

## Networked and Multi-Agent Systems

Course Workload		Assessment form (examination/ graded test/ ungraded test)
ECTS	Hours	
3	108	Test

The discipline focuses on methods for studying the dynamics of networked and multi-agent systems, studying the foundations of graph theory and the properties of Laplace matrices.

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### Course structure:

#### 1. Artificial neural networks

- 1.1. Neuron model
- 1.2. Forward propagation
- 1.3. Back propagation
- 1.4. History of artificial neural networks
- 1.5. Convolutional and recurrent neural networks

#### 2. Graphs and networks

- 2.1. Basics from graph theory
- 2.2. Laplace matrix
- 2.3. Agaev-Chebotarev theorem

#### 3. Passification and hyper-minimum-phase systems

- 3.1. Passivity
- 3.2. Hyper-minimum-phase system
- 3.3. Passification theorem

#### 4. Synchronization in networks of linear agents

- 4.1. Statement of the synchronization problem for networks of linear agents
- 4.2. Conditions for ensuring synchronization in the case of a balanced graph

#### 5. Synchronization in networks of nonlinear agents

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- 5.1. Semipassivity
  - 5.2. Synchronization of diffusively coupled oscillators
  - 5.3. Convergence
  - 5.4. Synchronization in networks of Hindmarsh-Rose systems
  - 6. Synchronization in heterogeneous networks
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- 6.1. Network representation in matrix form
  - 6.2. Coordinate transformation to the form "mean-field dynamics - synchronization errors"
  - 6.3. Mean-field and emergent dynamics
  - 6.4. Dynamics of synchronization error system
  - 6.5. Theorem about synchronization in heterogeneous networks
  - 6.6. Synchronization in a heterogeneous network of FitzHugh-Nagumo systems
  - 7. Synchronization in networks of linear agents with nonlinear couplings
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- 7.1. Applying a circle criterion to synchronization analysis
  - 7.2. Synchronization in a network of neural mass model populations
  - 8. Network dynamics modeling
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- 8.1. Modeling network dynamics of Hindmarsh-Rose systems
  - 8.2. Modeling dynamics of coupled Lorentz and Lu oscillators
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