UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Analiza omrežij
Course title:	Network Analysis

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Informatika v sodobni družbi, visokošolski strokovni študijski program prve stopnje	-	Drugi	Četrti
Informatics in Contemporary Society, first cycle Professional Study Programme	-	Second	Fourth

Vrsta predmeta / Course type Obvezni / Obligatory

Univerzitetna koda predmeta / University course code: 1-ISD-VS-AO-2020-05-14

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
30	-	45	-	-	105	6

Nosilec predmeta / Lecturer: izr. prof. dr. Zoran Levnajić

Jeziki / Languages:		
	Predavanja / Lectures:	Slovenski, angleški / Slovene, English
	Vaje / Tutorial:	Slovenski, angleški / Slovene, English

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:

Pogoj je vpis v 2. letnik.
Študent/študentka mora pred pristopom k zaključnem izpitu opraviti vse obveznosti na vajah.

Prerequisits:

The condition is the enrolment into the 2nd year of study. Student has to pass all requirements given at the exercises to access the final examination.

Vsebina:

- Uvod
  - Kaj so omrežja in zakaj jih preučujemo?
  - Šest stopenj ločenosti, pomen centralnosti
  - Socialna, informacijska, tehnološka in biološka omrežja, spletni socialni mediji
- Osnovni grafološki koncepti:

Content (Syllabus outline):

- Introduction
  - What are networks and why we study them?
  - Six degrees of separation, the importance of being central
  - Social, Information, Technological and Biological Networks, online social media
- Basic Graph Concepts:

- vozlišče, povezava, usmerjene/neusmerjene, obtežene/neobtežene povezave, povezana omrežja, glavna komponenta
- stopnja in povprečna stopnja, vhodna in izhoda stopnja
- matrika sosednosti, seznam sosednosti
- elementarni grafi: drevesa, cikli (prstani), kliki, zvezde
- planarna (geografska) omrežja, Eulerov problem Konigsberških mostov
- bipartitna omrežja
- multiplex omrežja

• Software za vizualizacijo omrežij
- Pajek, Gephi, Cytoscape, NetworkX, GraphViz, R
- Računalniška kompleksnost omrežnih problemov

• Osnove teorije omrežij:
- koncept statistične obravnave omrežij
- gručenje, najkrajša pot, povprečna najkrajša pot
- premer omrežja, breadth-first iskanje
- distribucija stopenj, centralnosti vozlišča in povezave, closeness in betweenness centralnost
- asortativnost vozlišč
- elementarni algoritmi za obravnavo omrežij: distribucija stopenj, gručenje, najkrajša pot, particija grafa

• Modeli omrežij
- Erdos-Renyi naključno omrežje
- Small world fenomen, model Watts in Strogatza
- polinomialni zakoni v naravi, model Barabasija in Alberta, preferencijalno povezovanje
- Zipfov zakon, razlika med eksponentnimi in polinomskimi distribucijami
- geometrijska omrežja, ostali modeli
- modeli naraščanja omrežij, naraščajoča in statična omrežja
- naključna omrežja s določenim stopnjami

• Struktura skupnosti:

- Node (vertex), link (edge), directed and non-directed, weighted and non, connected and non, giant connected component
- degree and mean degree, in- and out- degree
- adjacency matrix and adjacency list
- simple graphs: trees, cycles (rings), cliques, stars
- planar (geographic) networks, Euler Konigsberg problem
- bipartite networks
- multiplex networks

• Network visualization software
- Pajek, Gephi, Cytoscape, NetworkX, GraphViz, R
- Computational complexity of networks-related problems

• Fundamentals of Network Theory:
- concept of statistical treatment of networks
- clustering, shortest path, average shortest paths, diameter, breadth-first search
- degree distribution, Node and link centrality, closeness and betweenness centrality
- node assortativity
- simple algorithms: degree distributions, clustering coefficients, Shortest-path algorithms, Graph partitioning

• Network models
- Erdos-Renyi random networks
- Small world phenomena, Watts-Strogatz model
- power laws in nature, Barabasi-Albert model, preferential attachment and hubs
- Zipf's law, the difference between the exponential and potential distributions
- geometric networks, other network models
- models for network generation and growth, growing vs static networks
- random graphs with a given degree sequence

• Community structure:

- omrežja s skupnostmi, odkrivanje skupnosti, modularnost in modularna omrežja, motifi, grafki
- Procesi na omrežjih:
  - širjenje bolezni, SIS in SIR modeli, difuzija, trači, perkolacija, formiranje mnenj, igre
  - naključni sprehod, iskanje in navigacija, iskanje po spletu, Google in PageRank algoritmi, decentralizirano iskanje
  - odpornost omrežja na nepričakovane izpade in napade
- Ostale teme (odvisno od časa):
  - Eulerov problem Konigsberških mostov
  - Google in PageRank algoritmi, decentralizirano iskanje
  - multiplex omrežja
  - naključna omrežja z določenimi stopnjami

- Networks with communities, community detection, modularity and modular networks, network motifs, graphlets
- Processes on networks:
  - contagions and SIS/SIR models, diffusion, rumors, percolation, opinion formation models, games
  - random walks, Search and navigation methods, Searching the Web, Google and the PageRank algorithms, Decentralized search
  - network resilience to random failures and intentional attacks
- Other topics (to be covered depending on the available time):
  - Euler Konigsberg problem
  - Google and the PageRank algorithms, Decentralized search
  - multiplex networks
  - random graphs with a given degree sequence

Temeljni literatura in viri / Readings:

- Menczer, F., Fortunato, S. & Davis, C. A. (2020). A First Course in Network Science. Cambridge University Press.
- de Nooy, W., Mrvar, A. & Batagelj, V. (2005). Exploratory Social Network Analysis with Pajek. Cambridge University Press.
- Easley, D. & Kleinberg, J. (2010). Networks, Crowds, and Markets. Cambridge University Press.
- Newman, M. (2010). Networks: An introduction. Oxford University Press.

