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FORM I. DESCRIPTION OF THE STUDY PROGRAMME **"INFORMATICS"***

GENERAL INFORMATION	
1. *Name of the study programme*	**University Postgraduate Doctoral Study "Informatics"**
2. *Provider of the study programme*	University of Rijeka, Faculty of Informatics and Digital Technologies
3. *Institution implementing the study programme*	University of Rijeka, Faculty of Informatics and Digital Technologies
4. *Scientific/artistic area of the study programme*	Information and communication sciences
5. *Type of the study programme*	University study programme
6. *Level of the study programme*	Doctoral study programme
7. *Duration of the study programme (indicate whether there is a possibility of studying on a part-time basis - part-time study, distance learning)*	Full time study, maximum duration 6 years Part time study, maximum duration 10 years
8. *ECTS credits - minimum number of credits required for the completion of the study programme*	**180 ECTS**
9. *Academic /vocational title awarded upon completion of the study programme*	**PhD**
10. *Name and code of the qualification in the CROQF Register for which the study programme meets the requirement of minimum common learning outcomes (if applicable)*[1]	NA

*Version 07/2022

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List of compulsory and elective courses and/or modules with the number of class hours required for their implementation and the number of ECTS credits

LIST OF MODULES/COURSES							
Year of study: 1./2.							
Semester: winter							
MODULE	COURSE	COURSE INSTRUCTOR	L	E	S	ECTS	STATUS[1]
	Research Methodology	Prof. Sanda Martinčić-Ipšić, PhD	15	0	15	12	C
	Statistical Analysis of Research Data	Prof. Marta Žuvić, PhD	15	0	15	6	E
	Text Mining and Knowledge Discovery	Prof. Sanda Martinčić-Ipšić, PhD	15	0	15	6	E
	Computer Vision and Pattern Analysis	Assoc. Prof. Marina Ivašić-Kos, PhD	15	0	15	6	E
	Computer Speech and Language Processing	Prof. Ivo Ipšić, PhD	15	0	15	6	E
	Machine translation	Assoc. Prof. Marija Brkić Bakarić, PhD	15	0	15	6	E
	Computational linguistics	Assist. Prof. Lucia Načinović Prskalo, PhD	15	0	15	6	E
	Data Warehousing for Business Intelligence	Assist. Prof. Danijela Jakšić, PhD	15	0	15	6	E
	Selected Topics in Information Systems	Assoc. Prof. Sanja Čandrlić, PhD	15	0	15	6	E
	Development of Computer-Supported Learning Systems	Assist. Prof. Martina Holenko Dlab, PhD	15	0	15	6	E
	Interactive multimedia	Asocc. Prof. Božidar Kovačić, PhD	15	0	15	6	E

LIST OF MODULES/COURSES							
Year of study: 1./2.							
Semester: summer							
MODULE	COURSE	COURSE INSTRUCTOR	L	E	S	ECTS	STATUS
	Network Mining	Prof. Ana Meštrović, PhD	15	0	15	6	E
	Information Monitoring	Slobodan Beliga, PhD	15	0	15	6	E
	Digital Image Processing and Analysis	Assist. Prof. Miran Pobar, PhD	15	0	15	6	E
	Biometrics	Prof. Bojan Čukić, PhD	15	0	15	6	E
	Design of e-learning environments	Prof. Nataša Hoić-Božić, PhD	15	0	15	6	E
	Data mining techniques and models	Prof. Maja Matetić, PhD	15	0	15	6	E

[1] IMPORTANT: Insert C for compulsory courses or E for elective courses.

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	Computer assisted language learning	Assist. Prof. Vanja Slavuj, PhD	15	0	15	6	E
	Selected Topics in Databases	Prof. Patrizia Poščić, PhD	15	0	15	6	E
	Conceptual Modeling of Complex Systems	Assist. Prof. Martina Ašenbrener Katić, PhD	15	0	15	6	E
	Computational biochemistry and biophysics	Assist. Prof. Vedran Miletić, PhD	15	0	15	6	E

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General information		
Course instructor	Prof. Sanda Martinčić-Ipšić, PhD	
Name of the course	Research Methodology	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	compulsory	
Year of study	1.	
ECTS credits and manner of instruction	ECTS credits	12
	Number of class hours (L+E+S)	15+15+0

1.1. Course objectives

The goal of the course is to provide an overview of the research methodology, the research process and scientific publishing.

1.2. Course enrolment requirements

None

1.3. Expected learning outcomes

Upon successful completion of this course, students should be able to:

O1. Evaluate the research process and recommend methodology and methods for scientific research, Synthesize the challenges and advances od selected scientific field and select and analyze published paper from the selected scientific field,
O2. Detect and define research problems and challenges,
O3. Create a research questions for detected research problems,
O4. Compose research methods according to selected research methodology,
O5. Propose and write a scientific paper including the overview of related work with gaps and open questions in detected research problem,
O6. Evaluate scientific work and write a review of scientific papers,
O7. Understand a reviewing, revising and publishing process,
O8. Evaluate and asses the scientific choices following the ethical principles in science, especially for computer science and its influence on society.

1.4. Course content

- Principles in scientific research and research cycle, with emphasis for computer and information science research.
- Analytical and empirical methods, case studies, experiments, quantitative qualitative and mix methods
- Research methodology, Action Research, Design Research, Design Science Research, Case Studies, etc.
- Type of scientific publications: original scientific paper, long paper, short paper, overview paper, preliminary communication, posters, talks. The publication process.
- Bibliometric databases, impact factors, ranks, citations, h-index. Search.
- Structuring the overview of scientific research. The related work and citations. Identifying gaps and open questions.

- Writing the scientific paper, text, the structure and outline, paragraphs, tables and figures, captions, related work, methodology, experimental design, results, discussion and conclusion. Abstract. Language editing and proofreading.
- Presentation of the scientific work.
- The reviewing process, the structure of the review of scientific papers and projects. Recommendation and motivation letters.
- Ethics in the research, privacy, personal data protection. Research legislation.
- PhD process and PhD Dissertation.

1.5. Manner of instruction	☒ lectures ☐ seminars and workshops ☒ exercises ☐ distance learning ☐ fieldwork	☒ individual assignments ☒ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments		

1.7. Student responsibilities

Students are expected to: attend classes regularly, write a scientific paper according to the instructions, present the work and review papers.

1.8. Monitoring of student work[2]

Class attendance	1	Class participation		Seminar paper		Experimental work	2
Written exam		Oral exam		Essay		Research	4
Project		Continuous assessment		Report and presentation	2	Practical work	3
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes will be achieved through the preparation of the scientific paper for the selected research field of the PhD. Students will present their work and evaluate other works in the form of scientific review. Students will proceed toward publication of the prepared work with their PhD supervisors.

Specifically, the student will:

- Prepare the presentation of planned research and publication,
- Prepare the presentation of already publisher paper which is crucial related work for the research in progress,
- Prepare the scientific paper according to the instructions in the field of the PhD topic, present the conducted research and written paper in a presentation. Paper will include the overview of related work and the identification of open research question, preliminary plan of needed research methods and experimental design, conclusions and future Research plans,
- Review two scientific papers written by their peers and elaborate it during the presentation of the original paper.

1.10. Mandatory literature (at the time of submission of study programme proposal)

[2] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

1. Patricia Leavy, Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches, Guilford press,2017. https://www.guilford.com/books/Research-Design/Patricia-Leavy/9781462514380
2. Wayne C. Booth, Gregory G. Colomb, Joseph M. Williams, Joseph Bizup, William T. FitzGerald, The Craft of Research, Fourth Edition (Chicago Guides to Writing, Editing, and Publishing), 4th. edition. Chicago: University of Chicago Press.2016. https://www.amazon.com/Research-Chicago-Writing-Editing-Publishing/dp/022623973X
3. Saunders, M., Lewis, P. and Thornhill, A. Research methods for business students. Harlow: Pearson Education Limited. 2019. https://www.pearson.com/uk/educators/higher-education-educators/program/Saunders-Research-Methods-for-Business-Students-8th-Edition/PGM100003054179.html
4. Zobel, Justin. Writing for computer science. Springer, 2014. https://link.springer.com/book/10.1007/978-1-4471-6639-9

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Michael D Myers, David Avison. Qualitative Research in Information Systems. SAGE Publications Ltd. 2002. https://uk.sagepub.com/en-gb/eur/qualitative-research-in-information-systems/book205159
2. Briony J Oates, Researching Information Systems and Computing, SAGE Publications, 2005. https://uk.sagepub.com/en-gb/eur/researching-information-systems-and-computing/book226898
3. Jeff Leek, The Elements of Data Analytic Style, Leanpub, 2015. https://leanpub.com/datastyle
4. William Strunk Jr. The Elements of Style, Value Classic Reprints, 2016. http://www.jlakes.org/ch/web/The-elements-of-style.pdf
5. Joseph M. Williams, Joseph Bizup. Style - Lessons in Clarity and Grace, 12th Edition, Pearson; 2017. https://www.pearson.com/us/higher-education/product/Williams-Style-Lessons-in-Clarity-and-Grace-12th-Edition/9780134080413.html

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Patricia Leavy, Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches, Guilford press,2017.	*1 + online*	
Wayne C. Booth, Gregory G. Colomb, Joseph M. Williams, Joseph Bizup, William T. FitzGerald, The Craft of Research, Fourth Edition (Chicago Guides to Writing, Editing, and Publishing), 4th. edition. Chicago: University of Chicago Press.2016.	*1 + online*	
Saunders, M., Lewis, P. and Thornhill, A. Research methods for business students. Harlow: Pearson Education Limited. 2019.	*1 + online*	
Zobel, Justin. Writing for computer science. Springer, 2014.	*1 + online*	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Prof. Marta Žuvić, PhD	
Name of the course	Statistical Analysis of Research Data	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. *Course objectives*

The course serves as an introduction to the basics of mathematical statistics. The aim is to acquire basic knowledge, skills and competences for collecting, storing and presenting research data and performing statistical analyses.

1.2. *Course enrolment requirements*

none

1.3. Expected learning outcomes

Upon successful completion of this course, students should be able to:

O1. Interpret the basic concepts of probability theory, distinguish discrete and continuous random variables, distinguish and explain the distribution of probabilities of discrete and continuous random variables, know the properties of normal distribution (moments of distribution, forms of distribution).
O2. Correctly interpret the concepts of population and sample, distinguish the different types of samples and their characteristics.
O3. Correctly state the statistical hypothesis (null hypothesis and alternative hypothesis), define and distinguish the types of errors in accepting or rejecting the statistical hypothesis and correctly interpret the correlation with test power.
O4. Provide an example of setting up and testing the statistical hypothesis and interpreting the results for the analysis of simple categorical data (comparing the proportions in the sample with the given measure in the population, determining the proportional difference in the two groups in the sample, carrying out the analysis of contingency tables (hi2 - , Fisher's exact test, McNemar's test), determining the association parameters between categorical data (odds ratio and relative risk) and their 95% confidence intervals).
O5. Provide examples of the formulation and testing of the statistical hypothesis and the correct analysis and interpretation of the results for simple analysis of continuous numerical data (testing the normal distribution, comparing the central tendency measure of the sample with the given measure in the population and comparing the central tendency measure of the two sets of data; t-tests and non-parametric versions - Mann Whitney test, Wilcoxon test).
O6. Appropriately apply analysis of variance to independent and dependent data sets and apply appropriate non-parametric tests (Kruskal Wallis and Friedman ANOVA) with planned comparisons and post-hoc multiple comparison tests.
O7. Perform descriptive survival analysis comparing survival data in specific groups and determine significant predictor variables for survival, with appropriate interpretation of results.

O8. Determine the correlation of numerical data using simple linear regression and interpret the parameters, apply multiple regression analysis and determine the correlation of several numerical variables and select significant predictors for the selected dependent variable.
O9. Apply logistic regression (single and multiple) appropriately to determine the correlation of numerical data with dichotomous categorical data and correctly interpret the predictor(s) value and significance of the model.
O10. Apply ROC analysis and interpret output analysis parameters to determine criterion values for group separation based on predictor value and assess the predictor value.

1.4. Course content

- The basics of probability theory and correlation with mathematical statistics. Random variables - discrete and continuous. Probability distribution of random variables. Binomial and normal distribution and their properties.
- Population and sample, population description and sample measures, types and characteristics of samples.
- Concept of a statistical hypothesis testing (null hypotheses and alternative hypotheses) and the type I and type II errors in rejecting or accepting null hypothesis. Type II error and the statistical power.
- Description of normal distribution and testing of data on normality of distribution, introduction of the confidence interval concept.
- Formulation of and testing of the statistical hypothesis, selecting the statistical test, the results of statistical testing and the statement, analysis and interpretation of the results.
- Simple categorical data analysis - comparing proportion in a sample with a proportion in a population, determining difference of proportions, contingency tables analysis (chi2 test, Fisher exact test, McNemar test), determining correlation measures of categorical data in tables 2x2 (odds ratio and relative risk and respective 95% confidence intervals).
- Simple analysis of continuous numerical data: comparison of the sample mean with a given measure in the population (constant or population mean), comparison of the means in two groups of independent and dependent data (t-tests and nonparametric variants -Mann Whitney test, Wilcoxon test).
- Analysis of variance – comparing numerical data between 3 and more data groups. ANOVA testing and their nonparametric variants (Kruskal Wallis and Friedman ANOVA) with the application of planned comparisons and post-hoc multiple comparison tests.
- Applying survival analysis as a specific model for the description of an incomplete data set - descriptive methods (life tables, Kaplan Meier analysis) and inferential methods (group survival comparisons, regression analysis for predicting survival predictors).
- Concepts of correlation and regression. Simple linear correlation, correlation coefficient, determination coefficient. Linear regression as a model. Multiple linear regression analysis and interpretation of analysis parameters.11. Non-linear regression models. Logistic regression - determining the association of numerical data set to and dichotomic categorical data. Simple and multiple logistic regression. ROC analysis and output parameters of analysis, determination of criterion (cut-off value) for separation of groups.

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☐ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Raljević, Damir; Peršić, Viktor; Markova-Car, Elitza; Cindrić, Leon; Miškulin, Rajko; Žuvić, Marta; Kraljević Pavelić, Sandra. Study of vitamin D receptor gene polymorphisms in a cohort of myocardial infarction	

patients with coronary artery disease // BMC Cardiovascular Disorders, 21 (2021), 1; 188, 9 doi:10.1186/s12872-021-01959-x
2. Kraljević Pavelić, Sandra; Micek, Vedran; Bobinac, Dragica; Bazdulj, Edo; Gianoncelli, Alessandra; Krpan, Dalibor; Žuvić, Marta; Eisenwagen, Sandra; Stambrook, Peter J; Pavelić, Krešimir. Treatment of osteoporosis with a modified zeolite shows beneficial effects in an osteoporotic rat model and a human clinical trial // Experimental biology and medicine, 246 (2020), 529-537 doi:10.1177/1535370220968752
3. Peršić, Viktor; Raljević, Damir; Markova-Car, Elitza; Cindrić, Leon; Miškulin, Rajko; Žuvić, Marta; Kraljević Pavelić, Sandra. Vitamin D-binding protein (rs4588) T/T genotype is associated with anteroseptal myocardial infarction in coronary artery disease patients // Annals of Translational Medicine, 7 (2019), 16; 374, 10 doi:10.21037/atm.2019.07.49
4. Giacometti, Jasminka; Žauhar, Gordana; Žuvić, Marta. Optimization of Ultrasonic-Assisted Extraction of Major Phenolic Compounds from Olive Leaves (Olea europaea L.) Using Response Surface Methodology // Foods, 7 (2018), 9; 149, 14 doi:10.3390/foods7090149
5. Kraljić, Snježana; Žuvić, Marta; Deša, Kristian; Blagaić, Ana; Sotošek, Vlatka; Antončić, Dragana; Likić, Robert. Evaluation of nurses' workload in intensive care unit of a tertiary care university hospital in relation to the patients' severity of illness: A prospective study // International journal of nursing studies, 76 (2017), 100-105 doi:10.1016/j.ijnurstu.2017.09.004

1.7. Student responsibilities

Students should actively participate in all course activities. Students are expected to: attend at least 2/3 of the classes and complete all the homework that is being assessed. Seminar work is done in a form of providing answer to a research problem – students have to demonstrate (in written form) the knowledge on presentation of data, use of appropriate statistical procedures and methodology, presentation of statistical results and appropriate interpretation of results in context of the research problem.

