ALFA BK UNIVERSITY

Faculty of Mathematics and Computer Sciences

(ALFABK-FMCS)

STUDY PROGRAMME

Computer Science

DOCTORAL ACADEMIC STUDIES

Course:	**Methods of Scientific Research**
Course id:	
Number of ECTS: 10	
Teacher:	**Marija Paunović**
Course status:	Mandatory first year, first semester

Precondition courses: There are no conditions, but knowledge from the subject Research Methods from the Master Academic Studies is desirable.

Educational goal

Adoption of theoretical knowledge and algorithmic approaches in the implementation of the process of scientific research, as well as in the application of scientific research methods in (non) technical scientific fields. To enable students for successful writing of scientific papers and doctoral dissertations.

Educational outcomes (acquired knowledge):

- Ability to identify the task of independent research, set research goals, initial hypotheses and scientific methods
- Ability of understanding various scientific methods witch was used in scientific literature
- Ability of successful writing of scientific paper in area of interests
- Ability of successful creating and ending of doctoral dissertation.

Course content/structure

1. On the nature of scientific research and knowledge: Algorithms of methods and techniques of research work.
2. General characteristics of literature analysis: Fundamental works in a scientific field, up to modern research results.
3. Scientific statements and scientific arguments: Methodological aspects.
4. Algorithms of methods and techniques of analysis of (non) numerical data in setting the solution of the identified scientific problem.
5. Basics of statistical procedures of scientific analysis of experimental data.
6. Writing a scientific paper: Structure, content, composition, conclusion, references.
7. Subject and problem of research, research hypotheses, scientific method and research goals in the work on the doctoral dissertation: Critical review of known solutions, comparative analysis of used algorithms and crystal clear conclusions in the presentation of research results.

Literature

J.Richie and J.Lewis, Qualitative Research Practice, Sage Publications, 2003.
o A.Strauss and J.Corbin, Basics of Qualitative Research Groundid Theory Procedures and Techniques, Sage Publications, 1999.
o The New Guide To Writing Research Papers (1999) Monroe Community Colege, Retrieved February 1, 2004, from http://www.monroecc.edu/depts/library/cover.htm.
o G. Post and D. Anderson, Management Information Systems, Solving Business Problems with Information Technology, New York:McGraw-Hill, 2003.
o The Harvard Style of referencing published material, Including electronic information (2004) [Internet], Learning Support Services, Leeds Metropolitan University, 4th edition, July, Retrieved December 12, 2004, from http://www.leedsmet.ac.uk/lskills.

Number of active teaching classes	Lectures: 3	Study research work: 3

Teaching methods

Lectures. Consultations with students. Home work. Seminar paper.

Knowledge evaluation (maximum 100 points)

Seminar paper 50 points and oral exam with defence of seminar paper 50 points.

Course:	**Machine learning**
Course id:	
Number of ECTS: 10	
Teacher:	Dejan Đukić
Course status:	Mandatory, first year, first semester

Precondition courses: There are no requirements, but knowledge from the subjects Artificial Intelligence and Computer Vision from Basic Academic Studies is desirable.

Educational goal

The aim of the course is to present methods for processing data sets that are large, noisy, and multidimensional, for example: support vector network method, recursive method of majority decision-making (boosting), method of content distribution model (general mixture model), methods statistical regression and linear discriminants (LDA), nonlinear regression methods, probabilistic-Bayesian methods, etc.

Educational outcomes (acquired knowledge):

Upon successful completion of the course, the student will be able to: 1.choose a machine learning method that corresponds to a given problem, 2. design and apply a machine learning method for data processing, 3. evaluate the success or performance of the chosen machine learning method.

Course content/structure

Theory classes:

Vector spaces, dimensionality, functions, mappings, projections; differential and difference equations; statistical interpolation methods, optimization of model parameters; support vector network method, recursive method of majority decision-making (boosting), method of content distribution (general mixture model), methods of statistical regression and linear discriminants (LDA), methods of nonlinear regression, probabilistic-Bayesian methods of discrimination; shape recognition.

Practical classes:

Computational exercises. Laboratory exercises. Research project.

Literature

- Vapnik V.: The Nature of Statistical Learning Theory (Information Science and Statistics) Springer; 2nd edition, 1999.
- Dayan & Abbott : Theoretical Neuroscience, MIT Press 2001.
- David J. C. MacKay : Information Theory, Inference and Learning Algorithms : Cambridge University Press, 2003.
- Trevor Hastie, Robert Tibshirani, Jerome Friedman : The Elements of Statistical Learning: Data Mining, Inference, and Prediction : Springer; 2nd ed. 2009.

Number of active teaching classes (weekly)	Lectures: 3	Study research work: 4

Teaching methods

Lectures and / or mentoring, consultations, laboratory exercises, homework assignments, preparation of a seminar paper, research project.

Knowledge evaluation (maximum 100 points)

Final exam - 60 points, pre-exam obligations - 40 points (homework, seminar work, participation in projects).

