| MI007 | **Complex Networks** | L | P | S | ECTS |
|---|---|---|---|---|---|
| | | 2 | 2 | 0 | 6 |

**Course objectives**. Introduce students with the theory of complex networks and their applications in various areas of science and in everyday life. Analyze structural properties of complex networks by using well known results from graph theory. Identify the most important vertices in a network by using different centrality measures. Show the usage of various network models for analyzing the structure of a network, the processes that occur in it and its robustness. Understand the main methods for partitioning complex networks. Use computers to implement learned methods, to ilustrate and test methods on some concrete types of complex networks.

**Prerequisites**. Undergraduate university study programme of mathematics and/or computer science.

**Course content**.

1. Introduction. Complex networks: definition and basic properties. Examples of complex networks in computer science, physics, chemistry, biology, sociology.
2. Graph theory: basic terms. Directed and undirected graphs. Weighted graphs. Degree of a graph. Subgraph. Path. Cycle. Connectivity and distance in graphs. Random walk. Graph representation. Matrices associated to graphs. Bipartite graphs and trees. Eulerian and Hamiltonian graphs. Graph coloring. Planar graphs. Transportation networks.
3. Centrality measures in complex networks. Degree centrality. Eigenvector centrality. Katz centrality. PageRank centrality. Distance based measures of centrality. Betweenness centrality. Subgraph centrality.
4. The structure of complex networks. Connected components. Shortest paths and the small-world property. Degree distribution. 'Power-law' distribution and hubs. Clustering coefficient. Homophily and assortativity.
5. Models of complex networks. Erdös – Rényi model. Configuration model. Small - world network model. Scale – free network model. Random geometric networks.
6. Partitioning of complex networks. Kernighan – Lin method. Spectral partitioning methods that use Laplace and modularity matrix. Partitioning methods based on vertex betweenness. Hierarchical methods.
7. Dynamical processes in complex networks. Percolation. Molloy – Reed criterion. Epidemic and rumor spreading. Network robustness.

**LEARNING OUTCOMES**

| No. | LEARNING OUTCOMES |
|---|---|
| 1. | Recognize real-world problems that can be modelled by using complex networks. |
| 2. | Use graph theory tools for analyzing properties of complex networks. |
| 3. | Test the efficiency of centrality measures on different types of complex networks. |
| 4. | Describe the main structural properties of real complex networks, basic principles and methods for partitioning of complex networks. |
| 5. | Differentiate basic models of complex networks and explain their role in analysis of real complex networks. |
| 6. | Argue the effect of the structure of complex network to its robustness due to random and systematic failure. |
| 7. | Analyze the structure of complex network by using some software tools. |

**RELATING THE LEARNING OUTCOMES, ORGANIZATION OF THE EDUCATIONAL PROCESS AND ASSESSMENT OF THE LEARNING OUTCOMES**

| TEACHING ACTIVITY | ECTS | LEARNING OUTCOME ** | STUDENT ACTIVITY* | EVALUATION METHOD | POINTS | |
|---|---|---|---|---|---|---|
| | | | | | min | max |
| Attending lectures and exercises | 1 | 1-7 | Lecture attendance, discussion, teams work, independent work on given tasks and short written exams | Attendance lists, tracking activities, closed form exercises | 0 | 4 |
| Homework assignments | 1 | 1-7 | Independent work on given problems | Evaluation | 0 | 10 |
| Written exam (Mid-terms) | 2 | 1-7 | Preparing for written exam | Evaluation | 25 | 43 |
| Final exam | 2 | 1-7 | Revision | Oral exam | 25 | 43 |
| TOTAL | 6 | | | | 50 | 100 |

**Teaching methods and student assessment**. Lectures and exercises are obligatory. The exam consists of a written and an oral part. Upon completion of the course, students can take the exam. Successful midterm exam scores replace the written exam. Exercises are both auditory and laboratory. Laboratory exercises include the usage of computers. Students can improve their grades by writing homework assignments and seminars.

**Can the course be taught in English**: Yes

**Basic literature:**


1. M. E. J. Newman, Networks – An Introduction, Oxford University Press, 2010.
2. M. Newman, A.-L. Barabási, D. J. Watts, The structure and Dynamics of Networks, Princeton University Press, 2006.
3. L. A. Barabási, Network Science, Network Robustness, http://barabasi.com/f/619.pdf


**Recommended literature:**


1. E. Estrada, The Structure of Complex Networks – Theory and Applications, Oxford University Press, 2012.
2. P. Van Mieghem, Graph Spectra for Complex Networks, Cambridge University Press, 2011.
3. R. Diestel, Graph Theory, Electronic Edition 2005.
4. D. Veljan, Kombinatorika s teorijom grafova, Školska knjiga, Zagreb, 1989.