1.8. *Monitoring of student work*[3]

Class attendance	1	Class participation		Seminar paper	2	Experimental work	
Written exam	1	Oral exam		Essay		Research	
Project		Continuous assessment		Report		Practical work	2
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scholarly research in which the student applies theoretical and practical knowledge of the subject. Student research should be described through the production of seminar papers that can be used as the basis for the design of a scientific paper to be published at a conference or in a journal in consultation with the course instructor and student mentor.

The acquisition of learning outcomes is assessed in two ways - through the assessment of the seminar papers and through the assessment of the results of the final examination. The seminar paper is completed

[3] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

independently in which the student poses a research question and uses selected databases for statistical data processing, evaluates statistical results and interprets them in relation to the research question. In the written examination, the learning outcomes are tested by multiple-choice questions. Students' work and performance in the course is expressed by the% grade points achieved, on the basis of which the final grade is formed. Students can achieve a total of 100% grade points, a maximum of 70% grade points in class and a maximum of 30% grade points in the final examination. Students can take the final exam if they have achieved at least 35 grade points in class (50% of the possible points). The final examination consists of a written test (maximum 30 points) in which the student must achieve at least 15 points (50% of the possible points). The final grade is determined on the basis of the total achieved% of points and in accordance with Art. 43 of the Study Regulations of the University of Rijeka.

Evaluation		*Max grade points / %*
Activity	Practical work – seminar papers	70
Final exam	Written exam (test, 50 questions)	30
Total		*100*

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Rand R. Wilcox (2010). Fundamentals of Modern Statistical Methods, Springer
2. David M. Lane: Introduction to Statistics, Online edition (http://onlinestatbook.com/Online_Statistics_Education.pdf)

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. A. Petrie, C. Sabin: Medical Statistics at a Glance, Blackwell Science 2000.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Rand R. Wilcox (2010). Fundamentals of Modern Statistical Methods, Springer	*1*	
David M. Lane: Introduction to Statistics, Online edition	*online*	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Prof. Sanda Martinčić-Ipšić, PhD	
Name of the course	Text Mining and Knowledge Discovery	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The goal of the course is to apply machine and deep learning methods to natural language processing and solve standard tasks such as: text classification, information retrieval, automatic summarization, information extraction (e.g., name entity recognition, keyword extraction), topic detection, opinion mining and sentiment analysis, detection of toxic discourse or emotions from user comments, fake news detection, dialogue system development, text generation, semantics analysis, paraphrasing and natural language understanding, and other tasks. The trained models will be applied in the context of knowledge discovery from unstructured data sources.

1.2. Course enrolment requirements

none

1.3. Expected learning outcomes

O1. It is expected that upon successful completion of the obligations in this course, the student will be able to:
O2. Critically evaluate the principles, methods, and algorithms of text processing for solving standard information retrieval, text mining, natural language processing, and knowledge discovery problems.
O3. Design and develop an appropriate machine and/or deep learning model in combination with classical processing principles for a given information and knowledge discovery task.
O4. Evaluate machine and deep learning methods for the task using standard evaluation approaches to compare and assess scientific research results in the field of natural language processing.
O5. Asses the applicability of a deep network architecture or other deep structure for a given problem in light of recent scientific results and available data, architectures, and processing capabilities.
O6. Evaluate the applicability and understandability of the obtained model with respect to the problem of sparsity, imbalance of data, i.e., limitations in the conducted work.
O7. Implement a solution to the selected problem from the areas of text mining, information retrieval, knowledge discovery in accordance with the latest scientific knowledge in the field of , natural language processing.
O8. Design, plan and prepare a data set for a given problem, taking into account legal and ethical aspects.

1.4. Course content

- Introduction to machine and deep learning for NLP. Logistic regression. Loss functions.
- Text representations: sparse vector representation model (TF-IDF), bag-of-words model (BOW), dense representation models with low dimensionality vectors (embedding). Continuous bag-of-words and Skip-gram.
- Statistical language models. Neural (deep) language models.

<table>
<tr><td colspan="3">

- Information retrieval, similarity models, document retrieval and ranking. Semantic representation of words, sentences and texts. Semantic similarity. Evaluation methods.
- NLP methods for text mining. Text classification. Grouping. Principles of evaluation.
- Tasks of text classification: sentiment analysis, attitude and/or emotion detection, toxic content in texts, fake news detection and others. Multiclass and multilabel classification. Interpretation of the obtained models. Unbalanced classes**.**
- Deep learning models: feed-forward network. Recurrent neural network (RNN). Bidirectional networks. Long Short-Term Memory (LSTM), Gated Recurrent Unit (GRU). Encoder-Decoder.
- Modelling of long sequences. Part of speech tagging. Named entity recognition.
- Attention mechanisms. Transformers. Transfer learning, one-shot learning, or few-shoots learning. Multi-task learning.
- Examples of problems/tasks: Information extraction. Keyword extraction. Relation extraction. Principles of evaluation. Extractive and abstractive summarization, text generation. Principles of evaluation of generated text. Dialogue systems, chatbots, question answering. Principles of evaluation.
- Automatic topic detection. Latent representations of text. Principles of evaluation of latent models.
- Text coherence, resolution of co-references, paraphrasing. Fact checking and fact correctness verification. Knowledge discovery. Information and misinformation.
- Semantics and language understanding.
- Recent trends in natural language processing. Foundation language models / foundation models.
- Legal and ethical aspects. General artificial intelligence. Problems of bias and toxicity in foundation models. Responsible artificial intelligence.
- Incorporation of knowledge in deep learning. Incorporating knowledge into neural (deep) language models. (ERNIE: Enhanced Language Representation with Informative Entities). Knowledge Graphs. Knowledge/relation extraction for knowledge graph construction. Inference on knowledge graphs. Inference with language models and knowledge graphs. Evaluation procedures. Correction of facts/knowledge in deep models.

</td></tr>
<tr><td>1.5. Manner of instruction</td><td>☒ lectures
☒ seminars and workshops
☐ exercises
☐ distance learning
☐ fieldwork</td><td>☒ individual assignments
☐ multimedia and network
☐ laboratories
☒ mentorship
☐ other</td></tr>
<tr><td>1.6. Comments</td><td colspan="2">Relevant scientific papers by the course instructor:
1. E. Erdem et al. Neural Natural Language Generation: A Survey on Multilinguality, Multimodality, Controllability and Learning, Journal of Artificial Intelligence Research (JAIR)), https://doi.org/10.1613/jair.1.12918 Vol. 73. 2022. (WOS SCIE Q2, IF 2.774, SJR Q2)
2. Babić, S. Martinčić-Ipšić, A. Meštrović. Survey of Neural Text Representation Models. Information, Vol. 11, 511, 2020. doi:10.3390/info11110511 (WOS Emerging Sources IF 0.52 Q3, SJR Q3)
3. S. Martinčić-Ipšić, T. Miličić, Lj. Todorovski. "The Influence of Feature Representation of Text on the Performance of Document Classification". Applied Sciences, Vol. 9, No. 4, pp. 743-770, 2019. (IF 2.474, Q2)
4. S. Martinčić-Ipšić, E. Močibob, M. Perc. "Link prediction on Twitter". Plos ONE, 12(7): e0181079. 2017 (Q1, IF 2.806).
5. D. Aljević, Lj. Todorovski, S. Martinčić-Ipšić. Extractive Text Summarization Based on Selectivity Ranking. IEEE International Conference on INnovations in Intelligent SysTems and Applications (INISTA'21), pp. 1-6 , 2021.</td></tr>
</table>

1.7. Student responsibilities

Students should actively participate in all course activities. Students are expected to apply the theoretical knowledge acquired through the development and preparation of selected independent project work involving the solution of some of the standard tasks of natural language processing to extract information and knowledge from texts, such as: classification of texts, searching for information in unstructured data, information (e.g., entities, relations and keywords), extracting topics from texts, opinion mining, developing comment tracking systems, sentiment analysis, detecting toxic discourse or emotions from user comments, detecting fake news, developing dialog systems, generating texts, analyzing semantics, paraphrasing, and understanding natural language, and other state-of-the-art tasks. In addition to the practical part, a written part must contain of elements of scientific papers (overview of used methods, description of methods, description of the experiment, results, evaluation, discussion of results and limitations, etc.).

1.8. Monitoring of student work[4]

Class attendance	1	Class participation		Seminar paper	1	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project	2	Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.
The theoretical and practical part of the course will be assessed through project work, which includes solving some standard tasks of natural language processing, text mining and knowledge discovery (text classification, text mining, searching for information in unstructured data, automatic document summarization, information extraction, e.g. extraction of topics, relations, entities, keywords), development of a system for opinion mining an sentiment analysis, detection of toxic discourse or emotions in user comments, detection of fake news, development of dialog systems, text generation, analysis of semantics, paraphrasing, and natural language understanding, etc.) where the student will demonstrate the knowledge of the latest scientific discoveries through a submitted seminar paper (I1-I7).

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Dan Jurafsky, James H. Martin, Speech and Language Processing, Prentice Hall (3rd edition), 2021. https://web.stanford.edu/~jurafsky/slp3/
2. Jacob Eisenstein, Introduction to Natural Language Processing, MIT Press, 2019. https://mitpress.mit.edu/books/introduction-natural-language-processing
3. Yoav Goldberg, Neural Network Methods in Natural Language Processing (Synthesis Lectures on Human Language Technologies), Morgan & Claypool Publishers, 2017. https://www.morganclaypool.com/doi/10.2200/S00762ED1V01Y201703HLT037
4. C., Manning, H. Shütze: Foundations of Statistical Natural Language Processing, MIT Press, 1999. http://nlp.stanford.edu/fsnlp/

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

[4] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

1. François Chollet, Deep Learning with Python, Manning Pub. 2017. https://www.manning.com/books/deep-learning-with-python
2. S. Bird, E. Klein, E. Loper: Natural Language Processing with Python, O'Riley, 2009. http://nltk.org/book/
3. Bing Liu, Web Data Mining, Springer, 2011. http://www.cs.uic.edu/~liub/WebMiningBook.html
4. Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008. http://nlp.stanford.edu/IR-book/information-retrieval-book.html

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Dan Jurafsky, James H. Martin, Speech and Language Processing, Prentice Hall (3rd edition), 2021.	online	
Jacob Eisenstein, Introduction to Natural Language Processing, MIT Press, 2019.	1+ online	
Yoav Goldberg, Neural Network Methods in Natural Language Processing (Synthesis Lectures on Human Language Technologies), Morgan & Claypool Publishers, 2017.	1 online	
Manning, H. Shütze: Foundations of Statistical Natural Language Processing, MIT Press, 1999.	online	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Assoc. Prof. Marina Ivašić-Kos, PhD	
Name of the course	Computer Vision and Pattern Analysis	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. *Course objectives*

The main goal of this course is to introduce students to computer vision tasks, models and methods for working with image and video data, and with the possibilities of applying deep learning to tasks in the field of computer vision, such as image classification, object detection and object tracking.

1.2. *Course enrolment requirements*

There are no enrolment requirements

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students are expected to be able to:

O1. Distinguish between basic computer vision concepts and tasks
O2. Compare classical image analysis and feature excretion algorithms
O3. Compare classical and deep learning object classification methods
O4. Analyze often used methods and models in computer vision systems (e.g. analyze the architecture and the learning principle of the convolution neural network)
O5. Design and apply methods and models that are often used in computer vision systems
O6. Design the testing procedure for a computer vision method for a specific task
O7. Evaluate the performance of the given method on a specific computer vision task
O8. Create and evaluate a computer vision system for the selected task by applying the appropriate machine learning methods and parameters for building models

1.4. Course content

- Introduction to computer vision.
  - History
  - Applications
  - Image formation and processing.
- Technologies on which computer vision is based (Image Segmentation. Feature extraction. Edge detection. Color models.)
- Computer vision goals and tasks (object classification and detection, image search, image comparison, image description).
- Model learning methods
  - Classical image analysis, feature extraction and object classification algorithms (OpenCV)
  - Deep neural network models
- Basic architecture of the convolutional neural network and its layers. Activation function. Normalization. Definition of hyperparameters (depth, stride, zero-padding, weight sets)

- Model evaluation
  - Standard evaluation metrics
  - Analysis and interpretation of results
- System development
  - Deep convolution models: case studies
  - An example of a simple convolution network and training a model for object detection and recognition (TensorFlow, Keras environment, Google Colab cloud services).
- Case studies for selected computer vision tasks (image classification, object recognition and object detection, face detection and identification, action and gesture recognition, movement tracking and analysis).

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☒ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☒ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: Selected journal papers: 1. Sambolek, Saša; Ivašić-Kos, Marina, Automatic Person Detection in Search and Rescue Operations Using Deep CNN Detectors. // IEEE Access, 9 (2021), 37905-37922 doi:10.1109/ACCESS.2021.3063681 2. Pobar, Miran; Ivasic-Kos, Marina, Active Player Detection in Handball Scenes Based on Activity Measures. // Sensors, 20 (2020), 5; 1475, 24 doi:10.3390/s20051475 3. Kristo, Mate; Ivasic-Kos, Marina; Pobar, Miran, Thermal Object Detection in Difficult Weather Conditions Using YOLO. // IEEE Access, 8 (2020), 125459-125476 doi:10.1109/access.2020.3007481 Selected conference papers: 1. Sambolek, S., Ivašić-Kos, M. (2022). Transfer Learning Methods for Training Person Detector in Drone Imagery. In: Arai, K. (eds) Intelligent Systems and Applications. IntelliSys 2021. Lecture Notes in Networks and Systems, vol 295. Springer, Cham. https://doi.org/10.1007/978-3-030-82196-8_51 2. Ivasic-Kos, M., Kristo, M., Pobar, M. (2020). Person Detection in Thermal Videos Using YOLO. In: Bi, Y., Bhatia, R., Kapoor, S. (eds) Intelligent Systems and Applications. IntelliSys 2019. Advances in Intelligent Systems and Computing, vol 1038. Springer, Cham. https://doi.org/10.1007/978-3-030-29513-4_18 Other publications at: https://www.bib.irb.hr/profile/17011?page=2	

1.7. Student responsibilities

- The student is expected to study the literature and acquire basic knowledge about computer vision concepts, and to apply the appropriate methods to solve some of the tasks in the field of computer vision in practice.
- Design a task in the field of computer vision, create an experiment in which the student will choose the appropriate method and test the parameters to choose the optimal solution to the given problem

- Write a written report on the project and experimental work. The report should contain an analysis of the problem, a description of the used dataset, a description of the used method and architecture, and an evaluation and explanation of the obtained results.
- The student will orally present the project, the performed experiment and explain the obtained results.

1.8. *Monitoring of student work*[5]

Class attendance	1	Class participation		Seminar paper	1	Experimental work	2
Written exam		Oral exam		Essay		Research	1
Project	1	Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Forsyth, David A., and Jean Ponce. Computer Vision: a Modern Approach. Upper Saddle River, NJ: Prentice Hall, 2003. ISBN: 0130851981.
2. Ian Goodfellow and Yoshua Bengio and Aaron Courville: Deep Learning, The MIT Press, 2016. http://www.deeplearningbook.org/
3. Rajalingappaa Shanmugamani, Deep Learning for Computer Vision : Expert techniques to train advanced neural networks using TensorFlow and Keras, Packt Publishing Limited, 2018

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Duda, Richard O., Peter E. Hart, and David G. Stork. Pattern classification. 2nd ed. New York, NY: Wiley, 2001. ISBN: 0471056693.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Forsyth, David A., and Jean Ponce. *Computer Vision: a Modern Approach*. Upper Saddle River, NJ: Prentice Hall, 2003. ISBN: 0130851981.	1	
Ian Goodfellow and Yoshua Bengio and Aaron Courville: Deep Learning, The MIT Press, 2016. http://www.deeplearningbook.org/	online	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

[5] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

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General information		
Course instructor	Prof. Ivo Ipšić, PhD	
Name of the course	Computer Speech and Language Processing	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

Introduce to students state of the art methods and procedures in speech recognition and understanding systems.