Cilji in kompetence:

Učna enota prispeva k razvoju naslednjih splošnih in predmetno-specifičnih kompetenc:

- poznavanje in razumevanje širokega nabora aplikacij informacijsko komunikacijske tehnologije v sodobni družbi,
- obvladanje raziskovalnih metod, postopkov in procesov
- sposobnost interdiciplinarnega pristopa, ki se kaže kot razumevanje splošne strukture družbenih ved ter povezanosti med njenimi posameznimi disciplinami in poddisciplinami
- sposobnost fleksibilne in aplikativne uporabe teoretičnega znanja

Objectives and competences:

The instructional unit contributes to the development of the following general and subject-specific competences:

- knowledge and understanding of a wide range of applications of information communication technology in the modern society
- competence in research methods, procedures and processes
- ability for an interdisciplinary approach, shown as an understanding of general structure of social sciences and interconnections between its individual scientific disciplines and sub disciplines
- ability toflexibly apply knowledge in practice

- sposobnost pridobivanja, selekcije, ocenjevanja in umeščanja novih informacij in zmožnost interpretacije v kontekstu družboslovja
- usposobljenost za samostojno in avtonomno uporabo, nadzor in vzdrževanje informacijsko komunikacijske tehnologije v organizaciji

- the ability to acquire, select, evaluate and place new information and the ability to interpret this new information in the context of social science
- competence for independent and autonomous use, monitoring and maintenance of information communication technology in an institution

Predvideni študijski rezultati:

Znanje in razumevanje:

Študent/študentka:

- spozna metode analize družbenih omrežij
- se seznani z metodami in algoritmi za analizo in modeliranje velikih družbenih in informacijskih omrežij, spozna uporabo tega v praksi in se nauči, kako obstoječa orodja in programsko opremo uporabiti za analizo družbenih omrežij
- se seznani z metodami teoretičnega računalništva in z načrtovanjem algoritmov za potrebe analize velikih omrežij
- spozna računsko zahtevne metode za analizo malih omrežij, ter hitrejše metode za analizo večjih omrežij
- se usposobi za izvedbo najzahtevnejše statistične analize omrežij
- se nauči uporabljati nekaj najaktualnejših programskih orodij za te najzahtevnejše statistične analize omrežij

Intended learning outcomes:

Knowledge and understanding:

The student:

- becomes familiar and learn about Social network analysis
- learns methods and algorithms for analysis in modeling of large social and information networks, experiences the real world applications and learns how to use existing tools and software packages for socal network analysis
- is informed with methods of theoretical computing and analysis as well as planning algorihms in case of large scale networks
- encounter computational demanding methods for small scale networks as well as quicker methods of analysis of large scale networks
- is trained for the performance of most demanding statistical analysis of networks
- learns how to use some most up-to-date program tools for this most demanding statistical analysis

Metode poučevanja in učenja:

- *predavanja* z aktivno udeležbo študentov (razlaga, diskusija, vprašanja, primeri, reševanje problemov)
- *domače naloge*, kjer študenti ponovijo in preizkusijo svoje razumevanje predavane snovi
- *laboratorijske vaje* (vaje v računalniški učilnici), kjer bodo študentje pri konkretnih problemih ponovili, utrdili in

Learning and teaching methods:

- *lectures* with active student participation (explanation, discussion, questions, case studies, problem solving)
- *assignments* where students revise and test their comprehension of lectured material and solve problems on their own
- *(computer) lab work* where concepts and methods dealt with at lectures will

dodatno osvetlili pojme in metode, spoznane na predavanjih. Pri teh vajah bodo študentje spoznali nekaj najaktualnejših programskih orodij za analizo omrežij (Pajek) • *Zaključni projekt*, ki ga bodo študentje po potrebi pripravili v manjših skupinah. Vključeval bo konkreten problem, ki ga bodo morali študentje v celoti rešiti z metodami, spoznanimi na predavanjih in vajah	be additionally revised and lit up. Students will use some most up-to-date program tools (Pajek), students will learn to use software packages for social network analysis • *Final project* including a concrete problem and possibly prepared in small groups. It should be completely solved with methods encountered at lectures and lab work.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Način (pisni izpit, ustno izpraševanje, naloge, projekt): • Zaključna naloga	100	Type (examination, oral, coursework, project): • Final project

Reference nosilca / Lecturer's references:

- A. Crnkić, J. Povh, V. Jaćimović, Z. Levnajić, Collective dynamics of phase-repulsive oscillators solves graph coloring problem, Chaos 30, 033128, 2020
- M. Faggian, F. Ginelli, F. Rosas, Z. Levnajić, Synchronization in time-varying random networks with vanishing connectivity, Scientific Reports 9, 10207, 2019.
- M. Grau Leguia, R. G. Andrzejak, Z. Levnajić, Evolutionary optimization of network reconstruction from derivative-variable correlations, Journal of Physics A: Mathematical and Theoretical 50, 334001, 2017.
- L. Šubelj, M. Bajec, A. Kastrin, B. Mileva Boshkoska, Z. Levnajić, Quantifying the Consistency of Scientific Databases, PLoS ONE 10, e0127390, 2015.
- O. N. Yaveroglu, N. Malod-Dognin, D. Davis, Z. Levnajić, V. Janjić, R. Karapandža, A. Stojmirović, N. Pržulj, Revealing the Hidden Language of Complex Networks, Scientific Reports 4,4547, 2014.