

UČNI NAČRT PREDMETA / COURSE SYLLABUS						
Predmet:		Topološka analiza podatkov				
Course title:		Topological data analysis				
Študijski program in stopnja Study programme and level		Študijska smer Study field		Letnik Academic year	Semester Semester	
Interdisciplinarni magistrski študijski program Računalništvo in matematika		ni smeri		1 ali 2	drugi	
Interdisciplinary Masters study programme Computer Science and Mathematics		none		1 or 2	second	
Vrsta predmeta / Course type				izbirni		
Univerzitetna koda predmeta / University course code:				M2846		
Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
45	10	20			105	6
Nosilec predmeta / Lecturer:		prof. Neža Mramor-Kosta				
Jeziki / Languages:	Predavanja / Lectures:	slovenski/Slovene, angleški/English				
	Vaje / Tutorial:	slovenski/Slovene, angleški/English				
Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:				Prerequisites:		
Uspešno opravljene domače naloge in seminarsko-projektne naloge so pogoj za opravljanje izpita.				Successful completion of homework and projects is required for students to approach to a final exam.		
Vsebina:				Content (Syllabus outline):		

Topologija je področje matematike, ki se ukvarja z analizo oblik in več dimenzionalnih objektov. Topološka analiza podatkov pa je področje med topologijo in računalništvom, ki obravnava in analizira lastnosti oblik zajetih iz podatkov, slik in več dimenzionalnih podatkovnih množic. Ob množici podatkov, ki se neprestano zajemajo, na eni strani in pa vse bolj zmogljivimi računalniškimi sistemi na drugi se razvija tudi vrsta novih algoritmov za analizo in predstavitev, ki uporabljajo čedalje več topoloških pojmov in modelov. Za predstavitev podatkov se uporabljajo grafi in ploskve, triangulacije, simplicialni in celični kompleksi ter mnogoterosti. Za analizo podatkov pa se uporabljajo topološke invariante teh objektov kot so število komponent, fundamentalna grupa, homološke grupe in kohomološki kolobar, Morsova teorija, filtracije in vztrajnost. Takšne invariante se tipično lepo izračunajo in dajejo odgovore na vprašanja kot so, ali je objekt sestavljen iz enega li več kosov, ali ima kakšne luknje in tunele, kakšne značilnosti ima pri različnih resolucijah, kako so posamezni kosi zlepljeni skupaj v celoto... Na drugi strani je na voljo tudi čedalje več hitrih in učinkovitih algoritmov za njihovo računanje.

Pri predmetu bodo predstavljeni osnovni topološki pojmi in modeli, ki se uporabljajo za predstavitev večdimenzionalnih objektov in prostorov, nekaj njihovih osnovnih številskih in algebraičnih invariant. Poudarek pa bo na uporabi teh modelov in invariant pri analizi in rekonstrukciji objektov iz zajetih podatkov, konfiguracijskih prostorov robotov in mehaničnih sistemov, pri analizi omrežij in v drugih povsem uporabnih domenah. Posamezna teme, ki jih bomo obravnavali, so

Osnovni pojmi topoloških in metričnih prostorov;

Topology is the mathematical field dealing with shapes and with modeling and understanding higher dimensional objects. Topological data analysis is a field between topology and computer science dealing with shapes arising from data, images, and higher dimensional data sets. In view of massive quantities of experimental data on one hand, and available computing power on the other hand, numerous new algorithms and models for qualitative analysis and representation of such data sets using topological models and methods have been developed. Graphs, surfaces, triangulations, simplicial and cell complexes and manifolds are used for data representation and object reconstruction. Topological invariants like the number of components, the fundamental group, homology groups and the cohomology ring, Morse theory, filtrations and persistence are used for analyzing these models. These invariants are typically computable and give answers to questions like, is the object composed from one or more components, does it have holes and tunnels, which features appear at different resolutions, how do the separate pieces connect into the whole, ... On the other hand new algorithms for efficient computation of these invariants are appearing.

In the course, fundamental topological concepts and methods, which are used in modeling and analyzing higher dimensional objects and spaces, will be introduced. Further, basic numerical and algebraic invariants of the topological models will be explained. Special attention will be given to applications of these methods to analysis of data sets and reconstruction of the underlying objects, configuration spaces of robots and mechanical systems, analysis of networks and other practical problems and domains. We will introduce the following topological concepts and models:

<p>Grafi in ploskve;</p> <p>Triangulacije, simplicialni in celični kompleksi;</p> <p>Homološke grupe in Bettijeva števila, njihova interpretacija in osnovni algoritmi za njihovo računanje;</p> <p>Diskretne Morsove funkcije in njihova uporaba pri analizi podatkov;</p> <p>Filtracije in vztrajnost za analizo podatkov pri različnih resolucijah.</p> <p>Pri predmetu bo poudarek predvsem na uporabi opisanih topoloških pojmov in algoritmov pri analizi konkretnih podatkovnih množic, problemov in modelov.</p>	<p>Fundamentals of topological and metric spaces</p> <p>Graphs and surfaces</p> <p>Triangulations, simplicial and cell complexes</p> <p>Homology groups and Betti numbers, , their interpretation, and basic algorithms for their computation</p> <p>Discrete Morse functions and their application to data analysis and object reconstruction</p> <p>Filtrations and persistence for dealing with changing resolutions</p> <p>The main part of the course will be devoted to applications of the topological concepts and algorithms in analyzing specific data sets, problems and models.</p>
--	---