1.2. Course enrolment requirements

no requirements

1.3. Expected learning outcomes

The students will understand how to implement and develop speech recognition and understanding computer systems.

1.4. Course content

Introduction to speech recognition and understanding systems. Speech coding, sampling and processing procedures. Speech signal features. Short time spectral analysis of speech signals. Homomorphic signal analysis, cepstrum. Fundamental speech frequency estimation. Acoustic modeling using hidden Markov Models. Language resources, corpus, lexicons, speech databases. Language modeling. Speech recognition methods. Morphologic language analysis. Speech taggers. Parsing methods. Semantic analysis. Spoken dialog systems. Dialog modeling. Speech synthesis.

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☒ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. A Vranković, I Ipšić, J Lerga, Entropy-Based extraction of Useful Content from Spectrograms of Noisy Speech Signals, 2021 International Symposium ELMAR, 83-86, 2021 2. G Paulin, M Ivašić-Kos, I Ipšić, Mogućnost primjene govora u računalnim igrama temeljenim na lokaciji, Govor 37 (1), 31-59, 2020 3. Beliga, I Ipšić, S Martinčić-Ipšić, Evaluation of Language Models over Croatian Newspaper Texts, Information Technology and Control 46 (4), 425-444, 2017	

1.7. Student responsibilities

Students have to attend to all course activities and work on projects.

1.8. Monitoring of student work[6]

Class attendance		Class participation		Seminar paper		Experimental work	2
Written exam		Oral exam		Essay		Research	2
Project	2	Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

The presence to all course activities and work on projects will be evaluated

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Huang, X. D., A. Acero and H. W. Hon (2000). Spoken Language Processing: A Guide to theory, Algorithm and System Development, Prentice Hall, New Jersey, USA.
2. Nikola Pavešić: Raspoznavanje vzorcev, Založba FE in FRI Ljubljana, 2000, ISBN 961-6210-81-5.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Gyergyek L., Pavešić N., Ribarić S.: Uvod u raspoznavanje uzoraka, Tehnička knjiga Zagreb, 1988.
2. Jurafsky, D., and J. Martin (2000). Speech and Language Processing, An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition. Upper Saddle River, New Jersey: Prentice Hall.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Huang, X. D., A. Acero and H. W. Hon (2000). Spoken Language Processing: A Guide to theory, Algorithm and System Development, Prentice Hall, New Jersey, USA	1	
Nikola Pavešić: Raspoznavanje vzorcev, Založba FE in FRI Ljubljana, 2000, ISBN 961-6210-81-5.	2	
Gyergyek L., Pavešić N., Ribarić S.: Uvod u raspoznavanje uzoraka, Tehnička knjiga Zagreb, 1988.	2	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Department of Informatics quality methods will be employed.

[6] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

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General information		
Course instructor	Assist. Prof. Marija Brkić Bakarić, PhD	
Name of the course	Machine translation	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

Google Translate and similar engines generate translations from one natural language into another. Beside a historical overview of the development of machine translation, the goal of the course is to present the way contemporary machine translation systems are built, their limitations, and possible improvements. The course enables students to build their own machine translation system by presenting different algorithms and data structures, alternative architectures, and considering various linguistic aspects.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students will be able to:

O1. Explore and apply existing machine translation approaches and technologies and different pre-processing and post-processing techniques.
O2. Critically analyse different approaches to machine translation.
O3. Explore and evaluate concepts and methods used in the field of machine translation.
O4. Conduct research on a given domain.
O5. Apply evaluation procedures and conduct error analysis of machine translation output.
O6. Analyse a given problem in the field of machine translation and suggest a solution.
O7. Develop, optimize, and evaluate their own machine translation system.

1.4. Course content

- MT in translation industry. Problem definition.
- Introduction to machine translation.
- History of machine translation.
- Machine translation evaluation: task-based assessment, human assessment, automatic evaluation and metrics (BLEU, METEOR, TER, characTER). Confidence intervals and statistical significance.
- Alignment techniques and parallel corpora.
- N-gram language models. Word embeddings. Neural language models.
- Statistical machine translation.
- Neural machine translation. Encoder and decoder.
- Training and decoding. Direct decoding.
- Parameter optimization: grid search, MERT, PRO.
- Attention. Alternative architectures.

<table>
<tr><td colspan="3">

- System adaptation. Monolingual texts. Multilingual machine translation.
- Automatic post-editing.
- Challenges: out-of-domain data, corpus size, noise.
- Analysis and visualization.

</td></tr>
<tr><td>1.5. Manner of instruction</td><td>☒ lectures
☒ seminars and workshops
☐ exercises
☒ distance learning
☐ fieldwork</td><td>☒ individual assignments
☐ multimedia and network
☐ laboratories
☒ mentorship
☐ other</td></tr>
<tr><td>1.6. Comments</td><td colspan="2">Relevant scientific papers by the course instructor:
1. Popović, Maja; Poncelas, Alberto; Brkić Bakarić, Marija; Way, Andy. On Machine Translation of User Reviews // Proceedings of Recent Advances in Natural Language Processing (RANLP) / Angelova, Galia ; Kunilovskaya, Maria ; Mitkov, Ruslan ; Nikolova-Koleva, Ivelina (ur.), 2021. str. 1113-1122
2. Popovic, Maja; Poncelas, Alberto; Brkic, Marija; Way, Andy. Neural Machine Translation for translating into Croatian and Serbian // Proceedings of the 7th Workshop on NLP for Similar Languages, Varieties and Dialects / Zampier, Marco ; Nakov, Preslav ; Ljubešić, Nikola ; Tiedemann ; Jörg, Scherrer, Yves (ur.). Barcelona, Spain: International Committee on Computational Linguistics (ICCL), 2020. str. 102-113
3. Lalli Paćelat, Ivana; Brkić Bakarić, Marija; Matticchio, Isabella. Službena dvojezičnost u Istarskoj županiji: stanje i perspektive // Rasprave Instituta za hrvatski jezik i jezikoslovlje, 46 (2020), 2; 351-373. doi:.org/10.31724/rihjj.46.2.20
4. Brkic Bakaric, Marija; Tonkovic, Kristina; Nacinovic Prskalo, Lucia. Clash between Segment-level MT Error Analysis and Selected Lexical Similarity Metrics // International Journal of Advanced Computer Science and Applications, 11 (2020), 5; 35-42 doi:10.14569/ijacsa.2020.0110506
5. Brkic Bakaric, Marija; Lalli Pacelat, Ivana. Parallel Corpus of Croatian-Italian Administrative Texts // Proceedings of the 2nd Workshop on Human- Informed Translation and Interpreting Technology (HiT-IT 2019) / Temnikova, I. ; Orăsan, C. ; Corpas Pastor, G. ; Mitkov, R. (ur.). Varna, Bugarska, 2019. str. 11-18 doi:10.26615/issn.2683-0078.2019_002</td></tr>
<tr><td colspan="3">1.7. Student responsibilities</td></tr>
<tr><td colspan="3">Students should actively participate in all course activities. Student responsibilities for this course are as follows:
• Conduct a research study (define research hypotheses, prepare input data, develop their own machine translation system, optimize system parameters, and evaluate the system by comparing it to a baseline system).
• Write a seminar paper on the conducted research and present it to the course instructor as part of the final exam.
Continuous evaluation will be conducted based on several seminar papers and workshops.</td></tr>
</table>

1.8. Monitoring of student work[7]

Class attendance	1	Class participation		Seminar paper	1	Experimental work	1
Written exam		Oral exam		Essay		Research	1
Project	1	Continuous assessment		Report		Practical work	1
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Koehn, Philipp. Neural machine translation. Cambridge University Press, 2020.
2. Géron, Aurélien. Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow: Concepts, tools, and techniques to build intelligent systems. " O'Reilly Media, Inc.", 2019.
3. Vajjala, Sowmya, et al. Practical Natural Language Processing: A Comprehensive Guide to Building Real-World NLP Systems. O'Reilly Media, 2020.
4. A selection of scientific papers available online.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Koehn, Philipp. Statistical machine translation. Cambridge University Press, 2009.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Koehn, Philipp. Neural machine translation. Cambridge University Press, 2020.	1	
Géron, Aurélien. Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow: Concepts, tools, and techniques to build intelligent systems. " O'Reilly Media, Inc.", 2019.	1	
Vajjala, Sowmya, et al. Practical Natural Language Processing: A Comprehensive Guide to Building Real-World NLP Systems. O'Reilly Media, 2020.	1	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

[7] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

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General information		
Course instructor	Assist. Prof. Lucia Načinović Prskalo, PhD	
Name of the course	Computational linguistics	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The goal of the course is to familiarise students with the concepts of computational linguistics, the different levels of linguistic analysis, and the methods of applying computers in solving linguistic problems. Students will also become familiar with the structural features of languages and the principles of their computer processing to obtain linguistic (morphological, syntactic, semantic) information.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students will be able to:

O1. Identify key features of methods, technologies, and tools in the field of computational linguistics,
O2. critically analyse various approaches and procedures in computational linguistics,
O3. research and evaluate procedures used in the field of computational linguistics,
O4. design and develop components of problem-solving systems in the field of computational
O5. linguistics according to defined requirements,
O6. apply procedures to evaluate and analyse errors in systems or system components created to
O7. solve problems in the field of computational linguistics,
O8. investigate the problem in the field of computational linguistics and propose a solution,
O9. prepare scientific and professional papers presenting research results.

1.4. Course content

The proposed course includes the following content:

- Basic concepts related to the field of computational linguistics, overview, approaches, connections between computer science, statistics and linguistics
- Corpus linguistics - qualitative and quantitative analysis; representativeness, balance and sampling in computational linguistics
- Language complexity - probability theory, information theory (language as information, language models)
- Linguistic structure and annotation of linguistic phenomena, representation and exchange of linguistic annotations
- Syntax and grammars - syntactic sentence structure, probabilistic context-independent grammars, dependency analysis (parsing), parsing of collocations and noun phrases
- Lexical semantics - lexical relations, association measures, figurative language (metaphors, metonymies, etc.), applications based on lexical semantics (e.g., automatic thesaurus building)

- Resolution of word ambiguity, homographs, homonyms, homophones, lexical homonyms
- Application of machine learning and deep learning methods to solve linguistic problems, e.g., finding word usage patterns and using them to approximate lexical meaning, finding patterns of typicality in word sequences, etc.

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☒ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Načinović Prskalo, Lucia; Brkić Bakarić, Marija (2022). Identification of metaphorical collocations in different languages - similarities and differences. Text, Speech, and Dialogue: 24th International Conference TSD 202. Lecture Notes in Computer Science, Brno, Czech Republic, September 6–9, 2022. [accepted for publication] 2. Brkić Bakarić, Marija; Načinović Prskalo, Lucia; Popović, Maja (2022). A General Framework for Detecting Metaphorical Collocations // Proceedings of the LREC 2022 workshop on 18th Workshop on Multiword Expressions (MWE 2022) / Bhatia, Archna; Cook, Paul; Taslimipoor, Shiva; Garcia, Marcos; Ramisch, Carlos (ur.). Pariz: European Language Resources Association, 2022. str. 3-8 3. Pauletić, Iva; Načinović Prskalo, Lucia; Brkić Bakarić, Marija. (2019). An Overview of Clustering Models with an Application to Document Clustering. Proceedings of the 42nd International Convention MIPRO 2019, Opatija: MIPRO. 1928-1933 4. Načinović Prskalo, Lucia; Brkić Bakarić, Marija (2018). The Role of Homograms in Machine Translation. International journal of machine learning and computing (IJMLC), 8, 2; 90-97. 5. Nacinovic Prskalo, Lucia; Brkic Bakaric, Marija. (2017). Disambiguation of Homograms in a Pitch Accent Language. Proceedings of 2017 International Conference on Computer Science and Artificial Intelligence CSAI 2017, ACM, Jakarta - 32-37.	

1.7. Student responsibilities

Students are required to actively participate in all course activities and to write a seminar paper on a specific topic in the subject area.

1.8. Monitoring of student work[8]

Class attendance	1	Class participation		Seminar paper	1	Experimental work	1
Written exam		Oral exam		Essay		Research	1
Project	1	Continuous assessment		Report		Practical work	1
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

[8] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Alexander Clark, Chris Fox, Shalom Lappin. The Handbook of Computational Linguistics and Natural Language Processing. Wiley-Blackwell, 2010.
2. Bolshakov Igor, Gelbukh Alexander. COMPUTATIONAL LINGUISTICS, Models, Resources, Applications. INSTITUTO POLITÉCNICO NACIONAL, 2004.
3. Selection of relevant scientific articles prepared and made available via the learning management system.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Recent articles from scientific journals and conferences.
2. Jurafsky, Dan. Speech and language processing: an introduction to natural language processing, computational linguistics, and speech recognition. Prentice Hall series in artificial intelligence. - Pearson international edition, 2021. https://web.stanford.edu/~jurafsky/slp3/
3. Christopher D. Manning, Hinrich Schütze. Foundations of statistical natural language processing. Mit press, 2003.
4. S. Bird, E. Klein, E. Loper: Natural Language Processing with Python, O'Riley, 2009. http://nltk.org/book/

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Alexander Clark, Chris Fox, Shalom Lappin. The Handbook of Computational Linguistics and Natural Language Processing. Wiley-Blackwell, 2010.	In the procurement process	
Bolshakov Igor, Gelbukh Alexander. COMPUTATIONAL LINGUISTICS, Models, Resources, Applications. INSTITUTO POLITÉCNICO NACIONAL, 2004.	In the procurement process	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Assist. Prof. Danijela Jakšić, PhD	
Name of the course	Data Warehousing for Business Intelligence	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The objectives of the course are to: a) acquaint students with the methods for designing and the principles of building a business intelligence system with emphasis on data warehouses, based on current trends in industry and scientific research, and B) encourage students to do further research in the field. The emphasis of the course is on the design, development and management of data warehouses for business purposes, which includes research and application of approaches to the: a) design, organization and integration of heterogeneous data in the data warehouse, b) implementation of business analytics and visualization processes, c) data quality assurance in the data warehouse, and d) data and metadata management in the data warehouse.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students are expected to be able to:

O1. Recommend appropriate architecture and infrastructure for data warehouse and business intelligence systems, following current trends in the field and specific business needs.
O2. Develop a conceptual, logical and physical model for all layers of the selected architecture, following current trends in the design of data warehouses and business intelligence systems.
O3. Evaluate the procedures of extracting, transforming and loading data into the data warehouse, based on the developed plan of the ETL processes and the use of appropriate technologies.
O4. Recommend solutions for business analytics and data visualization in the business intelligence system, based on modern approaches, methods, technologies and programming languages.
O5. Review the data quality in the business intelligence system, applying appropriate standards and methods for quality assurance, as well as mechanisms and tools for data quality management, metadata quality management and integration quality management.
O6. Implement data governance procedures and audit processes in the business intelligence system, based on appropriate techniques, policies and standards.
O7. Evaluate relevant relational and/or non-relational technologies, as well as programming and query languages for data warehousing and business intelligence systems.

1.4. Course content

- Fundamentals of Business Intelligence:
  Definition and Features of Business Intelligence Systems. Architecture and elements of business intelligence systems. Technologies and infrastructure of business intelligence systems. Key factors

and problems in the development, maintenance and success of business intelligence systems. Trends and review of research. Case studies.

