UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Umetna inteligenca in strojno učenje
Course title:	Artificial intelligence and machine learning

Študijski program in stopnja **Study programme and level**	**Študijska smer** **Study field**	**Letnik** **Academic year**	**Semester** **Semester**
Računalništvo in spletne tehnologije, magistrski študijski program druge stopnje	-	Drugi	Tretji
Computer science and web technologies, second cycle Masters Study Programme	-	Second	Third

Vrsta predmeta / Course type	Obvezni / Obligatory
Univerzitetna koda predmeta / University course code:	2-RST-MAG-UISU-2022-12-16

Predavanja **Lectures**	**Seminar** **Seminar**	**Vaje** **Tutorial**	**Klinične vaje** **work**	**Druge oblike študija**	**Samost. delo** **Individ. work**	**ECTS**
40	-	40	-		160	8

Nosilec predmeta / Lecturer:	Izr. prof. dr. Biljana Mileva Boshkoska, doc. dr. Panče Panov

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Pogoj za vključitev v delo je znanje iz statistike, programiranja in algoritmov.	A prerequisite for participation in the course is knowledge of statistics, programming and algorithms.

Vsebina:	**Content (Syllabus outline):**
1. Uvod v umetno inteligenco (UI) in inteligentne agente: Kaj je UI? Temelji UI. Zgodovina UI. Pregled sodobnih pristopov v UI. Agenti in okolje. Narava okolij. Struktura agentov. 2. Reševanje problemov z iskanjem: Uporaba inteligentnih agentov za reševanje problemov. Iskalni algoritmi. Neinformirane strategije iskanja. Informirane (hevristične) strategije iskanja. Hevristične funkcije.	1. Introduction to AI and intelligent agents: What is AI? Foundations of AI. History of AI. State-of-the-art in AI. Agents and environment. Nature of environments. Structure of the agents. 2. Solving problems by searching: Problem-solving agents. Search algorithms. Uninformed search strategies. Informed (heuristic) search strategies. Heuristic functions.

3. Adversarialno iskanje in igre: Teorija iger. Optimalne odločitve v igrah (algoritem iskanja minimax, obrezovanje alfa-beta). Hevristično iskanje dreves Alpha-Beta. Napredni iskalni algoritmi v igrah.
4. Predstavitev znanja in sklepanje: Agenti, ki temeljijo na znanju. Uporaba propozicijske logike za predstavitev znanja. Logika prvega reda. Ontologije.
5. Avtomatsko načrtovanje: Uvod v klasično načrtovanje. Algoritmi za klasično načrtovanje. Hevristika za načrtovanje. Hierarhično načrtovanje.
6. Osnovni principi strojnega učenja: Vrste učenja. Učenje kot modeliranje (načelo najkrajšega opisa, načelo večkratne razlage). Izbira modela. Mere za ocenjevanje uspešnosti učenja za klasifikacijo in regresijo. Metode za vrednotenje uspešnosti nadzorovanega učenja (ločena testna množica, metoda izloči enega, prečno preverjanje, razmnoževanje učnih primerov). Kompromis med pristranskostjo in varijanco.
7. Klasične metode za nadzorovano učenje: Metoda k-najbližjih sosedov. Metoda Naive Bayes. Odločitvena in regresijska drevesa. Linearna regresija, polinomska regresija in regularizirani linearni modeli (Ridge, Lasso, Elastic net). Logistična regresija. Metoda podpornih vektorjev. Ansambelske metode (glasovanje, metoda Bagging, metoda Boosting, metoda Random Forest, metoda Stacking)
8. Nevronske mreže in globoko učenje: Perceptron. Večplastne nevronske mreže. Algoritem Backpropagation. Pregled različnih arhitektur globokih mrež (Feedforward, Convolution, Reccurent). Pregled aplikacij globokega učenja.
9. Zmanjšanje dimenzionalnosti podatkov: Metode za izbiro podmnožice značilk. Metode za rangiranje značilk. Metoda PCA.
10. Metode nenadzorovanega učenja: Metoda K-Means. Metoda DBSCAN. Aglomerativno in hierarhično

