Univerza v Mariboru

Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	**Kombinatorična optimizacija**
Course title:	**Combinatorial Optimization**

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Enovit magistrski študijski program druge stopnje Predmetni učitelj		5	9
Five-year master's degree program Subject Teacher			

Vrsta predmeta / Course type	izbirni/elective
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Laboratory work	Teren. vaje Field work	Samost. delo Individ. work	ECTS
30	15	30			135	7

Nosilec predmeta / Lecturer:	Drago Bokal

Jeziki / Languages:	**Predavanja / Lectures:**	Slovensko/Slovene
	Vaje / Tutorial:	Slovensko/Slovene

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Jih ni.	None.

Vsebina:	**Content (Syllabus outline):**
Obvezna vsebina, ki pri študentih vzpostavi temeljni nabor znanj s področja kombinatorične optimizacije: ● Diskretno odločitveno modeliranje in povezani optimizacijski problemi. ● Večkriterijska linearna optimizacija.	Mandatory content that familiarizes the students with fundamentals of combinatorial optimization: ● Discrete decision modelling and related optimization problems. ● Multicriteria linear optimization. Goal

Ciljno programiranje. Celoštevilsko programiranje. ● Problem nahrbtnika in njegove različice. ● Pretoki v omrežjih. Ford-Fulkersonov algoritem. ● Problem maksimalnega prirejanja. ● Problem maksimalnega prereza. ● Transportni problem. Problem kitajskega poštarja. ● Problem trgovskega potnika. ● Optimizacijski problemi v kombinatoričnih igrah. ● Spodbujevano učenje v diskretnih kontekstih. V okviru vsebine študentje izberejo zahtevnejši problem - projekt, s katerimi se poglobljeno ukvarjajo pri seminarski nalogi. Problem je povezan z njihovo bodočo kariero (praktični problemi iz gospodarstva, teoretični problemi iz teorije matematičnega programiranja in pripadajočih algoritmov). Preostala predavanja se prilagodijo problemom, ki so jih izbrali študentje, in obsegajo vsebine z naslednjega seznama: ● Aproksimacijski algoritmi. ● Hevristike in metahevristike. Lokalna optimizacija. Tabu search. Simulirano ohlajanje. Genetski algoritmi. Nevronske mreže. Samo-organizirajoče se mreže. ● Optimalni portfelj celoštevilskih lotov in celoštevilsko programiranje. ● Problem delovnega razporeda. ● Problem urnika. ● Problem razporejanja nalog enega in več strojev. ● Problem optimizacije zalog. ● Problemi rezanja in pakiranja. ● Diskretni modeli umetne inteligence kot kombinatorični optimizacijski problemi. Drugi s kombinatorično optimizacijo povezani problemi, usklajeni s študentskimi interesi.	programming. Integer programming. ● Knapsack problems and its variants. ● Network flows. Ford-Fulkerson’s algorithm. ● Maximum matching problem. ● Maximum cut problem. ● Transport problem. Chinese postman problem. ● Travelling salesman problem. ● <u>Optimization problems in combinatorial games.</u> ● Reinforcement learning in discrete contexts. Within the coursework, the students select a problem - project whose result is coursework report. The problem is related to their future career (practical problems from industry and business, theoretical problems from the areas of optimization, algorithms, modelling). The content of the remaining lectures is selected according to these projects from the following list: ● Approximation algorithms. ● Heuristics and metaheuristics. Local optimization. Tabu search. Simulated annealing. Genetic aglorithms. Neural nets. Self-organized maps. ● Optimal portfolio of integer lots and integer programming. ● Employee timetabling problem. ● School timetabling problems. ● Scheduling tasks of one or several processors. ● Stock optimization. ● Cutting and packing problems. ● Discrete artificial intelligence models as combinatorial optimization problems. ● Other problems, related to combinatirial optimization and student's interest.