- Fundamentals of data warehousing:
  Definition and features of a data warehouse. Data warehouse architectures. Data warehouse life cycle. Data warehouse development processes. Methods of conceptual design of data warehouses. Methods of logical design of data warehouses. Processes for retrieving data from the source, transforming the data and loading it into the repository (ETL). Business analytics (purpose, principles, technologies and approaches). Principles and problems of real-time data storage. Data warehousing technologies. Case studies.
- Trends and Review of Data Warehouse Development Research:
  Data Warehouse Design Methods. Frameworks and methodologies for building a data warehouse. Types of data and data sources (structured, semi-structured, unstructured data, big data/large-scale data, relational and non-relational data sources). Theorems, data models and ways of organizing heterogeneous data and sources. Modern architectures for data warehousing. Modern ways of organizing data warehouse (eg. Data Vault repository, data lake, data lakehouse). Integration of data warehouse with other business systems (eg. MDM system, GIS system, ...). Evolution of data and schemas in the data warehouse. Data access and information delivery. Models of processing heterogeneous data types. Techniques and principles of data visualization. Case studies.
- Data quality:
  Data quality. Data quality in data sources. Data quality in the data warehouse. Categories and dimensions of data quality. Data quality standards. Data quality assurance models, methods and frameworks. Data quality assurance mechanisms and tools. Master data. Master data management systems. Quality of integration. Metadata. Design and organization of metadata in a data warehouse. Data warehouse system catalog. Metadata quality in the data warehouse. An overview of current trends and directions of research in the field of data quality. Case studies.
- Data management:
  Data governance. Standards and problems of data management in a data warehouse. Problems of data integration into the data warehouse. Methods and techniques of data integration in a data warehouse. Data privacy and security in the data warehouse. Information ethics. Change management and audit. User roles in data management and quality management. An overview of current trends and directions of research in the field of data management. Case studies.
- Programming and query languages:
  Relational and non-relational programming and query languages for data warehouses and business intelligence systems. Temporality in query languages. Materialized views for the data warehouse. Query optimization for data warehousing needs. Business reporting. An overview of current trends and directions of research in the field of programming and query languages for data warehouse and business intelligence system. Case studies.

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☐ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Brajković, Helena; Jakšić, Danijela; Poščić, Patrizia. Data warehouse and data quality – an overview // Central European Conference on	

Information and Intelligent Systems CECIIS 2020. University of Zagreb, Faculty of Organization and Informatics, Varaždin, Croatia. 2020. 1, 8.
2. Jakšić, Danijela; Poščić, Patrizia; Jovanović, Vladan. Conceptual Model for the New Generation of Data Warehouse System Catalog // Advances in Information and Communication, FICC 2019. Lecture Notes in Networks and Systems, Springer, vol 69. San Francisco, SAD: Springer, Cham, 2020. doi:10.1007/978-3-030-12388-8_55
3. Babić, Andrea; Jakšić, Danijela; Poščić, Patrizia. QUERYING DATA IN NOSQL DATABASES // Zbornik Veleučilišta u Rijeci / Journal of the Polytechnic of Rijeka, 7 (2019), 1; 257-270 doi:10.31784/zvr.7.1.9
4. Černjeka, Katerina; Jakšić, Danijela; Jovanović, Vladan. NoSQL Document Store Translation to Data Vault Based EDW // Proceedings of the 41th International Convention on Information and Communication Technology, Electronics and Microelectronics – MIPRO. Opatija, Hrvatska, 2018.
5. Jakšić, Danijela; Jovanović, Vladan; Poščić, Patrizia. Integrating evolving MDM and EDW systems by Data Vault based System Catalog // Proceedings of the 40th Jubilee International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO 2017). Opatija, Croatia, 2017.

1.7. Student responsibilities

Students should actively participate in all course activities, which include, but are not limited to: reading and studying current literature, researching Internet resources, libraries and scientific databases, and writing a seminar paper in the form of scientific research paper (article).

1.8. Monitoring of student work[9]

Class attendance	1	Class participation		Seminar paper	2.5	Experimental work	
Written exam		Oral exam		Essay		Research	2.5
Project		Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which must be written in the form of a scientific paper. In this way, the seminar paper will serve as the basis for the publication of a scientific paper that can later be published at a conference or in a journal, in consultation with the student, course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. R. Sharda, D. Delen, E. Turban. Business Intelligence, Analytics, and Data Science: A Managerial Perspective. Pearson, 4th edition (2017).

[9] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

2. W. Inmon, F. Puppini. The Unified Star Schema: An Agile and Resilient Approach to Data Warehouse and Analytics Design. Technics Publications (2020).
3. W. Inmon, M. Levins, R. Srivastava. Building the Data Lakehouse. Technics Publications (2021).
4. R. Mahanti. Data Quality: Dimensions, Measurement, Strategy, Management, and Governance. ASQ Quality Press (2019).

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. R. Kimball, M. Ross. The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling, 3rd edition. John Wiley & Sons, Wiley Computer Publishing (2013).
2. R. Kimball et al. The Data Warehouse ETL Toolkit, Practical Techniques for Extracting, Cleaning, Conforming and Delivering Data. John Wiley & Sons (2004).
3. W. Inmon, D. Strauss, G. Neushloss. DW 2.0- The Architecture for the Next Generation of Data Warehousing, Morgan Kaufmann Publishers (2008).
4. D. Linstedt, M. Olschimke. Building a Scalable Data Warehouse with Data Vault 2.0. Morgan Kaufmann (2015).
5. J. Ladley. Data Governance: How to Design, Deploy, and Sustain an Effective Data Governance Program. Academic Press, 2nd edition (2019).
6. N. Kelly. Delivering Data Analytics: A Step-By-Step Guide to Driving Adoption of Business Intelligence from Planning to Launch. Kogan Page (2021).

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
R. Sharda, D. Delen, E. Turban. Business Intelligence, Analytics, and Data Science: A Managerial Perspective. Pearson, 4th edition (2017).	1	
W. Inmon, F. Puppini. The Unified Star Schema: An Agile and Resilient Approach to Data Warehouse and Analytics Design. Technics Publications (2020).	1	
W. Inmon, M. Levins, R. Srivastava. Building the Data Lakehouse. Technics Publications (2021).	1	
R. Mahanti. Data Quality: Dimensions, Measurement, Strategy, Management, and Governance. ASQ Quality Press (2019).	1	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Assoc. Prof. Sanja Čandrlić, PhD	
Name of the course	Selected Topics in Information Systems	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The main objective of the course is to familiarise students with the theory of information systems, to provide an overview of current research in the field, and to encourage students to further research in the field of information systems design and development.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

Upon completion of all obligations expected in the course, students should be able to:

O1. Review key issues and research problems of information systems in different application areas.
O2. Critically analyze existing information systems, their advantages and disadvantages, as well as the appropriateness of their use and the use of information and communication technologies to support users in the processes they perform or the process they are intended for
O3. Analyze the interaction between humans and information or software systems in a given domain and create models that represent the system and user experience when using the observed or future system
O4. Research and evaluate key concepts and modern methods and methodologies for the development of information systems and related software and assess when to apply them in practice
O5. Analyze relevant scientific and professional publications and write scientific and professional papers in which they present their research results

1.4. Course content

- Information system, system, business system, management and decision making, business strategies and their impact on IS and technology, IS strategies, IS planning
- Planning and investing in digital technology, implementation of new digital technologies in business and other information systems, mobile technologies, information systems and cloud computing, virtual and augmented reality and information systems.
- Life cycle stages, models, methods, IS development methodology, information engineering, software engineering, agile approach, test-driven development, prototype, development platforms and languages, database, 4GL, programming standardization, configuration management, team, global software development, documentation, IS development problems, quality, quality management.
- The role of IS and technology in organizations and society, the impact of IS on the organization and the individual, human-information interaction, interaction with information system, interactive

system, human-oriented software and information engineering, users, requirements elimination, user experience design and evaluation, usability, customer satisfaction. • Research on the state of IS in organizations, digital transformation, legacy systems, integration, process optimization, automation.		
1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☐ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Šuman, Sabrina; Čandrlić, Sanja; Jakupović, Alen. A Corpus-Based Sentence Classifier for Entity– Relationship Modelling // Electronics, 11 (2022), 6; 1-22 2. Jaksic, Danijela; Candrlic, Sanja; Poscic, Patrizia. From User Requirements to Document Repository Enriched with Metadata – a Case Study // Procedia computer science (2022) 3. Blašković, Kristina; Čandrlić, Sanja; Jakupović, Alen. Systematic Review of Methodologies for the Development of Embedded Systems // International Journal of Advanced Computer Science and Applications, 12 (2021), 1; 410-420 4. Čandrlić, Sanja; Pavlić, Mile; Ašenbrener Katić, Martina. Interviewing Model to Enhance Process Modelling Education // Proceedings of EDULEARN 12th International Conference on Education and New Learning Technologies / Gómez Chova, L.; López Martínez, A. ; Candel Torres, I. (ur.). Palma de Mallorca, Španjolska: IATED Academy, 2020. str. 6605-6613 5. Čandrlić, Sanja; Pavlić, Mile; Ašenbrener Katić, Martina. Information System Design and Development and Project-Based Learning // Proceedings of the 12th International Conference on Computer Supported Education / Lane, H. Chad; Zvacek, Susan ; Uhomoibhi, James (ur.). Portugal: SCITEPRESS, 2020. str. 404-411	
1.7. Student responsibilities		
Students should actively participate in all course activities, which include, but are not limited to: reading and studying current literature, researching Internet resources, libraries and scientific databases, and writing a seminar paper in the form of scientific research paper (article).		

1.8. Monitoring of student work[10]

Class attendance	1	Class participation		Seminar paper	2	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project		Continuous assessment		Report		Practical work	1
Portfolio							

[10] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which must be written in the form of a scientific paper. In this way, the seminar paper will serve as the basis for the publication of a scientific paper that can later be published at a conference or in a journal, in consultation with the student, course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. George Reynolds, Ralph Stair. Principles of Information Systems, Boston: Cengage, 2020. Dostupno na: https://drive.uqu.edu.sa/_/fbshareef/files/principles%20of%20information%20systems%209th%20-stair,%20reynolds.pdf
2. Joseph Valacich, Christoph Schneider, Matthew Hashim. Information Systems Today: Managing in the Digital World, Pearson, 2022.
3. David T. Bourgeois, James L. Smith, Shouhong Wang, Joseph Mortati. Information Systems for Business and Beyond, Open textbooks, 2019. Dostupno na: https://digitalcommons.biola.edu/open-textbooks/1/
4. Jenny Preece, Yvonne Rogers & Helen Sharp. Interaction Design: Beyond Human-Computer Interaction, John Wiley and Sons, 2019.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Relevant papers published in scientific journals and conference proceedings.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Principles of Information Systems	Online	
Information Systems for Business and Beyond	Online	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Assist. Prof. Martina Holenko Dlab, PhD	
Name of the course	Development of Computer-Supported Learning Systems	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The main objective of the course is to familiarise students with modern scientific research in the field of design and development of computer-supported learning. Within the course, students will acquire knowledge and skills for the design, development and evaluation of computer-supported learning systems using various methods and information and communication technologies adapted to the field of learning and teaching.
Students interested in this area of research will be supported in choosing topics for their dissertation, further research, and completion of their doctoral studies.

1.2. Course enrolment requirements

No requirements

1.3. Expected learning outcomes

Upon completion of the course, students are expected to be able to:

O1. Identify key features and critically evaluate modern methods and information and communication technologies for computer-supported learning (e. g. recommender systems, expert systems, adaptive hypermedia systems, computer-supported collaborative learning systems, artificial intelligence in education, etc.)
O2. Critically analyse the advantages, disadvantages and suitability of certain methods, techniques and information and communication technologies to support different pedagogical and technological requirements (e. g. online and blended learning, collaborative learning, game-based learning, personalized learning, continuous online evaluation, mobile learning, learning with augmented and virtual reality, etc.)
O3. Design and develop components of computer-supported learning systems using appropriate methods and information and communication technology, and in accordance with defined technological and pedagogical requirements
O4. Evaluate the computer-assisted learning system according to given criteria (e. g. efficiency, effectiveness, user satisfaction).
O5. Create scientific and professional papers in which they present their research findings.

1.4. Course content

- An overview of modern methods and information and communication technologies for the design and development of computer-supported learning systems (e. g. recommender systems, adaptive hypermedia systems, expert systems, computer-supported collaborative learning systems, etc.).

<table>
<tr><td colspan="3">

- Structure of adaptive hypermedia systems. Application of flexibility methods and techniques for computer-supported learning.
- Task and structure of educational recommendation systems. Methods and techniques of recommender systems and their adaptation to support learning (content-based recommendation, collaborative filtering, knowledge-based recommendation, hybrid recommendation techniques). Approaches to improving the algorithms of the educational recommendation systems (several characteristics and criteria for evaluating content, contextual information, recommendation to groups). Presentation of recommendations in the context of learning and teaching.
- Methods of user (student) model design. Implicit and explicit ways of collecting user data. Log management and data protection. System interoperability for computer-supported learning and digital tools outside the system.
- Development of personalized learning environments.
- Support for teachers in computer-supported learning systems (support for planning and conducting learning and teaching activities). Techniques and methods for assessing the level of knowledge and level of student activity. Application of artificial intelligence and learning analytics in the design of learning and teaching, personalization of learning experiences, predicting behaviour and actions of students and designing interventions. Application of dashboards for monitoring, analysis and visualization of key indicators related to student knowledge, activity and performance.
- Evaluation of computer-assisted learning systems (evaluation of efficiency, effectiveness, user satisfaction).

</td></tr>
<tr><td>1.5. Manner of instruction</td><td>☒ lectures
☒ seminars and workshops
☐ exercises
☒ distance learning
☐ fieldwork</td><td>☒ individual assignments
☒ multimedia and network
☐ laboratories
☒ mentorship
☐ other</td></tr>
<tr><td>1.6. Comments</td><td colspan="2">Relevant scientific papers by the course instructor:
1. Holenko Dlab, Martina; Botički, Ivica; Hoić- Božić, Nataša; Looi, Chee Kit. Exploring group interactions in synchronous mobile computer-supported learning activities // Computers & Education, 146 (2020), 103735; 2-18
2. Boticki, Ivica; Uzelac, Nino; Dlab Holenko, Martina; Hoić-Božić, Nataša. Making synchronous CSCL work: a widget-based learning system with group work support // Educational Media International, 57 (2020), 3; 187-207
3. Đurović, Gordan; Holenko Dlab, Martina; Hoić- Božić, Nataša. Obrazovni sustavi preporučivanja: pregled stanja sa smjernicama za daljnja istraživanja i razvoj // Croatian Journal of Education-Hrvatski Casopis za Odgoj i obrazovanje, 20 (2018), 2; 531-560
4. Knez, Tina; Holenko Dlab, Martina; Hoić-Božić, Nataša. Implementation of Group Formation Algorithms in the ELARS Recommender System // International journal of emerging technologies in learning, 12 (2017), 11; 198-207
5. Holenko Dlab, Martina; Hoić-Božić, Nataša. Student and Group Activity Level Assessment in the ELARS Recommender System // International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 11 (2017), 10; 2215-2222</td></tr>
</table>

1.7. Student responsibilities

Students should actively participate in all course activities. They should conduct research that will be described in seminar paper.

1.8. Monitoring of student work[11]

Class attendance	1	Class participation		Seminar paper	1	Experimental work	1
Written exam		Oral exam		Essay		Research	2
Project		Continuous assessment		Report		Practical work	1
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Technology Enhanced Learning (Research Themes) / Erik Duval, Mike Sharples, Rosamund Sutherland (ur.). Springer, 2017.
2. Design of Technology-Enhanced Learning: Integrating Research and Practice / Bower, M., Emerald Publishing, 2017.
3. Recommender Systems Handbook / Francesco Ricci, Lior Rokach, Bracha Shapira, Paul B. Kantor (Editors), Springer, 2010.
4. Educational Research: Competencies for Analysis and Applications / L. R. Gay, Geoffrey E. Mills, Peter Airasian, Pearson, 2015.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

Relevant papers published in scientific journals and conference proceedings.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Design of Technology-Enhanced Learning: Integrating Research and Practice / Bower, M., Emerald Publishing, 2017.	online	
Recommender Systems Handbook / Francesco Ricci, Lior Rokach, Bracha Shapira, Paul B. Kantor (Editors), Springer, 2010.	online	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

[11] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

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General information		
Course instructor	Asocc. Prof. Božidar Kovačić, PhD	
Name of the course	Interactive multimedia	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The aim of the course is to students become familiar with theoretical and practical knowledge about the design of interactive multimedia and acquiring knowledge about the development of interactive concepts applicable in solving problems of interface design for human-computer interaction. Students acquire the necessary knowledge to design, develop and evaluate prototypes of interactive programs

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

Upon completion of all obligations expected in the course, students should be able to:

O1. Identify for a given learning and teaching problem the possibility for improvement by application interactive multimedia.
O2. Create for a given problem of learning and teaching a conceptual solution for the application of interactive multimedia.
O3. Design a proposal to improve the interface for human-computer interaction based on application of interactive multimedia.
O4. Apply interactive multimedia in developing a prototype of interactive program.
O5. Evaluate prototypes of interactive programs.

