Study programme(s): Applied Mathematics – Data Science

Level: Master studies

Course title: Network science

Lecturer: Nataša M. Krklec Jerinkić

Status: obligatory

ECTS: 5

Requirements: Basics of linear algebra, graph theory, probability and statistics

Learning objectives

- Understanding of a wide range of network models, metrics, and processes
- Understanding of advantages/disadvantages of various network models for a given real-world application
- Ability to model and analyze networks using network analysis tools and libraries

Learning outcomes

- Ability and experience in modelling, sampling, and analyzing real-world networks
- Ability to apply the taught network concepts on research problems from a wide variety of application areas

Syllabus

Theoretical instruction

Elements of algebraic graph theory: adjacency matrix; Laplacian matrix; spectra of Laplacian matrix; Fiedler value. Graph types and representations. Network metrics and notions of connectedness, density, distance, centrality, transitivity and node similarity. Structure and evolution of complex networks: connected component analysis, *k*-cores, cliques and ego-networks, degree distribution analysis (identifying power-laws in empirical data and measuring of preferential attachment), assortativity mixing patterns, community structure, emergence of giant connected components, the densification law and shrinking diameters. Mathematical models of complex networks: random graphs (Erdős–Rényi, Gilbert, geometric models, the configuration model), small-world networks (Watts-Strogatz, Kleinberg) and scale-free networks (the Barabasi-Albert model and modifications, copying based models). Community detection techniques and graph clustering evaluation metrics. Link prediction. Processes on networks: diffusion; gossip; consensus; virus spreading; voter models; emergent behavior; mean-field analysis.

Practical instruction

Application examples in telecom, electric grid (smart grid), sensor networks, social networks, medicine, etc.; Implementation of the taught methods in MATLAB/Java/R; Application of selected methods on real-world examples through the course project. Network analysis tools (e.g. Gephi, Pajek) and libraries (e.g. iGraph, Jung). Practical introduction to graph databases.

Literature

7. E. D. Kolaczyk: Statistical Analysis of Network Data: Methods and Models, Springer, 2009
8. M. E. J. Newman: Networks - An introduction, Oxford University Press, 2010.
9. F. Chung: Spectral Graph Theory, CBMS Regional Conference Series in Mathematics, No. 92, 1996
10. D. Easley, J. Kleinberg. *Networks, Crowds and Markets: Reasoning About a Highly Connected World*. Cambridge University Press, 2010.

11. W. de Nooy, A. Mrvar, V. Batagelj. *Exploratory Social Network Analysis with Pajek*. Cambridge University Press, 2005.					
Weekly teaching load					Other: 0
Lectures: 2	Exercises: 2	Other forms of teaching: 0	Student research: 0		
Teaching methodology Lectures; revisions of the material; active students' participation in problem solving; knowledge tests – colloquia; application of the taught material on real-world examples within the course project.					
Grading (maximum number of points 100)					
Pre-exam obligations		**points**	**Final exam**	**points**	
Colloquia	Course project	60 = 30 (Colloquia) + 30 (Course project)	written exam	40	