Temeljni literatura in viri / Readings:

Herbert Edelsbrunner, John Harer: Computational Topology, American Mathematical Society, 2010

Afra J. Zomorodian: Topology for Computing, Cambridge University Press, 2005

Hjelle, Øyvind, Dæhlen, Morten: Triangulations and applications, Springer, 2006

Kevin Knudson: Morse theory, smooth and discrete, World Scientific, 2015

Cilji in kompetence:

Objectives and competences:

Cilj predmeta je študentom na razumljiv način predstaviti osnovne pojme algebraične topologije, ki se uporabljajo v računalniških algoritmih pri analizi velikih množic večdimenzionalnih podatkov, pri rekonstrukciji objektov in konfiguracijskih prostorov robotov in mehaničnih sistemov in pri drugih realnih problemih. Matematični pojmi bodo predstavljeni predvsem z uporabnega zornega kota, poudarek bo na konkretnih primerih in računalniških algoritmih.

The aim of this course is to introduce in an informal and intuitive way the basic concepts of algebraic topology which are used in algorithms for analysis of big, possibly higher dimensional data sets, for reconstruction of objects and configuration spaces of robots and mechanical systems and in other practical applications. Mathematical concepts will be presented from the point of view of applications, special attention will be given to specific examples and algorithms.

Predvideni študijski rezultati:

Po uspešno opravljenem predmetu bo študent:

razumel pojem topološke invariante in njenega pomena pri analizi oblike in drugih lastnosti podatkov;

razumel pojem simplicialnega kompleksa in poznal osnovne algoritme za konstrukcijo simplicialnih kompleksov na danih podatkih;

poznal osnovne računske prijeme in algoritme za računanje Eulerjeve karakteristike, homoloških grup in Bettijevih števil;

razumel pojem filtracije in vztrajnosti;

znal pridobljeno znanje uporabiti za konstrukcijo preprostih topoloških algoritmov za analizo podatkovnih množic in rezultate interpretirati.

Intended learning outcomes:

After completing the course students will:

understand the concept of a topological invariant and its role in analyzing shape and other properties of data;

understand the concept of a simplicial complex and the basic algorithms for constructing simplicial complexes on data sets;

understand the basic computational approaches and algorithms for computing Euler characteristic, homology groups and Betti numbers;

understand the concepts of filtrations and persistence;

be able to use the concepts introduced to construct simple topological algorithms for analyzing data sets and interpret the results.

--

--

Metode poučevanja in učenja:

Predavanja s podporo avdio-vizualne opreme, predstavitev teoretičnih pojmov in prikaz pomena na konkretnih primerih,

laboratorijske vaje v računalniški učilnici z ustrezno programsko opremo. Delo posamezno in v skupinah. Velik poudarek na praktičnem delu in na skupinskem reševanju praktičnih problemov.

Learning and teaching methods:

Combined lecturing with simultaneous use of the blackboard and computer projection explaining the theoretical concepts and specific meaning in specific cases. Lab work in computer-equipped lecture rooms. Individual and work in team. Emphasis on practical problem solving and group work.

Delež (v %) /

Načini ocenjevanja:

Weight (in %)

Assessment:

Način (pisni izpit, ustno izpraševanje, naloge, projekt):		Type (examination, oral, coursework, project):
Sprotno preverjanje (domače naloge, kolokviji in projektno delo)		Continuing (homework, midterm exams, project work)
Končno preverjanje (pisni in ustni izpit)		Final: (written and oral exam)
Ocene: 6-10 pozitivno, 5 negativno	60%	Grading: 6-10 pass, 5 fail.
(v skladu s Statutom UL)	40%	

Reference nosilca / Lecturer's references:

Neža Mramor-Kosta:

- JURČIČ-ZLOBEC, Borut, MRAMOR KOSTA, Neža. Geometric constructions on cycles. Rocky Mountain journal of mathematics, ISSN 0035-7596, 2004, vol. 34, no. 4, str. 1565-1585 [COBISS.SI-ID 13268057]
- KING, Henry C., KNUDSON, Kevin, MRAMOR KOSTA, Neža. Generating discrete Morse functions from point data. Experimental mathematics, ISSN 1058-6458, 2005, vol. 14, no. 4, str. 435-444

[COBISS.SI-ID 13872985]

– JAWOROWSKI, Jan, MRAMOR KOSTA, Neža. The degree of maps of free G-manifolds. Journal of fixed point theory and its applications, ISSN 1661-7738, 2007, vol. 2, no. 2, str. 209-213 [COBISS.SI-ID 14569305]

– JERŠE, Gregor, MRAMOR KOSTA, Neža. Ascending and descending regions of a discrete Morse function. Computational geometry, ISSN 0925-7721. [Print ed.], 2009, vol. 42, iss. 6-7, str. 639-651 [COBISS.SI-ID 14994265]

– AYALA, Rafael, VILCHES, Jose Antonio, JERŠE, Gregor, MRAMOR KOSTA, Neža. Discrete gradient fields on infinite complexes. Discrete and continuous dynamical systems, ISSN 1078-0947, 2011, vol. 30, no. 3, str. 623-639 [COBISS.SI-ID 15865945]