1.4. Course content

- The role and functions of theory in the development and delivery of digital multimedia content.
- Development of interactive multimedia infrastructure.
- Characteristics of media for the needs of application in various industries.
- Use of multimedia technologies in various fields.
- Strategies for developing learning components for multimedia presentations.
- The role of interactive multimedia in the design of teaching content and achieving learning outcomes.
- Applications and case studies: interactive learning for engineering education; multimedia systems to support the study of science in scientific centre; educational multimedia design for interactive learning in the medical sciences; interactive tools for language learning purposes.
- Design, development and evaluation of prototypes of interactive multimedia programs.

1.5. Manner of instruction		
	☒ lectures	☒ individual assignments
	☒ seminars and workshops	☐ multimedia and network
	☐ exercises	☐ laboratories

	☒ distance learning ☐ fieldwork	☒ mentorship ☒ other: consultative teaching
1.6. Comments	Relevant scientific papers by the course instructor: 1. Kovacic Bozidar.; Slavuj Vanja; Asenbrener Katic Martina, Analyzing the benefits of using a document repository to aid decision-making in the field of culture, iSCSi - International Conference on Industry Sciences and Computer Sciences Innovation, Porto, Portugal, 2022. 2. Slavuj, Vanja; Kovačić, Božidar; Jugo, Igor, User evaluation of an adaptive language learning system prototype // Proceedings of the 42nd International Convention MIPRO 2019, Rijeka: Croatian Society for Information and Communication Technology, Electronics and Microelectronics - MIPRO, 2019. str. 873-878 3. Gligora Marković, Maja; Kadoić, Nikola; Kovačić, Božidar, Selection and prioritization of adaptivity criteria in intelligent and adaptive hypermedia e-learning systems // TEM Journal, 7 (2018), 1; 137-146 4. Jugo, Igor; Kovačić, Božidar, A Method for Automatic Selection and Interpretation of Student Clustering Models According to their Activity on e-learning System // Central European Conference on Information and Intelligent Systems/Strahonja, Vjeran ; Kirinić, Valentina (ur.). Varaždin: Faculty of Organisation and Informatics, Varazdin, 2017. str. 61-68 5. Jugo, Igor; Kovačić, Božidar, Providing Hints Based On Discovered Frequent High- Utility Patterns In A Web-Based ITS // Proceedings of 8th Conference on e-learning / Jovanović, Slobodan ; Trebinjac, Bojana ; Kovačević, Sanja (ur.). Beograd: Belgrade Metropolitan University, 2017. str. 87-92	

1.7. Student responsibilities

Students should actively participate in all course activities, which include, but are not limited to: reading and studying current literature, researching Internet resources, libraries and scientific databases, and writing a seminar paper in the form of scientific research paper (article).

1.8. Monitoring of student work[12]

Class attendance	1	Class participation		Seminar paper	3	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project		Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which must be written in the form of a scientific paper. In this way, the seminar paper will serve as

[12] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

the basis for the publication of a scientific paper that can later be published at a conference or in a journal, in consultation with the student, course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Sanjaya M., Ramesh C. S., Interactive multimedia in education and training, Idea Group Publishing, 2005
2. Dragan Cvetković, Interactive Multimedia: Multimedia Production and Digital Storytelling Hardcover, Intechopen, 2019

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Richard A., Earl R. M., Interactive multimedia instruction, Educational Technology Publications, Englewood Cliffs, New Jersey, 1993.
2. Grupa autora: Theory and Practice of Online Learning, drugo izdanje, uredio Terry Anderson, AU Press, svibanj 2008.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Sanjaya M., Ramesh C. S., Interactive multimedia in education and training	1	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Prof. Ana Meštrović, PhD	
Name of the course	Network Mining	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

Network science develops algorithms for analysis of data that can be represented as network or graph. The course provides an overview of advanced techniques and procedures for data analysis represented in the form of a network / graph such as machine and deep learning. Network algorithms can be applied in various domains: social networks, information networks, biological networks, technology networks, etc. The goal of the course is to enable students to practically apply advanced algorithms for the representation and analysis of networks and knowledge discovery from networks.

1.2. Course enrolment requirements

none

1.3. Expected learning outcomes

It is expected that upon successful completion of the obligations in this course, the student will be able to:

O1. Design a dataset in the form of a network / graph for a research problem from a given domain.
O2. Critically evaluate methods and procedures for representing graph-based data.
O3. Design and develop an appropriate machine and/or deep learning model for a given task in the field of network knowledge discovery.
O4. Evaluate machine and / or deep learning methods for the set task in the field of discovering knowledge from networks.
O5. Evaluate the applicability of algorithms for a given problem of link prediction in the network within a given problem domain.
O6. Design and develop a dataset in the form of a multilayer network and apply appropriate algorithms for the analysis of the multilayer network structure.
O7. Implement a solution to the problem from the field of complex networks analysis taking into account the latest scientific findings.

1.4. Course content

- Introduction to Network Science. Examples of application of network science in different domains: social networks, information networks, technology networks, biological networks.
- Graph / network representation. Graph representation learning methods. Traditional and modern methods of graph embedding. Graph neural networks.
- Algorithms for network structure analysis and their application in different domains.
- Network dynamics analysis. Models of dynamic processes on complex networks
- Link prediction algorithms

<table>
<tr><td colspan="3">• Analysis of multilayer networks and its examples. Tensor representation of multilayer networks.
• Machine learning on graphs. Graphs/nodes classification.</td></tr>
<tr><td>1.5. Manner of instruction</td><td>☒ lectures
☒ seminars and workshops
☐ exercises
☐ distance learning
☐ fieldwork</td><td>☒ individual assignments
☐ multimedia and network
☐ laboratories
☒ mentorship
☐ other</td></tr>
<tr><td>1.6. Comments</td><td colspan="2">Relevant scientific papers by the course instructor:
1. Babić, Karlo, Milan Petrović, Slobodan Beliga, Sanda Martinčić-Ipšić, Mihaela Matešić, and Ana Meštrović. "Characterisation of COVID-19-related tweets in the Croatian language: framework based on the Cro-CoV-cseBERT model." Applied Sciences 11, no. 21 (2021): 10442.
2. Petrović, Milan, Zoran Levnajić, and Ana Meštrović. “Analysis of the COVID-19 Communication on Twitter via Multilayer Network”, 2021 2nd International Symposium on Automation, Information and Computing (ISAIC 2021), December 3rd-6th, 2021;
3. Vukić, Đurđica, Sanda Martinčić-Ipšić, and Ana Meštrović. "Structural analysis of factual, conceptual, procedural, and metacognitive knowledge in a multidimensional knowledge network." Complexity 2020 (2020).
4. Grba, Bojan, and Ana Meštrović. "Tracking the evolution of scientific collaboration networks." In 2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), pp. 0503-0508. IEEE, 2018.
5. Matas, Neven, Sanda Martinčić-Ipšić, and Ana Meštrović . "Comparing Network Centrality Measures as Tools for Identifying Key Concepts in Complex Networks: A Case of Wikipedia." Journal of Digital Information Management 15, no. 4 (2017).</td></tr>
<tr><td colspan="3">1.7. Student responsibilities</td></tr>
<tr><td colspan="3">Students should actively participate in all course activities. The student is expected to practically apply the acquired theoretical knowledge through the elaboration and development of a selected independent project work that includes solving tasks in the field of knowledge discovery from networks.</td></tr>
<tr><td colspan="3">1.8. Monitoring of student work[13]</td></tr>
</table>

Class attendance	1	Class participation		Seminar paper	1	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project	2	Continuous assessment		Report		Practical work	
Portfolio							

<table>
<tr><td>1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)</td></tr>
<tr><td>Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve</td></tr>
</table>

[13] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Wu, L., Cui, P., Pei, J., Zhao, L., & Song, L. (2022). Graph Neural Networks. In Graph Neural Networks: Foundations, Frontiers, and Applications (pp. 27-37). Springer, Singapore.
2. Newman, M. (2018). Networks. Oxford university press.
3. Russell, Stuart, and Peter Norvig. "Artificial intelligence: a modern approach." (2010.).
4. Russell, M. A. (2013). Mining the Social Web: Data Mining Facebook, Twitter, LinkedIn, Google+, GitHub, and More. " O'Reilly Media, Inc.".

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Easley, D., & Kleinberg, J. (2010). Networks, crowds, and markets: Reasoning about a highly connected world. Cambridge university press.
2. Scott, J. (2017). Social network analysis. Sage.
3. Liu, Zhiyuan, and Jie Zhou. "Introduction to graph neural networks." Synthesis Lectures on Artificial Intelligence and Machine Learning 14, no. 2 (2020): 1-127.
4. Wasserman, S., & Faust, K. (1994). Social network analysis: Methods and applications (Vol. 8). Cambridge university press.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Wu, L., Cui, P., Pei, J., Zhao, L., & Song, L. (2022). Graph Neural Networks. In Graph Neural Networks: Foundations, Frontiers, and Applications (pp. 27-37). Springer, Singapore.	1	
Newman, M. (2018). Networks. Oxford university press.	1	
Russell, Stuart, and Peter Norvig. "Artificial intelligence: a modern approach." (2010.).	1	
Russell, M. A. (2013). Mining the Social Web: Data Mining Facebook, Twitter, LinkedIn, Google+, GitHub, and More. " O'Reilly Media, Inc.".	1	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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COURSE DESCRIPTION		
Course instructor	Slobodan Beliga, PhD	
Name of the course	Information Monitoring	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1.1. Course objectives

The development of information and communication technology and social media significantly changes the information environment. The goal of the course is to enable students to develop automatic computer procedures for analysing and monitoring content on online content dissemination platforms (social media, search engines, news aggregators, messaging or short video applications, central online information points of various associations, organizations, etc.), using advanced statistical methods and techniques and models of text mining for information monitoring. The course includes an overview of the state and trends in the global information environment and the concepts, methods, and architecture of information monitoring in complex techno-social systems. Through the course, students will acquire the knowledge and skills necessary to develop algorithmic methods for automatically collecting, monitoring, ranking, determining the importance, visibility, reach, credibility of media content, etc., and learn to apply these methods, read, and interpret media content analysis, and finally critically evaluate their own research.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

O1. Critically analyse current platforms for media communication and develop a strategy for the development of ICT support on which data-driven communication will be based on a specific set of large-scale textual data.
O2. Design and develop application support or use available sophisticated software to collect textual data from various electronic media and organize it into a structured or semi-structured format suitable for advanced computer processing.
O3. Identify key characteristics and critically evaluate modern natural language processing approaches for the purposes of crisis media communication monitoring and surveillance.
O4. Analyse and discuss media, mass communication, information overload, and information disruption.
O5. Apply techniques of exploratory media content analysis, statistical analysis of time series, and sophisticated text mining tasks (e.g., author profiling, argumentation mining, assertion or facts detection, clickbait detection, named entity recognition and linking, etc.) in the design and development of information monitoring system components.
O6. Evaluate the adequacy of the system architecture which is intended to verify information and establish facts based on a given conceptual framework.
O7. Design, implement, describe, and critically evaluate the results of a case study dealing with the analysis and monitoring information from media sources in a particular domain (e.g., health care).
O8. Recommend and implement a methodological approach to information monitoring tailored to each of the network's information sources.

1.4. Course content

- Introduction to social media. An overview of current platforms for media communication and the evolution of media systems. Influence of the media. Data-driven strategic communication: the role of internet platforms, big data, algorithms and artificial intelligence in public information and strategic communication.
- Techniques and models for automatic data collection from different media platforms: social networks, internet portals, news aggregators, instant messaging, etc. Searching unstructured data sources. Scraping content from the web. Crawler engineering, extraction, and link analysis. Use of available APIs. Formats for structuring, organizing, and storing data.
- ICT, media, and legislation. Mass communication. Copyright. Electronic media law. Challenges of disinformation, fact checkers, trust in media and institutions. Modeling a system for monitoring, tracking and managing online communication patterns. Monitoring multimedia content (deepfake).
- Infodemia and infodemiology. Monitoring crisis communication in the media. Exploratory analysis of textual data from the media. Text processing and normalization, conversion into features. Application of descriptive and inferential statistics in data sciences - special tasks related to media content analysis.
- Introduction to temporal structures. Fundamentals of time series data analysis. Components of time series, trends, seasonality, etc. Statistical models for analysis of time-dependent data and introduction to forecasting. Visualization of time series data. Overview of standard data sets with time series data.
- Information overload, information interference, and disinformation as challenges. Applications of computer systems to verify information and establish facts. Conceptual framework for observing information disorder (elements, phases, and types). Technological tools for creating and combating information disturbances. System architectures for filtering, organizing, and presenting relevant information.
- Selected methods of natural language processing for the purposes of information monitoring. Modeling sentiment and topics in online media. Information extraction from big data. Named entity recognition and linking. Combining entities with text sentiments and storing to the knowledge base. Temporal analysis of sentiments. Detection of hate speech, fake news, clickbait, and deceptive language. Argumentation mining and author profiling.
- Complex techno-social systems modeling. Case studies: information monitoring with application in public health; campaign and analysis of consumer reactions to YouTube data; trend mining on Github, monitoring election and political campaign monitoring on Facebook, etc. Information dissemination and influence on social networks. SIR epidemic model. Crisis communication during pandemics, information wars and similar extreme situations. Analysis and evaluation of data obtained with the monitoring tool.

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☐ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	**Relevant scientific papers by the course instructor:** 1. Beliga, Slobodan; Martinčić-Ipšić, Sanda; Matešić, Mihaela; Meštrović, Ana. Natural language processing and statistic: The first six months of the COVID-19 infodemic in Croatia. *The Covid-19 Pandemic as a Challenge for Media and Communication Studies.* Kopecka-Piech, Katarzyna ; Łódzki, Bartłomiej (ur.). London: Routledge, 2022. str. 78-92 doi:10.4324/9781003232049-9	

2. Beliga, Slobodan; Martinčić-Ipšić, Sanda; Matešić, Mihaela; Petrijevčanin Vuksanović, Irena; Meštrović, Ana. Infoveillance of the Croatian Online Media During the COVID-19 Pandemic: One-Year Longitudinal Study Using Natural Language Processing. *JMIR Public Health and Surveillance*, 7 (2021), 12; e31540, 15 doi:10.2196/31540
3. Babić, Karlo; Petrović, Milan; Beliga, Slobodan; Martinčić-Ipšić, Sanda; Pranjić, Marko; Meštrović, Ana. Prediction of COVID-19 related information spreading on Twitter. *Proc. of 44th International convention on Information, Communication and Electronic Technology (MIPRO)*. Rijeka: Croatian Society for Information, Communication and Electronic Technology - MIPRO, 2021. str. 395-399 doi:10.23919/MIPRO52101.2021.9596693
4. Babić, Karlo; Petrović, Milan; Beliga, Slobodan; Martinčić-Ipšić, Sanda; Matešić, Mihaela; Meštrović, Ana. Characterisation of COVID-19-Related Tweets in the Croatian Language: Framework Based on the Cro-CoV-cseBERT Model. *Applied Sciences-Basel*, 11 (2021), 21; 10442, 22 doi:10.3390/app112110442
5. Beliga, Slobodan; Ipšić, Ivo; Martinčić-Ipšić, Sanda. Evaluation of Language Models over Croatian Newspaper Texts. *Information Technology and Control*, 46 (2017), 4; 425-444 doi:10.5755/j01.itc.46.4.18367

1.7. Student responsibilities

Students should actively participate in all course activities. They should conduct research that will be described in seminar paper.

1.8. Monitoring of student work[14]

Class attendance	1	Class participation		Seminar paper	1	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project	2	Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Jason Brownlee (2020). Introduction to Time Series Forecasting with Python. Machine Learning mastery.
2. Russell, M. A. (2013). Mining the Social Web: Data Mining Facebook, Twitter, LinkedIn, Google+, GitHub, and More. " O'Reilly Media, Inc.".
3. David Easley, Jon Kleinberg (2010). Networks, Crowds, and Markets: Reasoning about a Highly Connected World. Cambridge University Press.

