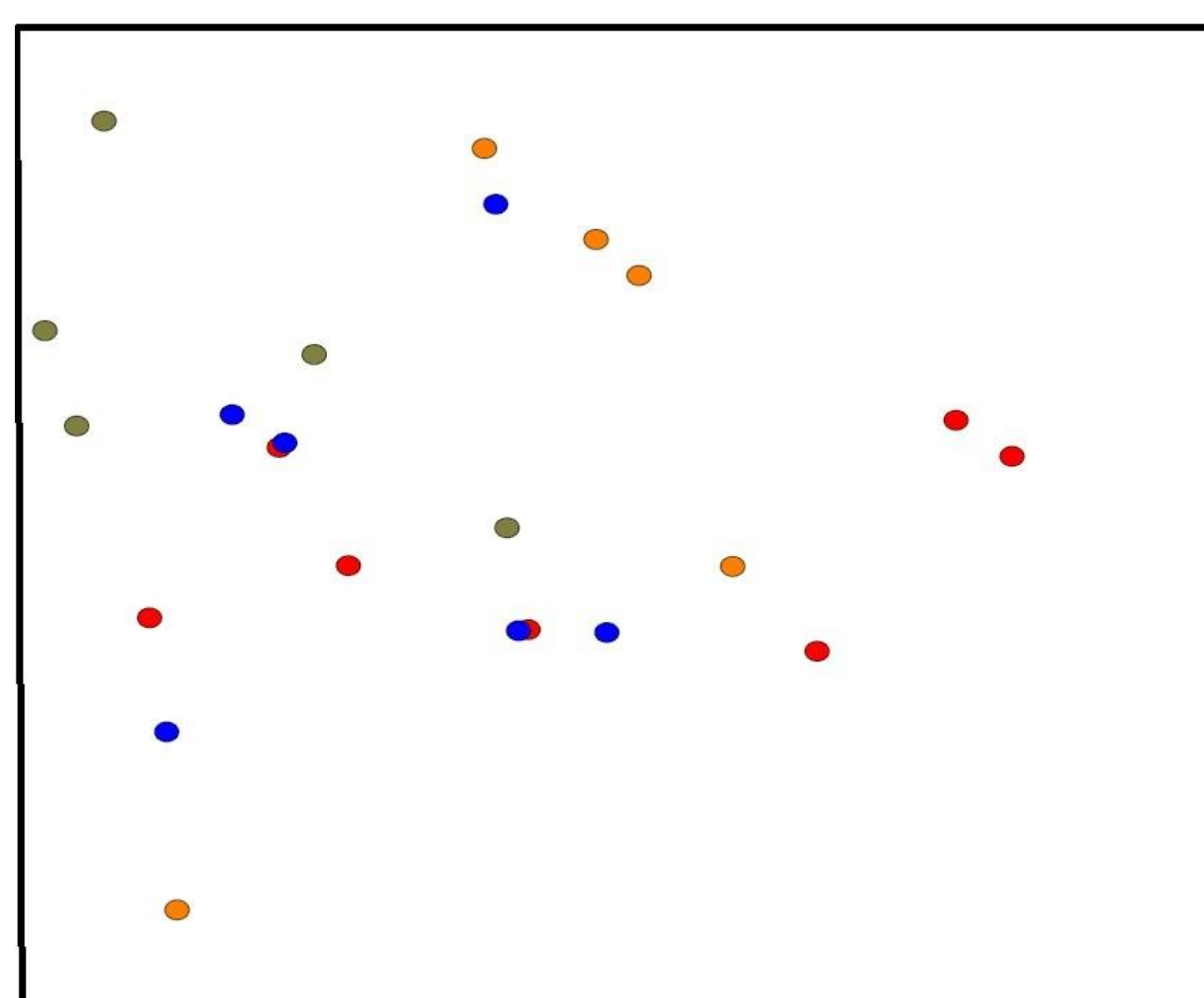
- Compute similarity of the network's nodes in one simulation run by detecting spikes in each node's time series and computing co-activation matrix
- Compute average co-activation matrix for all simulation runs with the same noise setting
- Compute correlation matrix to capture the pair-wise similarities between all ensemble members with different noise settings