Temeljni literatura in viri / Readings:

J.Žerovnik: Osnove teorije grafov in diskretne optimizacije (druga izdaja), Fakulteta za strojništvo, Maribor 2005.
R. Wilson, M. Watkins, Uvod v teorijo grafov, DMFA, Ljubljana 1997.
B. Robič: Aproksimacijski algoritmi, Založba FRI, Ljubljana 2002.
E. Zakrajšek: Matematično modeliranje, DMFA, Ljubljana 2004.
B. Korte, J. Vygen: Combinatorial Optimization, Theory and Algorithms, Springer, Berlin 2000.
D. Cvetković, V. Kovačević-Vujčić: Kombinatorna optimizacija, DOPIS Beograd 1996.
S. Zlobec, J. Petrić: Nelinearno programiranje, Naučna knjiga, Beograd 1989.
E. Kreyszig: Advanced Engineering Mathematics, (seventh edition), Wiley, New York 1993.

Cilji in kompetence:	**Objectives and competences:**
Usvojiti proces matematičnega modeliranja na diskretnih optimizacijskih problemih. Razviti kompetenco samostojnega apliciranja matematičnih metod na probleme iz logistike, organiziranja, odločanja, finančne optimizacije, ekonomije, ter širše iz gospodarstva. Spoznati tehnološka orodja, s katerimi se srečujemo pri reševanju optimizacijskih problemov in problemov matematičnega modeliranja.	Familiarize the students with the process of mathematical modelling of discrete optimization problems. Develop competent skills of independent application of mathematical methods to the problems from logistics, scheduling, decision making, financial optimization, economics, and broader from industry. Familiarize the students with technological tools that assist solving optimization problems and problems related to mathematical modelling.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: ● Razumevanje zahtevnejših principov kombinatorične optimizacije. ● Poglobi znanje iz sodobnih metod za reševanje problemov kombinatorične optimizacije. ● Poglobiti znanje iz diskretnih modelov in drugih zahtevnih aplikacij kombinatorične optimizacije v finančni matematiki, optimiranju virov, in širše Prenesljive/ključne spretnosti in drugi atributi: ● Direktne aplikacije v finančni matematiki, ekonomiji, poslovnih vedah, inžinirstvu, fiziki in številnih drugih družboslovnih in naravoslovnih vedah. ● Suvereno obvladovanje procesa matematičnega modeliranja in uporabe tehnik kombinatorične optimizacije v	Knowledge and understanding: ● To be able to understand advanced principles of combinatorial optimization. ● To deepen the knowledge of modern methods for solving combinatorial optimization problems. ● To deepen the knowledge of details of discrete models and other advanced applications of combinatorial optimization in financial optimization, resource optimization, and wider. Transferable/Key Skills and other attributes: ● Direct applications in finacial mathematics, economy, business, engineering, physics, and numerous other social and natural sciences. ● Competent mastering of the process of mathematical modelling and applications of the techniques of combinatorial