[14] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

4. Chengqing Zong, Rui Xia, Jiajun Zhang (2021). Text Data Mining. Tsinghua University Press, Springer.
5. Sholom M. Weiss, Nitin Indurkhya, Tong Zhang, Fred J. Damerau, (2005). Text Mining: Predictive Methods for Analyzing Unstructured Information. Springer Science +Business Media, Inc.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Allen B. Downey (2015). Think Stats: Exploratory Data Analysis (2nd edition). O'Reilly Media.
2. Peter Bruce, Andrew Bruce & peter Gedeck (2020). Practical Statistics for Data Scientists: 50+ Essential Concepts Using R and Python (2nd edition). O'Reilly Media.
3. Wasserman, S., & Faust, K. (1994). Social network analysis: Methods and applications (Vol. 8). Cambridge university press.
4. Charu C. Aggarwal (2008). Machine Learning for Text. Springer International Publishing AG.
5. Gillespie, Marie and Toynbee, Jason eds. (2006). Analysing Media Texts. Understanding Media, 4. Maidenhead: Open University Press.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Jason Brownlee (2020). Introduction to Time Series Forecasting with Python. Machine Learning mastery.	1	
Russell, M. A. (2013). Mining the Social Web: Data Mining Facebook, Twitter, LinkedIn, Google+, GitHub, and More. " O'Reilly Media, Inc.".	1	
David Easley, Jon Kleinberg (2010). Networks, Crowds, and Markets: Reasoning about a Highly Connected World. Cambridge University Press.	online	
Chengqing Zong, Rui Xia, Jiajun Zhang (2021). Text Data Mining. Tsinghua University Press, Springer.	1	
Sholom M. Weiss, Nitin Indurkhya, Tong Zhang, Fred J. Damerau, (2005). Text Mining: Predictive Methods for Analyzing Unstructured Information. Springer Science +Business Media, Inc	1	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

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General information		
Course instructor	Assist. Prof. Miran Pobar, PhD	
Name of the course	Digital Image Processing and Analysis	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The objective of this course is to introduce students to digital image processing and digital image analysis methods, and and with their applications in typical tasks in computer vision, science and industry.

1.2. Course enrolment requirements

There are no enrolment requirements

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students are expected to be able to:

O1. Distinguish between basic digital image processing concepts
O2. Recommend algorithms for image processing and analysis for a given problem
O3. Design an image processing process for a specific task.
O4. Design an image analysis procedure for specific task
O5. Design a testing procedure and evaluate the performance of a given method for a specific task

1.4. Course content

- Introduction to image processing and image analysis. Image acquisition and processing.
- Image enhancement. Histogram operations.
- Morphological operations. Edge detection.
- Image feature extraction. Texture features.
- Analysis of image regions. Key points detection. Key point descriptors. Point prominence.
- Motion estimation and optical flow.
- Color images and multispectral images.
- Image registration. Geometric transformations. Homography.
- Imate processing and analysis software.
- Case studies for selected image processing and analysis tasks.

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☒ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☒ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Pobar, Miran; Ivasic-Kos, Marina, Active Player Detection in Handball Scenes Based on Activity Measures. // Sensors, 20 (2020), 5; 1475, 24 doi:10.3390/s20051475	

2. Kristo, Mate; Ivasic-Kos, Marina; Pobar, Miran, Thermal Object Detection in Difficult Weather Conditions Using YOLO. // IEEE Access, 8 (2020), 125459-125476 doi:10.1109/access.2020.3007481
3. Ivasic-Kos, M., Kristo, M., Pobar, M. (2020). Person Detection in Thermal Videos Using YOLO. In: Bi, Y., Bhatia, R., Kapoor, S. (eds) Intelligent Systems and Applications. IntelliSys 2019. Advances in Intelligent Systems and Computing, vol 1038. Springer, Cham. https://doi.org/10.1007/978-3-030-29513-4_18
4. Pobar, Miran; Ivašić-Kos, Marina, Detection of the leading player in handball scenes using Mask R-CNN and STIPS // Proc. SPIE 11041, Eleventh International Conference on Machine Vision (ICMV 2018)
5. Pobar, Miran; Ivašić-Kos, Marina, Mask R-CNN and Optical Flow Based Method for Detection and Marking of Handball Actions // 2018 11th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI) / Li, W ; Li, Q ; Wang, L (ur.). Peking, Kina: IEEE, 2018

Other publications at:
https://scholar.google.hr/citations?user=UieaDlkAAAAJ&hl=en

1.7. Student responsibilities

Students should actively participate in all course activities.

1.8. Monitoring of student work[15]

Class attendance	1	Class participation		Seminar paper	1	Experimental work	2
Written exam		Oral exam		Essay		Research	1
Project	1	Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Rafael C. Gonzalez, Richard E. Woods: Digital Image Processing, 4th ed., Pearson, 2018.
2. Richard Szeliski. Computer Vision: Algorithms and Applications. Springer, New York, 2nd edition, 2022

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

[15] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

1. Wilhelm Burger, Mark J. Burge: Digital Image Processing – An Algorithmic Introduction Using Java (2nd Edition). Springer, London, 2016.
2. Mark Nixon, Alberto Aguado, Feature Extraction and Image Processing for Computer Vision, Academic Press; 4th edition (December 2, 2019)
3. John Jensen: Introductory Digital Image Processing: A Remote Sensing Perspective, Pearson; 4th edition (April 21, 2015)
4. Adrian Davies: Digital Ultraviolet and Infrared Photography (Applications in Scientific Photography), Routledge; 1st edition (October 2, 2017)

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Rafael C. Gonzalez, Richard E. Woods: Digital Image Processing, 4th ed., Pearson, 2018.	1	
Richard Szeliski. Computer Vision: Algorithms and Applications. Springer, New York, 2nd edition, 2022	online	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Prof. Bojan Čukić, PhD	
Name of the course	Biometrics	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The course introduces fundamental and some advanced biometrics topics. The emphasis of the course is on algorithmic approaches to the construction biometric systems modules. The aim of the course is for the student to adopt the necessary knowledge for understanding, designing, modeling, applying and analyzing biometric systems. To facilitate this, selected topics from the field of image processing, computer vision and pattern recognition will be presented. Project work will involve applying biometric algorithms to biometric modalities such as the face, fingerprint or the iris of the eye.

1.2. Course enrolment requirements

There are no enrolment requirements

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students are expected to be able to:

O1. use biometric system modules
O2. both developand apply algorithms often used in biometric systems
O3. design testing and evaluation procedures for biometric systems
O4. build and evaluate proof-of-concept biometric recognition systems
O5. Discuss identity management concepts
O6. discuss security, vulnerability and privacy issues.
O7. explain and anticipate the legal, cultural and social consequences of using biometrics

1.4. Course content

- Biometrics fundamentals
  - History
  - Applications
  - Technologies underpinning biometrics
- Biometrics modalities
  - Characteristics
  - Multi-biometrics
- System design procedures
  - Architectures
  - Algorithms
- System evaluation
  - Classification
  - Statistical testing measures

<table>
<tr><td colspan="3">

Security, voulnerability, privacy

System development

Face detection and recognition
Texture based iris recognition methods
Elastic fingerprint transformations and recognition

Social, legal and cultural aspects
Acceptance, identity theft, local/international considerations

</td></tr>
<tr><td>1.5. Manner of instruction</td><td>☒ lectures
☒ seminars and workshops
☐ exercises
☒ distance learning
☐ fieldwork</td><td>☒ individual assignments
☐ multimedia and network
☐ laboratories
☒ mentorship
☐ other</td></tr>
<tr><td>1.6. Comments</td><td colspan="2">Relevant scientific papers by the course instructor:
1. P Liguori, E Al-Hossami, D Cotroneo, R Natella, B Cukic, S Shaikh: Can we generate shellcodes via natural language? An empirical study, Automated Software Engineering 29 (1), 1-34, 2022
2. Z Syed, J Helmick, S Banerjee, B Cukic, Touch gesture-based authentication on mobile devices: The effects of user posture, device size, configuration, and inter-session variability, Journal of Systems and Software 149, 158-173, 2019
3. Z Syed, J Helmick, S Banerjee, B Cukic, Touch gesture-based authentication on mobile devices: A controlled dataset to study the effects of user posture device size configuration and inter-session variability, J. Syst. Softw. 149, 158-173, 2018
4. E Marasco, P Wild, B Cukic, Robust and interoperable fingerprint spoof detection via convolutional neural networks, 2016 IEEE symposium on technologies for homeland security (HST), 1-6
Other publications at:
https://scholar.google.com/citations?hl=en&user=B7N812UAAAAJ&view_op=list_works&sortby=pubdate</td></tr>
<tr><td colspan="3">1.7. Student responsibilities</td></tr>
<tr><td colspan="3">Each student should present some research and write a seminar. The lecturer will provide a list with approximately 20 topics related to biometrics. Within the first few weeks, the student must choose one topic (or propose his own in agreement with the mentor) for the presentation of the research and seminar work. The student should independently look for additional references, study them and summarize the findings and results in a 20-minute presentation, and write a 7-12 page seminar paper. (font size 10-12, spacing 1.5). Additional references include textbooks, research articles, industry/government brochures, newspaper articles, etc. Presentations will be held in front of colleagues in the lecture hall according to a predetermined schedule. Presentations and seminars are independent works. Seminars written on the basis of the presentation must be submitted on the last week of the lecture.
Students will also receive one programming assignment of implementation of a biometric recognition system. The student will work in a team of 2-3 members to shape, develop and demonstrate his program. Students can use any programming language, and Matlab or similar environments are the best choice for modeling and performance.</td></tr>
</table>

1.8. Monitoring of student work[16]

Class attendance		Class participation		Seminar paper	2	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project	2	Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Jain, Anil K., Ross, Arun A., Nandakumar, Karthik: Introduction to Biometrics, Springer 2011

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. A. K. Jain, P. J. Flynn and A. Ross (Editors), "Handbook of Biometrics", Springer Publishers. ISBN: 978-0-387-71040-2.
2. A. Ross, K. Nandakumar and A. K. Jain, "Handbook of Multibiometrics", Springer Publishers, 1st edition, 2006. ISBN: 0-3872-2296-0.
3. A. K. Jain, A. Ross and S. Prabhakar, " An Introduction to Biometric Recognition", IEEE Transactions on Circuits and Systems for Video Technology, Special Issue on Image- and Video-Based Biometrics, Vol. 14, No. 1, pp. 4-20, January 2004.
4. C. Marzban, "The ROC Curve and the Area Under it as a Performance Measure", Weather and Forecasting, Vol. 19, No. 6, 1106-1114.
5. A. Y. Johnson, J. Sun, A. F. Bobick, "Predicting large population data cumulative match characteristic performance from small population data", 4th International Conference on Audio- and Video Based Biometric Person Authentication (AVBPA 2003), University of Surrey, Guildford, UK, June 2003.
6. G. Doddington, W. Liggett, A. Martin, M. Przybocki, D. Reynolds," Sheep, Goats, Lambs and Wolves: A Statistical Analysis of Speaker Performance in the NIST 1998 Speaker Recognition Evaluation", Proceedings of the Fifth International Conference on Spoken Language Processing (ICSLP), Sydney, Australia, November/December, 1998.
7. N. Yager and T. Dunstone, "The Biometric Menagerie," IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 32, No. 2, pp. 220 - 230, 2010.
8. A.K. Jain, L. Hong and R. Bolle, "On-line Fingerprint Verification", IEEE Transactions on PAMI, Vol. 19, No. 4, pp. 302-314, 1997
9. Ming-Hsuan Yang, David Kriegman, and Narendra Ahuja, "Detecting Faces in Images: A Survey ", IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI), vol. 24, no. 1, pp. 34-58, 2002.
10. P. Viola and M. Jones, "Rapid object detection using a boosted cascade of simple features," in Proc. of Conference on Computer Vision and Pattern Recognition, (Kauai, Hawaii), pp. 511-518, 2001.

[16] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

11. P. N. Belhumeur, J. P. Hespanha, and D. J. Kriegman, "Eigenfaces vs. Fisherfaces: Recognition using class specific linear projection," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 19, no. 7, pp. 711-720, Jul. 1997.
12. Daugman J (2003) "The importance of being random: Statistical principles of iris recognition." Pattern Recognition, 36(2), pp 279-291.
13. K. Bowyer, K. Hollingsworth, P. Flynn, " Image understanding for iris biometrics: A survey," Computer Vision and Image Understanding, Volume 110, Issue 2, Pages 281-307, May 2008.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Jain, Anil K., Ross, Arun A., Nandakumar, Karthik: Introduction to Biometrics, Springer 2011	1	
A. K. Jain, P. J. Flynn and A. Ross (Editors), "Handbook of Biometrics", Springer Publishers. ISBN: 978-0-387-71040-2.	1	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Prof. Nataša Hoić-Božić, PhD	
Name of the course	Design of e-learning environments	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The main objective of the course is to familiarise students with modern scientific research in the field of e-learning - learning and teaching supported by information technology. Within the course, students will be introduced to new digital technologies that can be used in education for learning and teaching, as well as to modern pedagogical and methodological theories and principles necessary for the successful implementation of e-learning.
Students interested in this area of research will be supported in choosing topics for their dissertation, further research, and completion of their doctoral studies.

1.2. Course enrolment requirements

No requirements

1.3. Expected learning outcomes

Upon completion of the course, students are expected to be able to:

O1. Identify key features and critically evaluate modern information and communication technologies for e-learning design and development (e.g. systems based on modern digital tools and digital games, adaptive hypermedia, recommender systems, MOOC).
O2. Identify key features, critically evaluate and discuss various pedagogical learning theories and didactic principles needed for e-learning, including: collaborative computer-supported learning, problem-based learning, use of courseware, personalized learning environments, social networking, mobile learning, game-based learning, gamification)
O3. Analyze, design, and evaluate e-learning environments according to technological and pedagogical requirements
O4. Think critically and analytically about technological and pedagogical models for e-learning
O5. Create scientific and professional papers in which they present their research findings.

1.4. Course content

- Application of modern digital technologies for e-learning (web-based learning systems, mobile communication learning systems, modern digital tools, MOOC, AR, VR, digital games).
- An overview of pedagogical and methodological theories and principles for successful implementation of e-learning.
- Learning theories and their relevance to the development of technologies and environments for e-learning.

• Computer-assisted collaborative and problem-based learning, assessment of knowledge using computers, use of educational software, personalized learning environments, social networks, learning through computer games, mobile learning. • Development of modern pedagogical and technological frameworks to improve the quality of learning and teaching and to promote inclusive education. • Development of e-learning models based on educational games, gamification, adaptive hypermedia educational recommender systems.

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☒ distance learning ☐ fieldwork	☒ individual assignments ☒ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Holenko Dlab, Martina; Hoic-Bozic, Natasa. Effectiveness of game development-based learning for acquiring programming skills in lower secondary education in Croatia // Education and Information Technologies, 26 (2021), 2; 18, 24 doi:10.1007/s10639-021-10471-w 2. Stančin, K.; Hoić-Božić, N.; Skočić Mihić, S. Using Digital Game-Based Learning for students with intellectual disabilities – A systematic literature review // Informatics in Education, 19 (2020), 2; 323-341 doi:10.15388/infedu.2020.15 3. Holenko Dlab, Martina; Botički, Ivica; Hoić- Božić, Nataša; Looi, Chee Kit. Exploring group interactions in synchronous mobile computer-supported learning activities // Computers & Education, 146 (2020), 103735; 2-18 doi:10.1016/j.compedu.2019.103735 4. Đurović, Gordan; Holenko Dlab, Martina; Hoić- Božić, Nataša. Research on the Use of Digital Tools by STEM Students at the University of Rijeka // TEM Journal, 8 (2019), 2; 636-641 doi:10.18421/TEM82-43 5. Hoić-Božić, Nataša; Lončarić, Darko; Holenko Dlab, Martina. Preparing Primary Junior Grade Teachers to Teach Computational Teaching: Experiences from the GLAT Project // Mathematics and Informatics, 62 (2019), 5; 487-499	

1.7. Student responsibilities
Students should actively participate in all course activities. They should conduct research that will be described in seminar paper.