Large noise values abolish the influence of topology on dynamics



Ensemble view

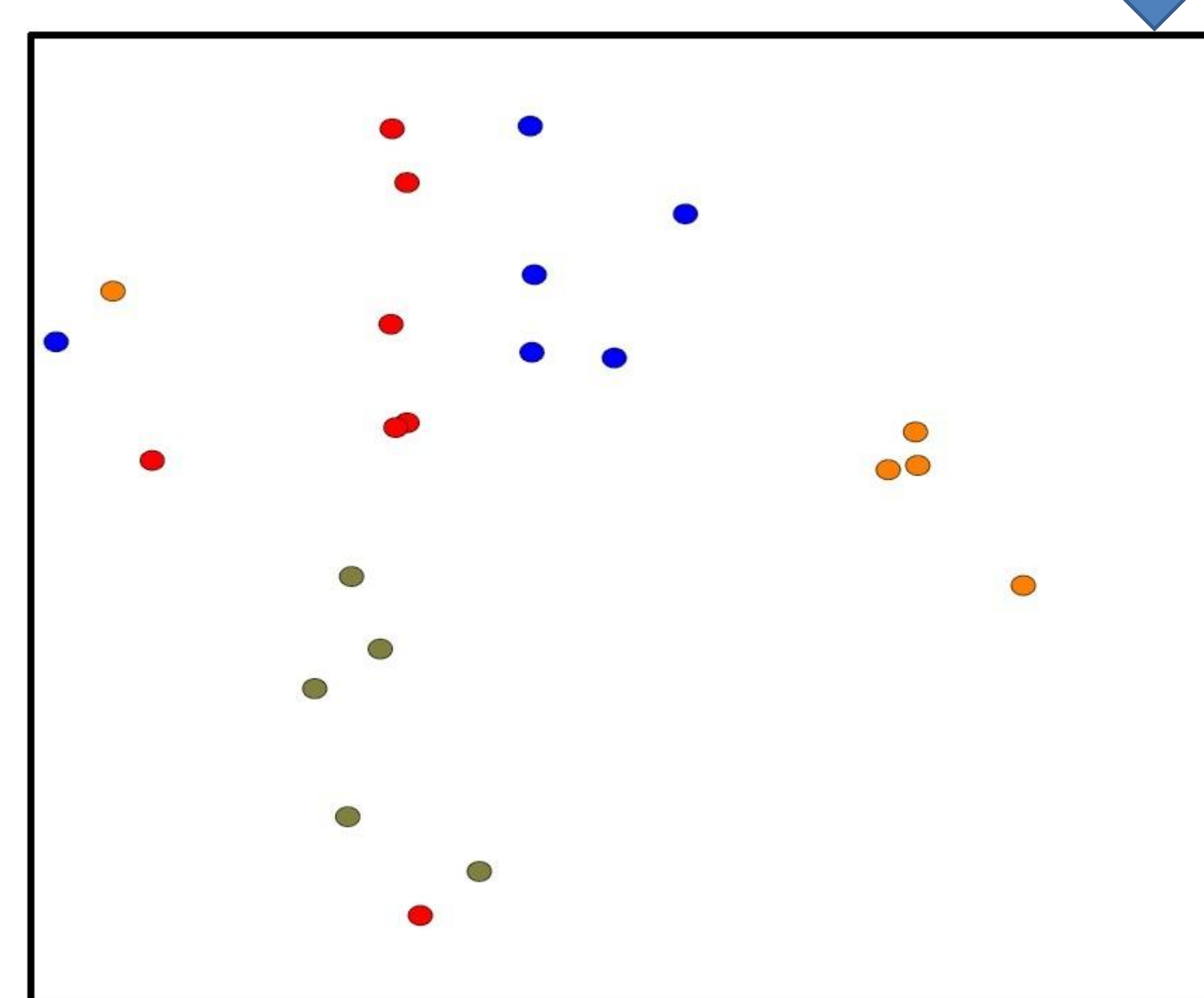
For medium-sized noise values topology drives the dynamics.