problemih s področja finančne optimizacije, ekonomije in širše. ● Izdelava temeljitega elaborata ali zgoščenega članka uporabe matematičnega modela na konkretnem matematičnem problemu, ki ga študent najde ob razmisleku o svoji bodoči karieri.	optimization in problems from financial optimization, economics, and wider. ● Preparation of a detailed technical report or focused report paper describing a mathematical model of a specific mathematical problem the students encounter while investigation their possible future careers.
Metode poučevanja in učenja:	**Learning and teaching methods:**
● Pri predavanjih študentje spoznajo snov predmeta. Z uporabo obrnjenega (flipped) poučevanja na predavanjih aktivno spoznavajo povezavo med snovjo in njihovimi projekti. ● V okviru seminarskih vaj študentje razumevanje snovi utrjujejo na večjem projektu, povezanem z njihovo bodočo kariero. Razporejeni so v večje skupine, ki po metodah problemskega učenja obravnavajo izbrani problem od zbiranja podatkov, preko razvoja modela, izbora in prilagajanja ustreznih tehnoloških rešitev do razmisleka o implementaciji rešitve. Koncept poučevanja je podrobneje predstavljen kot ciljni aplikativni predmet. ● V okviru seminarja študentje uporabljajo, analizirajo in vrednotijo svoje projekte za potrebe ustvarjanja novih rešitev za okolje, iz katerega izvirajo problemi. ● Z uporabo izkušanja matematičnega modeliranja študenti merijo svoj napredek in ga reflektirajo. Tako uporabljajo svoj matematični model za opazovanje izboljšanja, ki izvira iz matematično podprtega odločanja. ● Tri predstavitve njihovih rezultatov pomagajo študentom priučiti se suverenosti javnega nastopanja in zagovarjanja svojih rezultatov. ● Osredotočeni dvodnevni organizirani hackathon pomaga študentom izkusiti veselje ob osredotočenem raziskovanju in sodelovanju z vrstniki.	● At the lectures, the students are familiarized with the course content. Applying flipped learning approach, they discuss their coursework projects in relation to the material of the course. ● At the tutorials, the student deepen their understanding of the material by working on an extensive problem related to their future career. They are organized in larger groups who research the chosen problem guided by methodologies of problem-based learning. Within solving the problem, they experience all the stages from requirements and data gathering, model development, selecting and adapting technological solutions to discussing various aspects of implementation of the results. ● At the seminar, the students apply, analyse, and evaluate their projects in order to create new solutions desired by the environment the problems are coming from. ● Applying principles of embedded mathematical modelling, the students measure and reflect upon their progress thus using its mathematical model to experience improvement coming from mathematically supported decision making. ● Three presentations of their results help students acquire confidence with public presentation and defending their results. ● Focused two-day workshop-style organized hackathon helps students experience the joy of focused research and collaboration with peers.

Načini ocenjevanja:		**Assessment:**
Način (pisni izpit, ustno izpraševanje, naloge, projekt): Seminarska naloga Ustni izpit Vsaka izmed naštetih obveznosti mora biti opravljena s pozitivno oceno. Pozitivna ocena pri seminarski nalogi je pogoj za pristop k izpitu.	Delež (v %) / Weight (in %) 80%, 20%	Type (examination, oral, coursework, project): Coursework report Oral exam Each of the mentioned commitments must be assessed with a passing grade. Passing grade of the coursework report is required for taking the exam.

Reference nosilca / Lecturer's references:

SMOLE, Andreja, JAGRIČ, Timotej, BOKAL, Drago. Principal/Two-Agent model with internal signal. *Central European journal of operations research*. sep. 2021, vol. 29, no. 3, str. 791-808, ilustr. ISSN 1435-246X. https://link.springer.com/content/pdf/10.1007/s10100-020-00719-0.pdf, DOI: 10.1007/s10100-020-00719-0. [COBISS.SI-ID 75068163]

BOKAL, Drago, STEINBACHER, Mitja. Phases of psychologically optimal learning experience : task-based time allocation model. *Central European Journal of Operations Research*, ISSN 1435-246X, 2019, str. 1-23, doi: 10.1007/s10100-019-00609-0. [COBISS.SI-ID 24408328]

BOKAL, Drago, BREŠAR, Boštjan, JEREBIC, Janja. A generalization of Hungarian method and Hall's theorem with applications in wireless sensor networks. Discrete Applied Mathematics, ISSN 0166-218X. [Print ed.], 2012, vol. 160, iss. 4-5, str. 460-470. http://dx.doi.org/10.1016/j.dam.2011.11.007. [COBISS.SI-ID 16191577]

ČAMPULOVÁ, Martina, MICHÁLEK, Jaroslav, MIKUŠKA, Pavel, BOKAL, Drago. Nonparametric algorithm for identification of outliers in environmental data. *Journal of chemometrics*, ISSN 0886-9383, 2018, str. 1-17, graf. prikazi, doi: 10.1002/cem.2997. [COBISS.SI-ID 23647240]

BAŠIĆ, Nino, BOKAL, Drago, BOOTHBY, Tomas, RUS, Jernej. An algebraic approach to enumerating non-equivalent double traces in graphs. *MATCH Communications in Mathematical and in Computer Chemistry*, ISSN 0340-6253, 2017, vol. 78, no. 3, str. 581-594. http://match.pmf.kg.ac.rs/electronic_versions/Match78/n3/match78n3_581-594.pdf. [COBISS.SI-ID 18108505]