1.8. Monitoring of student work[17]

Class attendance	1	Class participation		Seminar paper	2	Experimental work	1
Written exam		Oral exam		Essay		Research	2
Project		Continuous assessment		Report		Practical work	

[17] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Technology Enhanced Learning (Research Themes) / Erik Duval, Mike Sharples, Rosamund Sutherland (ur.). Springer, 2017.
2. Bates, A. W. (2019). Teaching in a Digital Age – Second Edition. Vancouver, B.C., Tony Bates Associates Ltd. Online: https://pressbooks.bccampus.ca/teachinginadigitalagev2/ (9.5.2020.)
3. Hoić-Božić, N., Holenko Dlab, M. (2021). „Uvod u e-učenje: obrazovni izazovi digitalnog doba“, Sveučilište u Rijeci, Odjel za informatiku, Rijeka. Online: https://repository.inf.uniri.hr/islandora/object/infri:768
4. Relevant papers published in scientific journals and conference proceedings.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

Relevant papers published in scientific journals and conference proceedings.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Bates, A. W. (2019). Teaching in a Digital Age – Second Edition. Vancouver, B.C., Tony Bates Associates Ltd.	online	
Hoić-Božić, N., Holenko Dlab, M. (2021). „Uvod u e-učenje: obrazovni izazovi digitalnog doba“, Sveučilište u Rijeci, Odjel za informatiku, Rijeka.	online	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Prof. Maja Matetić, PhD	
Name of the course	Data mining techniques and models	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

Data mining is based on the collection, management, research and action on large amounts of data and has become a source of competitive advantage for companies. The course provides an overview of advanced techniques of data mining for the development of descriptive and predictive models, which are the base for practical student work with the aim of gaining experience in working with modern tools in designing and performing data mining.

1.2. Course enrolment requirements

Programming and knowing the basics of probability and statistics.

1.3. Expected learning outcomes

Upon completion of the course, students are expected to be able to:

O1. Critically analyze the methodology of data mining and knowledge discovery with the aim of evaluating and selecting best practices in application to the problems of data mining in a specific context
O2. Research and evaluate key concepts and advanced techniques of data mining and assess when to apply them in practice
O3. Research and use existing approaches and technologies of data analysis in order to select strategies for processing data sets of different characteristics
O4. Perform advanced and complex research procedures for data mining in a given field of application with the aim of developing new knowledge, methods and tools.
O5. Apply their skills in applying machine learning in a specialized and useful area related to a large amount of data in everyday life (financial transactions, education systems, tourism, sensory data, etc.) with ethical and social responsibility of research.
O6. Analyze data sets from different domains with different tasks of predicting structured outputs, for example multi-target regression, multi-label classification, hierarchical multi-label classification.
O7. Apply, optimize, create and evaluate procedures in the task of predicting output for the selected relevant problem of doctoral research.

1.4. Course content

The content of the course consists of topics:

- Features engineering. Dimensionality reduction.
- Advanced classification methods. Regularization. Multiclass logistic regression. Ensembles.
- Shallow and deep neural networks. Explanatory machine learning algorithms.

<table>
<tr><td colspan="3">

- Advanced clustering methods and cluster evaluation procedures.
- Reinforcement learning.
- Mining of stream data. Concept drift detection. Stream based clustering. Learning of deep neural network over data stream. Sequential association analysis. Anomaly analysis.
- Special statistics of model evaluation. Model performance metrics. Procedures for preserving privacy in data analysis.
- Independent project task that includes solving the selected relevant problem within the doctoral research.

</td></tr>
<tr><td>1.5. Manner of instruction</td><td>☒ lectures
☒ seminars and workshops
☐ exercises
☒ distance learning
☐ fieldwork</td><td>☒ individual assignments
☐ multimedia and network
☐ laboratories
☒ mentorship
☐ other</td></tr>
<tr><td>1.6. Comments</td><td colspan="2">Relevant scientific papers by the course instructor:
1. Čumlievski, Nola; Brkić Bakarić, Marija; Matetić, Maja
A Smart Tourism Case Study: Classification of Accommodation Using Machine Learning Models Based on Accommodation Characteristics and Online Guest Reviews. // Electronics, 11 (2022), 6; 11060913, 23 doi:10.3390/electronics11060913 (međunarodna recenzija, članak, znanstveni)
2. Juric, Petar; Brkic Bakaric, Marija; Matetic, Maja
Detecting Students Gifted in Mathematics with Stream Mining and Concept Drift Based M-Learning Models Integrating Educational Computer Games. // International journal of emerging technologies in learning, 16 (2021), 12; 155-168 (međunarodna recenzija, članak, znanstveni)
3. Ljubobratović, Dejan; Vuković, Marko; Brkić Bakarić, Marija; Jemrić, Tomislav; Matetić, Maja
Utilization of Explainable Machine Learning Algorithms for Determination of Important Features in ‘Suncrest’ Peach Maturity Prediction. // Electronics, 10 (2021), 24; 3115, 18 doi:10.3390/electronics10243115 (međunarodna recenzija, članak, znanstveni)
4. Jurić, Petar; Brkić Bakarić, Marija; Matetić, Maja
Implementing M-Learning System for Learning Mathematics Through Computer Games and Applying Neural Networks for Content Similarity Analysis of an Integrated Social Network. // International Journal of Interactive Mobile Technologies, 15 (2021), 13; 145-161 doi:10.3991/ijim.v15i13.22185 (međunarodna recenzija, članak, znanstveni)
5. Zhang, Guoxiang; Fu, Qiqi; Fu, Zetian; Li, Xinxing; Matetić, Maja; Brkić Bakarić, Marija; Jemrić, Tomislav
A Comprehensive Peach Fruit Quality Evaluation Method for Grading and Consumption. // Applied Sciences-Basel, 10 (2020), 4; 1348, 11</td></tr>
</table>

	doi:10.3390/app10041348 (međunarodna recenzija, članak, znanstveni)

1.7. Student responsibilities

Students should actively participate in all course activities. It is the student's obligation to acquire basic knowledge of models and techniques of data mining. The student is expected to lead a research project with the aim of solving problems in the field of data mining using models and algorithms of data mining and to finally present the results of the research project. Continuous evaluation of student work will be performed on the basis of several seminars and workshops.

1.8. Monitoring of student work[18]

Class attendance	1	Class participation		Seminar paper	1	Experimental work	1
Written exam		Oral exam		Essay		Research	1
Project	1	Continuous assessment		Report		Practical work	1
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar. Introduction to data mining, 2nd ed., Pearson, 2019.
2. Kelleher, John D., Brian Mac Namee, and Aoife D'arcy. Fundamentals of machine learning for predictive data analytics: algorithms, worked examples, and case studies. MIT press, 2020.
3. Gareth, James, Witten Daniela, Hastie Trevor, and Tibshirani Robert. An introduction to statistical learning: with applications in R. Springer, 2021., dostupno na: https://www.statlearning.com/

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

- Shmueli, Galit, Peter C. Bruce, Inbal Yahav, Nitin R. Patel, and Kenneth C. Lichtendahl Jr. Data mining for business analytics: concepts, techniques, and applications in R. John Wiley & Sons, 2017.
- Ian Witten, Eibe Frank, Mark Hall. Data Mining: Practical Machine Learning Tools and Techniques, 4th ed., Morgan Kaufmann, 2016.
- Flach, Peter. Machine learning: the art and science of algorithms that make sense of data. Cambridge university press, 2012.
- Sutton, Richard S., and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018.
- Kuhn, Max, and Kjell Johnson. Applied predictive modeling. Vol. 26. New York: Springer, 2013.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

[18] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

Title	*Number of copies*	*Number of students*
Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar. Introduction to data mining, 2nd ed., Pearson, 2019.	*3*	
Kelleher, John D., Brian Mac Namee, and Aoife D'arcy. Fundamentals of machine learning for predictive data analytics: algorithms, worked examples, and case studies. MIT press, 2020.	*3*	
1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences		
Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).		

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General information		
Course instructor	Assist. Prof. Vanja Slavuj, PhD	
Name of the course	Computer assisted language learning	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The objective of the course is to present the students with the main issues surrounding the design and development of computer assisted language learning systems/tools and enable them to create a basic framework for the critical analysis and research of the capabilities of the existing systems/tools, as well as the possibilities for their improvement and further development based on contemporary scientific research results and modern digital technology.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students are expected to be able to:

O1. use field-specific terminology (terms, concepts) related to computer assisted language learning in scientific and expert contexts, emphasizing finer distinctions of meaning of similar/related concepts
O2. identify design and technical characteristics of the selected systems/tools for language learning, depending on their type and purpose
O3. evaluate approaches to user activity and user progress tracking in systems/tools for language learning, given the ways of collecting, organising, and visualising relevant data
O4. suggest own prototype or improvements to the existing system/tool for computer assisted language learning with regards to a specific language skill or area and the particular context of application
O5. examine learning effectiveness of using a system/tool for language learning in a particular educational context by applying appropriate research methods

1.4. Course content

The course includes the following topics:

- Basic concepts related to the field of computer assisted language learning (CALL), literature overview, state of the art
- Types and characteristics of computer assisted language learning systems, including intelligent tutoring systems, adaptive systems, multimedia systems, collaborative environments, mobile learning systems, and tools, as well as their design
- Users of systems for computer assisted language learning and their role in developmental and educational processes
- User activity and user progress tracking in systems for language learning, feedback formation and delivery

<table>
<tr><td colspan="3">

- Technologies in systems for computer assisted language learning – overview based on different language skills and the requirements for their implementation
- Analysis and evaluation of the existing language learning systems, design and (prototype) development of a new language learning system
- Research into the effectiveness of computer assisted language learning

</td></tr>
<tr><td>1.5. Manner of instruction</td><td>☒ lectures
☒ seminars and workshops
☐ exercises
☒ distance learning
☐ fieldwork</td><td>☒ individual assignments
☐ multimedia and network
☐ laboratories
☒ mentorship
☐ other</td></tr>
<tr><td>1.6. Comments</td><td colspan="2">Relevant scientific papers by the course instructor:
1. Slavuj, V., Načinović Prskalo, L., & Brkić Bakarić, M. (2021). Automatic generation of language exercises based on a universal methodology: An analysis of possibilities. Bulletin of the Transilvania University of Brasov, Series IV: Philology and Cultural Studies, 14(2), 29-48.
2. Slavuj, V. (2020). Methodology for developing learning materials for a web-based adaptive language learning system. Proceedings of the 12th Annual International Conference on Education and New Learning Technologies (EDULEARN20), online, 3810-3819.
3. Slavuj, V., Kovačić, B., & Jugo, I. (2019). User evaluation of an adaptive language learning system prototype. Proceedings of the 42nd International Convention on Information, Communication and Electronic Technology (MIPRO 2019), Croatia, 873-878.
4. Slavuj, V., Kovačić, B., & Jugo, I. (2019). Web-based adaptive system for English language learning [poster/technology showcase]. CALICO Conference 2019, Canada.
5. Slavuj, V., Meštrović, A., & Kovačić, B. (2017). Adaptivity in educational systems for language learning: a review. Computer Assisted Language Learning, 30, 64-90.</td></tr>
<tr><td colspan="3">1.7. Student responsibilities</td></tr>
<tr><td colspan="3">Students should actively participate in all course activities. Student responsibilities for this course are as follows:

- Regularly follow course activities within the learning management system and attend classes taking place in the form of lectures.
- Write a research seminar paper on a given topic within the field and present it to the course instructor as part of the final exam.

</td></tr>
<tr><td colspan="3">1.8. Monitoring of student work[19]</td></tr>
</table>

Class attendance	1	Class participation		Seminar paper	2	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project		Continuous assessment		Report		Practical work	
Portfolio							

[19] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Colpaert, J., & Stockwell, G. (Eds.). (2022). *Smart CALL: Personalization, contextualization, & socialization*. Castledown Publishers.
2. Farr, F., & Murray, L. (Eds.). (2020). *The Routledge handbook of language learning and technology*. Routledge.
3. Stockwell, G. (Ed.). (2018). *Computer-assisted language learning: Diversity in research and practice*. Cambridge University Press.
4. A selection of relevant scientific and expert papers which will be prepared in advance and made available in the learning management system.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Beatty, K. (2012). *Teaching & researching: Computer-assisted language learning* (2nd ed.). Routledge.
2. Claypole, M. (2020). *Artificial intelligence in autonomous language learning: An expert systems approach to computer assisted EFL self stud*y (3rd ed.). LinguaBooks.
3. Gimeno Sanz, A., Levy, M., Blin, F., & Barr, D. (Eds.). (2017). *WorldCALL: Sustainability and computer-assisted language learning*. Bloomsbury Academic.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Computer-assisted language learning: Diversity in research and practice	1	
The Routledge handbook of language learning and technology	currently being acquired	
Smart CALL: Personalization, contextualization, & socialization	currently being acquired	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Prof. Patrizia Poščić, PhD	
Name of the course	Selected Topics in Databases	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The main objective of the course is to familiarise students with the theory of databases and to provide an overview of current research in the field of databases. It also aims to explore the characteristics of different types of databases (distributed, non-relational, multimedia, geographic, etc.) and to encourage students to further research in the field of data storage and databases.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

Upon completion of all obligations expected in the course, students should be able to:

O1. Compare concepts and techniques of different types of databases
O2. Critically analyze various security aspects of databases
O3. Recommend database technologies for a specific application domain
O4. Review key and research problems of different types of databases (relational and non-relational)
O5. Analyze relevant scientific and professional publications and write scientific and professional papers in which they present their research results

1.4. Course content

- Overview of relational database research:
  Database concepts. Relational data model. Relational algebra. Operations in the relational model. Integrity rules in a relational data model. Elements of dependency theory. Normalization. Physical organization, B-trees, R-trees. Database management system. Data modeling in a database. Notations and methodologies for database modeling. Stored procedures. Triggers. Transactions.
- Overview of database administration and security research:
  Database administration. Database security. Database recovery after failure. Database attacks. Protection against unauthorized access. Query optimization in a relational database. Client-server architecture. Different indexing techniques.
- Overview of research in the field of different database organizations in a database:
  Distributed databases. Object databases. Multimedia databases. Geographical databases. Non-relational databases. Ontologies. Large-volume databases.

1.5. Manner of instruction		
	☒ lectures	☒ individual assignments
	☒ seminars and workshops	☐ multimedia and network
	☐ exercises	☐ laboratories
	☐ distance learning	☒ mentorship

	☐ fieldwork	☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Ilijanic, Martina; Jaksic, Danijela; Poscic, Patrizia. Intrusion detection using data mining – an overview of methods and their success // MIPRO 2022 Proceedings / Skala, Karolj (ur.). Rijeka: Croatian Society for Information and Communication Technology, Electronics and Microelectronics - MIPRO, 2022. 2. Stančin, Kristian; Poščić Patrizia; Jakšić Danijela. Ontologies in education – state of the art // Education and information technologies, 25 (2020). 3. Šuman, Sabrina; Poščić, Patrizia; Gligora Marković, Maja. Big Data Management Challenges // International journal of advanced trends in computer science and engineering, 9 (2020), 1; 717-723 doi:10.30534/ijatcse/2020/102912020 4. Crnjak, Anamarija; Jaksic, Danijela; Poscic, Patrizia. Query Optimization in Relational Database Systems // Proceedings of 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics - MIPRO / Skala, Karolj (ur.). Rijeka: Croatian Society for Information and Communication Technology, Electronics and Microelectronics - MIPRO, 2019. 5. Puja, Ivana; Poscic, Patrizia; Jaksic, Danijela. Overview and Comparison of Several Relational Database Modelling Metodologies and Notations // Proceedings of 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics - MIPRO / Skala, Karolj (ur.). Rijeka: Croatian Society for Information and Communication Technology, Electronics and Microelectronics - MIPRO, 2019. doi:10.23919/MIPRO.2019.8756667	

1.7. Student responsibilities

Students should actively participate in all course activities, which include, but are not limited to: reading and studying current literature, researching Internet resources, libraries and scientific databases, and writing a seminar paper in the form of scientific research paper (article).