3. Adversarial search and games: Game theory. Optimal decisions in games (minimax search algorithm, alpha-beta pruning). Heuristic Alpha-Beta tree search. Advanced search algorithms in games.
4. Knowledge representation and reasoning: Knowledge-based agents. Using propositional logic for knowledge representation. First-order logic. Ontologies
5. Automated planning: Introduction to classical planning. Algorithms for classical planning. Heuristics for planning. Hierarchical planning.
6. Basic principles of machine learning: Types of learning. Learning as modelling (shortest description principle, multiple explanation principle). Model selection. Evaluation measures for classification and regression. Methods for evaluation of the success of supervised learning (separate test set, leave-one-out validation, cross-validation, bootstrapping). Bias-variance tradeoff.
7. Classical supervised learning methods: k-nearest neighbors method, Naive Bayes method, decision and regression trees, linear regression, polynomial regression and regularized linear models (ridge regression, lasso regression, elastic net), logistic regression, support vector machines, ensemble methods (voting, bagging, boosting, random subspaces, random forests, stacking)
8. Neural networks and deep learning: Perceptron. Multi-layered neural networks. Backpropagation algorithm. Feedforward networks. Recurrent networks. Convolutional networks. Overview of deep learning applications.
9. Dimensionality reduction: Feature selection methods. Feature ranking methods. Principle Component Analysis (PCA).
10. Unsupervised learning methods: K-Means clustering. DBSCAN. Agglomerative and hierarchical clustering. Spectral clustering. Biclustering.

razvrščanje. Spektralno razvrščanje. Biklasteriranje. 11. Spodbujevalno učenje: Učenje iz nagrad. Pasivno in aktivno učenje s spodbujanjem. Posploševanje pri učenju s spodbujanjem. Iskanje učnih politik. 12. Računalniški vid: Uvodni pojmi. Generiranje značilk iz slik. Klasifikacija slik. Detekcija objektov. Pregled aplikacij računalniškega vida.	11. Reinforcement learning: Learning from rewards. Passive and active reinforcement learning. Generalization in reinforcement learning. Policy search. 12. Computer vision: Basic concepts. Generating features from images. Image classification. Object detection. Overview of computer vision applications.

Temeljni literatura in viri / Readings:

- Russel, S., Norvig, P. (2022). Artificial Intelligence. A Modern Approach (Fourth edition). Prentice Hall.
- James, G., Witten, D., Hastie, T., Tibshirani, R. (2021) An Introduction to Statistical Learning (Second edition). Springer
- Geron, A (2019) Hands-on Machine Lerning with Sickit-Learn, Keras and TensorFlow. O'Reilly
- Kononenko, I., Robnik-Šikonja, M. (2010) Inteligentni sistemi. Založba FE in FRI, Ljubljana

Cilji in kompetence:	**Objectives and competences:**
Cilj je predstaviti osnove umetne inteligence, metode za reševanje problemov z iskanjem, načine predstavitve znanja, metode avtomatskega načrtovanja ter različne metode strojnega učenja. Dodatno je cilj, da študenti uporabijo pridobljene veščine za reševanje različnih vrst nalog. Študenti bodo dobili teoretično znanje iz omenjenih področij in ga uporabili pri resničnih problemih iz znanstvenega in poslovnega okolja. Učna enota prispeva k razvoju naslednjih splošnih in predmetno specifičnih kompetenc: • sposobnost pridobivanja, selekcije, ocenjevanja in umeščanja novih informacij in zmožnost interpretacije raziskovalnega problema; • razvoj kritične in samokritične presoje; • obvladanje raziskovalnih metod, postopkov, procesov in algoritmov na področju umetne inteligence in strojnega učenja;	The goal is to present the basics of artificial intelligence, methods for solving search problems, ways of presenting knowledge, automatic planning methods and various machine learning methods. Additionally, the goal is for students to use the acquired skills to solve different types of tasks. Students will get theoretical knowledge from the mentioned fields and apply it to real problems from the scientific and business environment. The learning unit contributes to the development of the following general and subject-specific competences: • The ability to obtain, select, evaluate and place new information and the ability to interpret the research problem. • The development of a critical and self-critical assessment. • Mastering research methods, procedures processes and algorithms in the field of artificial intelligence and machine learning. • Ability to solve practical problems with different search strategies.