Dynamics view

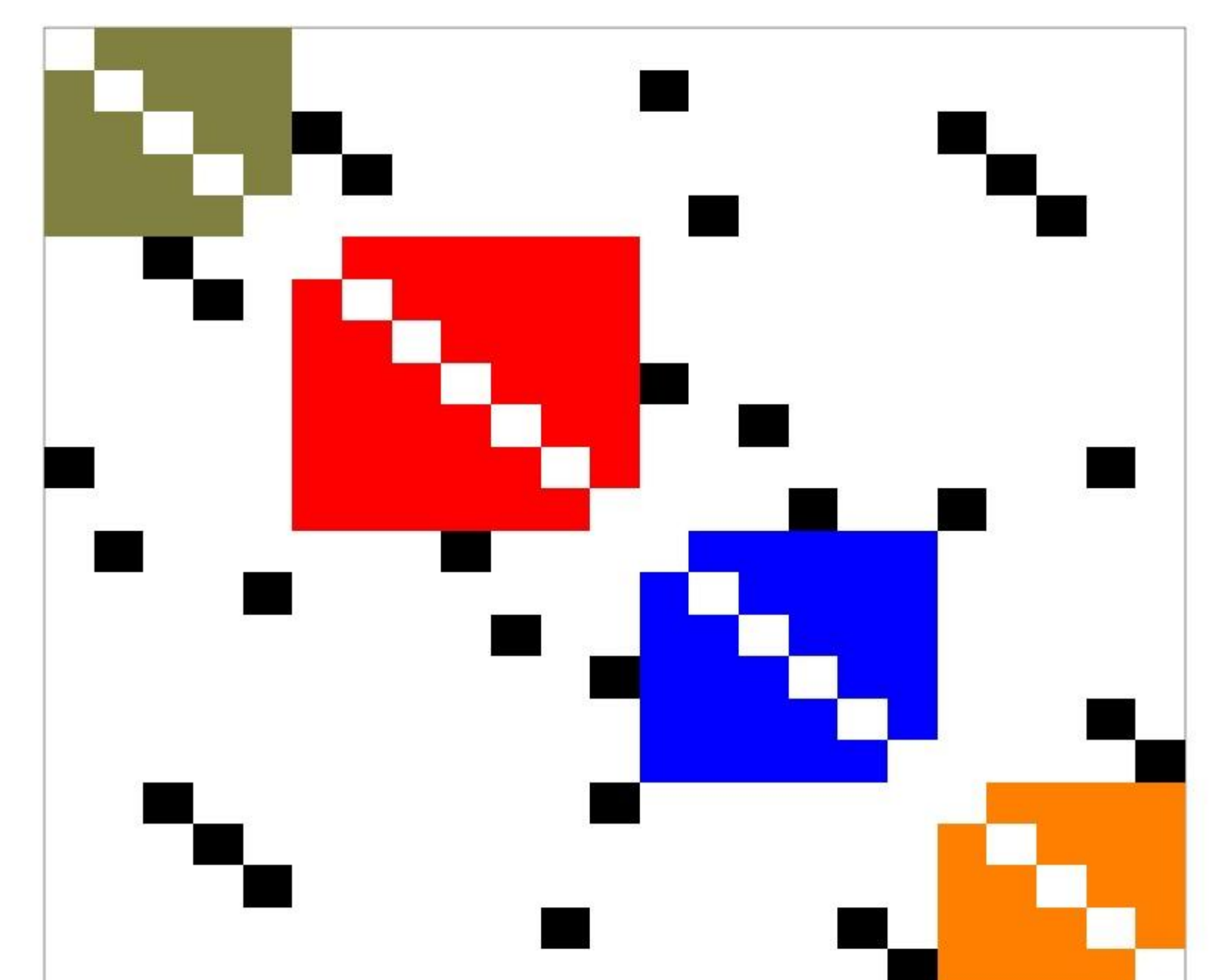
MDS-based similarity plot for ensemble of simulation runs with different noise values (color-coded) based on correlation matrix

MDS-based similarity plot for one noise value based on average co-activation matrix



Dynamics view

We cannot see if topology influences dynamics by looking at color-coded time-series view



Topology view

Adjacency matrix reveals modular network structure

Linking between topological and dynamical views using colors shows if topology impacts dynamics

Results and Conclusions

- We detected three clusters of noise parameter settings in the ensemble
- Coordinated topology-dynamics views reveal their relationship