1.8. Monitoring of student work[20]

Class attendance	1	Class participation		Seminar paper	2,5	Experimental work	
Written exam		Oral exam		Essay		Research	2,5
Project		Continuous assessment		Report		Practical work	
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar

[20] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

paper, which must be written in the form of a scientific paper. In this way, the seminar paper will serve as the basis for the publication of a scientific paper that can later be published at a conference or in a journal, in consultation with the student, course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. R. Elmasri, S. B. Navathe (2017). Fundamentals of Database Systems: seventh edition. Pearson
2. C. S. Mullins (2013). Database Administration: the Complete Guide to DBA Practices and Procedures. Addison-Wesley
3. J. Hoffer, R. Venkataraman, H. Topi (2019). Modern Database Management. Thirteenth edition. Pearson

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. M. Hamer (2017). Relational Database Practices: Bridging the Gap between the theory of Database Design and Real-World Practices.
2. M. T. Özsu, P. Valduriez (2019). Principles of Distributed Database Systems. Fourth edition. Springer
3. S. Balamurugan, S. Charanyaa (2014). Principles of Database Security. OmniScriptu
4. A. Singh, R. Shekhar (2022). Graph Database Modeling.
5. Relevant papers published in scientific journals and conference proceedings.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
C. S. Mullins (2013). Database Administration: the Complete Guide to DBA Practices and Procedures. Addison-Wesley	1	
J. Hoffer, R. Venkataraman, H. Topi (2019). Modern Database Management. Thirteenth edition. Pearson	1	
M. T. Özsu, P. Valduriez (2019). Principles of Distributed Database Systems. Fourth edition. Springer	1	
S. Balamurugan, S. Charanyaa (2014). Principles of Database Security. OmniScriptu	1	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Assist. Prof. Martina Ašenbrener Katić, PhD	
Name of the course	Conceptual Modeling of Complex Systems	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The goal of the course is to familiarize students with modern trends related to recognizing and understanding complex systems, as well as methods, techniques, and tools needed to model these systems. Students will become familiar with approaches to the problem domain at a higher level of abstraction (metamodeling) that will enable them to use a higher level of abstraction in the development of organizational and information systems, particularly in describing the problem domain, which is interdisciplinary in nature. This knowledge helps them to choose the appropriate methodology depending on the systems they are modeling, in order to analyze the systems and find good solutions for their functioning. Metamodeling gives students a new approach to describing problem domains and a new approach to scientific work and research in general.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students are expected to be able to:

O1. rethinking key problems and research issues of conceptual models of complex systems
O2. identify key features and critically assess current trends related to the recognition and understanding of complex systems and the methods, techniques, and tools required to model them
O3. critically analyze various models and metamodels in the development of organizational and information systems
O4. create a metamodel for the selected problem domain
O5. analyze relevant scientific and professional publications and preparation of scientific and professional papers presenting research results.

1.4. Course content

- Domain and definition of complex systems, methods, concepts and examples. Evolution: from cybernetics to artificial intelligence.
- Step-by-step descriptions of the system, effects of fine changes at lower levels on behavior at higher levels of the system, behavior patterns, multiple steady states, degree of complexity, behavior of the system in relation to the environment; dependence, interdependence, and stability of parts; rule 7 + -2, relationships between different system representations, information selection, composition.
- Importance of metamodeling - model, modeling, metamodel, metamodeling. Ontology and metamodeling. Metamodeling vs semantic modeling. Modeling problem domains. Problem domain

knowledge set and its meaning. The role of metamodeling in domain standardization. Different semantics of the same metamodels.

- Structural methods in the analysis and design of information systems. Models as results of structural modeling. Data flow diagram, activity flow diagram, ER model, relational model. Concepts of metamodels of structural methods. Connecting metamodels of structural methods by common concepts. Construction of a unique metamodel of structural methodology. Agile development processes. Model-driven development. Flexible development, software reengineering, computer-aided software engineering. Methods of strategic planning of information systems.
- Knowledge treasure as a repository of data generated during information systems development. Treasure data, metadata. Metamodels as conceptual schemas of treasuries. Independence of treasury metamodels from implementation technology. Metamodel as conceptual rather than physical layer. Translation of a conceptual metamodel to a physical model is a distinct process. Reverse engineering from a physical model to a conceptual metamodel. The importance of metamodels in integrating the data part of information systems. Presentation of knowledge. Reasoning of knowledge.
- Practical examples of metamodels (metamodel ERA, RM; metamodel DTP; metamodel of English and Croatian written language - NOK; metamodel of codebooks, non-standard documents; metamodel of ERP) and presentation of implementation of these metamodels in relational databases.
- Defining research goals and hypotheses, researching research methodology: collecting data on the structure, behavior and dynamics of the system, selecting an appropriate methodology for developing a conceptual and computer model, conducting experiments, analyzing the results and proposing solutions.

1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☐ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Ašenbrener Katić, Martina; Čandrlić, Sanja; Pavlić, Mile Nouns in the Conceptual Framework "Node of Knowledge". // Tehnički vjesnik : znanstveno-stručni časopis tehničkih fakulteta Sveučilišta u Osijeku, 28 (2021), 6; 2088-2093 2. Čandrlić, Sanja; Ašenbrener Katić, Martina; Pavlić, Mile A system for transformation of sentences from the enriched formalized Node of Knowledge record into relational database. // Expert Systems with Applications, 115 (2019), 442-464 doi:10.1016/j.eswa.2018.07.021 3. Rauker Koch, Marina; Čandrlić, Sanja; Ašenbrener Katić, Martina Automation of the conversion of natural language to formalized node of knowledge record. // Zbornik Veleučilišta u Rijeci / Journal of the Polytechnic of Rijeka, 10 (2022), 1; 57-71 doi:10.31784/zvr.10.1.4 4. Čandrlić, Sanja; Pavlić, Mile; Ašenbrener Katić, Martina Information System Design and Development and Project-Based Learning. // Proceedings of the 12th International Conference on Computer	

Supported Education / Lane, H. Chad ; Zvacek, Susan ; Uhomoibhi, James (ur.). Portugal: SCITEPRESS, 2020. str. 404-411
5. Čandrlić, Sanja; Ašenbrener Katić, Martina; Jakupović, Alen Preliminary Multi-lingual Evaluation of a Question Answering System Based on the Node of Knowledge Method. // Lecture Notes in Networks and Systems / Arai, Kohei ; Bhatia, Rahul (ur.). San Francisco, SAD: Springer, 2020. str. 998-1009 doi:10.1007/978-3-030-12388-8_69

1.7. Student responsibilities

Students should actively participate in all course activities such as, among others: reading and studying current literature, researching Internet sources, libraries, and scientific databases, and writing a seminar paper in the form of a scholarly research (article).

1.8. Monitoring of student work[21]

Class attendance	1	Class participation		Seminar paper	2	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project		Continuous assessment		Report		Practical work	1
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. N. Boccara, Modeling Complex Systems, Springer, 2010.
2. J. Awrejcewicz and Miguel AF Sanjuán. "Introduction to Focus Issue: Recent advances in modeling complex systems: Theory and applications." Chaos: An Interdisciplinary Journal of Nonlinear Science 31.7 (2021): 070401.
3. S. Thurner, R. Hanel, and P. Klimek. Introduction to the theory of complex systems. Oxford University Press, 2018.
4. Sunny Y. Auyang, Foundations of Complex-system Theories In Economics, Evolutionary Biology, and Statistical Physics, Cambridge University Press, 1999
5. T. Clark, A. Evans, P. Sammut, J. Willans, Applied Metamodelling: A Foundation for Language Driven Development, Xactim 2004.
6. Gregory G. Nordstrom, Metamodeling Rapid Design and Evolution of Domain-Specific Modeling Environments, Dissertation, Faculty of the Graduate School of Vanderbilt University

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Relevant papers published in scientific journals and conference proceedings
2. Griffiths, Carol, and Adem Soruç. Individual differences in language learning: A complex systems theory perspective. Springer Nature, 2020.

[21] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

3. D. Marco, M. Jennings, Universal Meta Data Model, Wiley 2004.

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Modeling Complex Systems	online	
Introduction to Focus Issue: Recent advances in modeling complex systems: Theory and applications	online	
Introduction to the theory of complex systems	currently being acquired	
Foundations of Complex-system Theories In Economics, Evolutionary Biology, and Statistical Physics	online	
Applied Metamodelling: A Foundation for Language Driven Development	online	
Metamodeling Rapid Design and Evolution of Domain-Specific Modeling Environments	online	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).

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General information		
Course instructor	Assist. Prof. Vedran Miletić, PhD	
Name of the course	Computational biochemistry and biophysics	
Study programme	University Postgraduate Doctoral Study Informatics	
Status of the course	elective	
Year of study	1./2.	
ECTS credits and manner of instruction	ECTS credits	6
	Number of class hours (L+E+S)	15+0+15

1. COURSE DESCRIPTION

1.1. Course objectives

The human genome project began in the 1990s to identify and sequence all human genes. As early as the early 2000s, a large amount of data on genes encoding proteins was publicly available for research. These data and the information derived from them, the availability of ever faster supercomputers, and the advancement of methods used in computational biochemistry and biophysics in the next two decades enabled the rapid development of a branch of molecular biology called structural biology, which links the structure and function of biological macromolecules proteins, nucleic acids, and membranes.
The objective of the course is to acquire knowledge about data structures and algorithms that form the basis of modern software in the field of computational biochemistry and biophysics and the possibilities of application and procedures for further development of existing software by scientific research needs. There is a specific focus on data structures and algorithms that enable the execution of this software on exascalar supercomputers. The objective of the course is also to get acquainted with current scientific research issues in this area and approaches that answer these questions.

1.2. Course enrolment requirements

There are no enrolment requirements.

1.3. Expected learning outcomes

After fulfilling all the obligations anticipated by the course, students are expected to be able to:

O1. Propose an improvement of an existing algorithm or method in the molecular dynamics simulation.
O2. Predict the performance of molecular dynamics simulators on supercomputers and in cloud computing.
O3. Design an extension of the molecular dynamics simulator with a new feature.
O4. Develop a new feature of the molecular dynamics simulator.

1.4. Course content

The course includes the following topics:

- Historical development of computational biochemistry and biophysics. Implementation of atom models within molecular and quantum mechanics.
- Molecular dynamics simulation. Algorithms, data structures, and file formats for storing parameters, molecular structures, and simulation results. Implementation of force fields and interaction functions. Parallelization methods and software adaptation for performing molecular dynamics simulation on heterogeneous computer systems.
- Implementation of methods based on molecular dynamics: calculation of free energy, non-equilibrium withdrawal, adaptive bias, imposed rotation, simulation of uniform and shear flow, and interactive molecular dynamics.

• Performing molecular dynamics simulation in cloud computing and on supercomputers. Analysis and visualization of simulation results. Customizations of software for performing simulation on exascale supercomputers. • Applications of machine learning in computer biochemistry and biophysics.		
1.5. Manner of instruction	☒ lectures ☒ seminars and workshops ☐ exercises ☒ distance learning ☐ fieldwork	☒ individual assignments ☐ multimedia and network ☐ laboratories ☒ mentorship ☐ other
1.6. Comments	Relevant scientific papers by the course instructor: 1. Svedružić, Ž. M, Vrbnjak, K., Martinović, M. & Miletić, V. Structural Analysis of the Simultaneous Activation and Inhibition of γ-Secretase Activity in the Development of Drugs for Alzheimer's Disease. Pharmaceutics 13(4), 514 (2021). doi:10.3390/pharmaceutics13040514 (WoS-SCIE, Q1 (2020), JIF: 6.321 (2020); times cited: 2) 2. Miletić, V., Ašenbrener Katić, M. & Svedružić, Ž. High-throughput Virtual Screening Web Service Development for SARS-CoV-2 Drug Design. in 2020 43rd International Convention on Information, Communication, and Electronic Technology (MIPRO), 371–376 (2020). doi:10.23919/MIPRO48935.2020.9245082 3. Herrera-Rodríguez, A., Miletić, V., Aponte-Santamaría, C. & Gräter, F. Molecular dynamics simulations of molecules in uniform flow. Biophys. J. 116(6), 621–632 (2019). doi:10.1016/j.bpj.2018.12.025 (WoS-SCIE, Q1, JIF: 3.854; times cited: 5) 4. Franz, F., Aponte-Santamaría, C., Daday, C., Miletić, V. & Gräter, F. Stability of Biological Membranes upon Mechanical Indentation. J. Phys. Chem. B 122(28), 7073–7079 (2018). doi:10.1021/acs.jpcb.8b01861 (WoS-SCIE, Q2, JIF: 2.923; times cited: 2) 5. Miletić, V., Odorčić, I., Nikolić, P. & Svedružić, Ž. M. In silico design of the first DNA-independent mechanism-based inhibitor of mammalian DNA methyltransferase Dnmt1. PLOS ONE 12(4), e0174410 (2017). doi:10.1371/journal.pone.0174410 (WoS-SCIE, Q1, JIF: 2.766; times cited: 14)	
1.7. Student responsibilities		
Students should actively participate in all course activities.		
1.8. Monitoring of student work[22]		

Class attendance	1	Class participation		Seminar paper	1	Experimental work	
Written exam		Oral exam		Essay		Research	2
Project		Continuous assessment		Report		Practical work	2
Portfolio							

1.9. Assessment of learning outcomes in class and at the final exam (procedure and examples)

[22] IMPORTANT: Enter the appropriate proportion of ECTS credits for each activity so that the total number of credits equals the ECTS value of the course. Use empty fields for additional activities.

Learning outcomes are assessed through scientific research in which the student applies theoretical and practical knowledge of the subject. The student should describe the results of the research in a seminar paper, which can also be written in the form of a scientific paper. In this way, the seminar paper can serve as the basis for the publication of a scientific paper that will be published at a conference or in a journal in consultation with the course instructor and the student's mentor.

1.10. Mandatory literature (at the time of submission of study programme proposal)

1. Advances in Molecular Simulation. (MDPI, 2021). doi:10.3390/books978-3-0365-2711-6. Available online: www.mdpi.com/books/pdfview/book/4780
2. Molecular Dynamics Simulation. (MDPI, 2014). doi:10.3390/books978-3-906980-66-9. Available online: www.mdpi.com/books/pdfview/book/75
3. Garmon, A. Accelerated Molecular Dynamics for the Exascale. (Clemson Libraries, 2020). Available online: www.tigerprints.clemson.edu/all_dissertations/2716
4. GROMACS Reference Manual, User Guide, and Developer Guide. Available online: manual.gromacs.org
5. Content prepared for learning through a learning system.

1.11. Optional/additional literature (at the time of submission of the study programme proposal)

1. Computational Biochemistry and Biophysics. (CRC Press, 2001). doi:10.1201/9780203903827.
2. Frenkel, D. & Smit, B. Understanding Molecular Simulation: From Algorithms to Applications. (Academic Press, 2001).
3. Cramer, C. J. Essentials of Computational Chemistry: Theories and Models. (Wiley, 2004).
4. Jensen, F. Introduction to Computational Chemistry. (John Wiley & Sons, 2017).
5. Griebel, M., Knapek, S. & Zumbusch, G. Numerical Simulation in Molecular Dynamics: Numerics, Algorithms, Parallelization, Applications. (Springer, 2010).
6. Todd, B. D. & Daivis, P. J. Nonequilibrium Molecular Dynamics: Theory, Algorithms and Applications. (Cambridge University Press, 2017).
7. OpenMM User Guide and Developer Guide. Dostupno online: openmm.org/documentation
8. LAMMPS User Guide and Programmer Guide. Dostupno online: docs.lammps.org/Manual.html

1.12. Number of assigned reading copies in relation to the number of students currently attending the course

Title	*Number of copies*	*Number of students*
Advances in Molecular Simulation	Available online	
Molecular Dynamics Simulation	Available online	
Accelerated Molecular Dynamics for the Exascale	Available online	
GROMACS Reference Manual, User Guide, and Developer Guide	Available online	

1.13. Quality monitoring methods that ensure the acquisition of exit knowledge, skills and competences

Regular evaluation is planned in order to ensure and continuously improve the quality of teaching and study programs (as part of the activities of the Quality Assurance Committee of the Faculty of Informatics and Digital Technologies).