• sposobnost za reševanje konkretnih praktičnih problemov z različnimi metodami iskanja; • sposobnost za reševanje konkretnih raziskovalnih in praktičnih problemov z uporabo metod strojnega učenja (nadzorovano in nenadzorovano učenje) ; • razumevanje teoretičnih temeljev teorije iger, predstavitve znanja, avtomatskega načrtovanja, globokega učenja, spodbujevalnega učenja in računalniškega vida.	• Ability to solve concrete research and practical problems using the methods of machine learning (supervised and unsupervised learning); • Understanding the theoretical foundations of game theory, knowledge representation, automated planning, deep learning, reinforcement learning and computer vision.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študent/Študentka: • se seznani s teoretskimi osnovami in s praktičnimi vidiki strojnega učenja in bo lahko uporabil znanje različnih tehnik in metod strojnega učenja za analizo, sintezo in predvidevanje rešitev ter njihovih posledic za ciljne probleme. • se nauči uporabljati nekaj najaktualnejših programskih orodij za umetno inteligenco in strojno učenje. Prenesljive/ključne spretnosti in drugi atributi: • prenos znanja na različna strokovna in znanstvena področja, kjer se uporabljajo metode strojnega učenja.	Knowledge and Understanding: The student: • will get acquainted with the theoretical and practical aspects of machine learning and will be able to use the knowledge of different techniques and methods from machine learning for analysis, synthesis and anticipation of solutions and their consequences for target problems • will learn to use some of the most current software tools for artificial intelligence and machine learning. Transferable / Key Skills and other attributes: • transfer of knowledge to various professional and scientific fields, where machine learning methods are used.

Metode poučevanja in učenja:	**Learning and teaching methods:**
• predavanja z aktivno udeležbo študentov (razlaga, diskusija, vprašanja, primeri, reševanje problemov); • vaje, kjer bodo študentje pri konkretnih problemih ponovili, utrdili in dodatno osvetlili pojme in metode, spoznane na predavanjih; • laboratorijske vaje: študentje bodo spoznali nekaj najaktualnejših programskih orodij. Vaje bodo potekale v manjših skupinah, tako da bo imel vsak študent na razpolago en računalnik.	• *Lectures with active students participation* (explanation with discussions, questions, case-studies, presentations); • *Tutorials where students will repeat, consolidate and further highlight concepts and methods learned during lectures in specific problems;* • *laboratory work: students will learn some of the most current software tools. Exercises will take place in small groups, so each student will work on one available computer.*

• strokovni pregled seminarskih nalog: študenti bodo pripravili seminarsko nalogo v obliki kratkega članka in opisali določeno temo iz UI, članek bo nato strokovno pregledan s strani drugih študentov pred predstavitvijo v razredu	• Peer-review of seminar papers: the students will prepare a seminar paper covering a topic from AI and the paper will be peer-reviewed by several other students before being presented in class.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Način (pisni izpit, ustno izpraševanje, naloge, projekt):		Type (examination, oral, coursework, project)
• pisni izpit	50 %	• Written exam
• seminarska naloga in predstavitev seminarske naloge	15 %	• Seminar paper and presentation
• projektna naloga s poročilom ter predstavitev naloge	35 %	• Project work with reports and presentation

Reference nosilca / Lecturer's references:

- Stepišnik, T., Simidjievski, N., Nikola, Petković, M., Panov, P., Džeroski, S., Kocev, D., et al. (2022) Machine learning for effective spacecraft operation: Operating INTEGRAL through dynamic radiation environments. Advances in space research. 2022, vol. 69, iss.. 11, str. 3909-3920
- Ring, N., Stepišnik, T., Panov, P., Kocev, D., Fortuna, S., Džeroski, S., et al. (2022) Wet-dry-wet drug screen leads to the synthesis of TS1, a novel compound reversing lung fibrosis through inhibition of myofibroblast differentiation. Cell death & disease. 2022, vol. 13, str. 2-1-2-12, DOI: 10.1038/s41419-021-04439-4.
- Vitali, F., Zinno, P., Schifano, E., Gori, A., Costa, Ana, De Filippo, C., Koroušič Seljak, B., Panov, P., Devirgilis, C., Cavalieri, D. (2022) Semantics of dairy fermented foods: A microbiologist's perspective. Foods. 2022, vol. 11, no. 13, str. 1939-1-1939-18, ilustr. ISSN 2304-8158. DOI: 10.3390/foods11131939.
- Petković, M., Levatić, J., Breskvar, M., Stepišnik, T., Kostovska, A., Panov, P., Osojnik, A., Džeroski, S., Simidjievski, N., Ženko, B., Kocev, D., et al. (2022) Machine-learning ready data on the thermal power consumption of the mars express spacecraft. Scientific data. 2022, vol. 9, str. 229-1-229-8.DOI: 10.1038/s41597-022-01336-z.
- Kostovska, A., Bogatinovski, J., Džeroski, S., Kocev, D., Panov, P. (2022) A catalogue with semantic annotations makes multilabel datasets FAIR. Scientific reports. 2022, vol. 12, str. 7267-1-7267-11, DOI: 10.1038/s41598-022-11316-3.
- Kostovska, A., Vermetten, D., Doerr, C., Džeroski, S., Panov, P., Eftimov, (2021) T., OPTION: optimization algorithm benchmarking ontology. In: GECCO '21, Proceedings of the Genetic and Evolutionary Computation Conference Companion, 10 July - 14 July, 2021, Lille, France, Francisco Chicano (ur.), New York: ACM = Association for Computing Machinery, 2021, str. 239-240, DOI: 10.1145/3449726.3459579.
- Osojnik, A., Panov, P., Džeroski, S. (2020) Incremental predictive clustering trees for online semi-supervised multi-target regression. Machine learning vol. 109, no. 11, str. 2121-2139.
- STROJNIK, Lidija, STOPAR, Matej, ZLATIĆ, Emil, KOKALJ, Doris, NAGLIČ, Mateja, ŽENKO, Bernard, ŽNIDARŠIČ, Martin, BOHANEC, Marko, MILEVA BOSHKOSKA, Biljana, LUŠTREK,

Mitja, GRADIŠEK, Anton, POTOČNIK, Doris, OGRINC, Nives. Authentication of key aroma compounds in apple using stable isotope approach. *Food chemistry*, ISSN 0308-8146. [Print ed.], 2019, vol. 277, str. 766-773, doi: 10.1016/j.foodchem.2018.10.140.

- BOŠKOSKI, Pavle, DEBENJAK, Andrej, MILEVA BOSHKOSKA, Biljana. Rayleigh copula for describing impedance data - with application to condition monitoring of proton exchange membrane fuel cells. *European journal of operational research*, ISSN 0377-2217. [Print ed.], 2018, vol. 266, no. 1, str. 269-277, doi: 10.1016/j.ejor.2017.08.058.
- GRAŠIČ, Valerij, KOS, Andrej, MILEVA BOSHKOSKA, Biljana. Classification of incoming calls for the capital city of Slovenia smart city 112 public safety system using open Internet of Things data. *International journal of distributed sensor networks*, ISSN 1550-1477. [Online ed.], 2018, vol. 14, no. 9, str. 1-12, ilustr. https://journals.sagepub.com/doi/pdf/10.1177/1550147718801703, doi: 10.1177/1550147718801703.
- MILJKOVIĆ, Dragana, LAVRAČ, Nada, BOHANEC, Marko, MILEVA BOSHKOSKA, Biljana. Discovering dependencies between domains of redox potential and plant defence through triplet extraction and copulas. *International journal of intelligent engineering informatics*, ISSN 1758-8723, 2018, vol. 6, no. 1/2, str. 61-77. http://www.inderscience.com/info/ingeneral/forthcoming.php?jcode=ijiei, doi: 10.1504/IJIEI.2018.10012065.
- MILEVA BOSHKOSKA, Biljana, LIU, Shaofeng, CHEN, Huilan. Towards a knowledge management framework for crossing knowledge boundaries in agricultural value chain. *Journal of decision systems*, ISSN 1246-0125, [in press] 2018, 15 str., doi: 10.1080/12460125.2018.1468173.
- MILEVA BOSHKOSKA, Biljana, RONČEVIĆ, Borut, DŽAJIĆ URŠIČ, Erika. Modeling and evaluation of the possibilities of forming a regional industrial symbiosis networks. *Social sciences*, ISSN 2076-0760, 2018, vol. 7, iss. 1. http://www.mdpi.com/2076-0760/7/1/13/pdf, doi: 10.3390/socsci7010013.
- BOHANEC, Marko, MILEVA BOSHKOSKA, Biljana, PRINS, Theo W., KOK, Esther. SIGMO: a decision support System for Identification of genetically modified food or feed products. *Food control*, ISSN 0956-7135. [Print ed.], 2016, vol. 71, str. 168-177, doi: 10.1016/j.foodcont.2016.06.032.