Course:	**Cloud computing and virtualization**	
Course id:		
Number of ECTS: 10		
Teacher:	Aleksandar Zakić	
Course status:	Mandatory, first year, first semester	
Precondition courses: none		
Educational goal Introduction to concepts and techniques of cloud computing application using virtualization and distributed process processing and data warehousing. Topics include virtualization, distributed network storage, distributed computing, cloud models (IAAS, PAAS, and SAAS), and cloud security.		
Educational outcomes (acquired knowledge): Understanding the major technologies enabled by cloud computing, including virtualization, computer networks, distributed processing and storage, network and data security, service-oriented architecture, and web applications. By managing virtual machines. Understanding security challenges in applying and working with different cloud computing architectures.		
Course content/structure 1. Basic concepts of cloud computing and virtualization 2. Virtualization technologies 3. Cloud computing architecture 4. Development and programming of applications and services using cloud computing and virtualization 5. Different models of cloud computing services (IAAS, PAAS and SAAS)		
Literature ● Dan C. Marinescu, Cloud Comupting – Theory and Practice, 2018 ● Dac-Nhuong Le Raghvendra Kumar Gia Nhu Nguyen Jyotir Moy Chatterjee, Cloud Computing and Virtualization, Scrivener Publishing LLC, 2018		
Number of active teaching classes (weekly)	Lectures: 4	Study research work: 3
Teaching methods Lectures and / or mentoring, consultations, laboratory exercises, homework assignments, preparation of seminar paper.		
Knowledge evaluation (maximum 100 points)		
Final exam - 60 points, pre-exam obligations - 40 points (homework, seminar work, participation in projects).		

Course:	**Combinatorial algebra algorithms**
Course id:	
Number of ECTS: 10	
Teacher:	Duško Bogdanić
Course status:	Elective, first year, second semester

Precondition courses: none

Educational goal

The aim of this course is to introduce students to the basic combinatorial algorithms for calculating various algebraic invariants. During the course, we will study the design of these algorithms, efficiency and complexity, as well as implementation in programming languages.

Educational outcomes (acquired knowledge):

After attending the course, the student will be ready to:

- understands basic concepts related to discrete structures of modern algebra,
- gets acquainted with classical algorithms for calculating various invariants of algebraic structures,
- understands the complexity of classical combinatorial algorithms,
- designs and implements combinatorial algorithms,
- applies learned concepts in other areas of science and industry.

Course content/structure

Discrete algebraic structures, algorithms for computing with matrices, optimization of algorithms in special cases, algorithms for symmetric group representations, basics of GAP and MAGMA software systems.

Literature

- K. Geddes, S. Czapor, G. Labahn, Algorithms for Computer Algebra, Springer, 1992.
- J. Gathen, J. Gerhard, Modern Computer Algebra, Cambridge University Press, 2013.
- GAP manuals, https://www.gap-system.org/Doc/manuals.html

Number of active teaching classes (weekly)	Lectures: 2	Study research work: 2

Teaching methods

Classes are conducted through lectures and / or mentoring, consultations, seminars, study and research work. Within the study and research work, complex tasks are solved, so that the candidates can understand the given material, which they could later apply in practice. Special attention is paid to the implementation of algorithms in GAP and MAGMA software packages.

Knowledge evaluation (maximum 100 points)

Research work: 40; Oral exam: 60 points.

Course: **Course id:** **Number of ECTS: 10**	**Logic in computing**
Teacher:	Dragiša Žunić
Course status:	Elective, first year, second semester

Precondition courses: none

Educational goal

Acquisition of advanced knowledge of formal logic, logical concepts as the basis of fundamental informatics, as well as initial involvement in scientific research.

Educational outcomes (acquired knowledge):

Knowledge of basic concepts and results from mathematical logic, development of abstract thinking in the context of logic as the basis of some basic aspects of informatics. Involvement in

Course content/structure

1. Basic concepts and basic logics (classical, intuitionistic, linear).
2. Formalisms for representing logics, and formal systems of corresponding logics (statement calculus, predicate calculus)
3. Axiomatic system (Hilbert), natural deduction calculus and sequential calculus (Gencen, Pravic)
4. Computational interpretations of logic - lambda calculations. Accounts without types
5. Basic accounts with types; Curry Howard correspondence (formulas-types, proofs-terms, normalization-calculation)
6. Basic concepts from the semantics of logical systems.

Literature

- B. Pierce, Types and programming languages, MIT Press, 2002.
- Z. Ognjanović i S. Gilezan, Uvod u teorijsko računarstvo, Fakultet Tehničkih Nauka, Novi Sad, 2014.
- Z. Petrić, Uvod u matematičku logiku (skripta), Matematički Institut SANU, 2016.
- R. Harper, Practical foundations for programming languages, Cambridge University Press, 2016.
- J. Y. Girard, Linear logic, in Theoretical Computer Science Volume 50, Issue 1, 1987, Pages 1-101.

Number of active teaching classes (weekly)	Lectures: 3	Study research work: 3

Teaching methods

The lectures present the theoretical part of the material, followed by examples for easier understanding. Where possible, practical implementation is demonstrated as an additional illustration. The student independently studies a part of the literature (research), which he discusses with the teacher at the consultations.

Knowledge evaluation (maximum 100 points)

Final exam - 60 points, pre-exam obligations - 40 points (homework, seminar work, participation in projects).

Course:	**Selected Chapters in Coding Theory**	
Course id.		
Number of ECTS: 10		
Teacher:	**Ivan D. Pavkov**	
Course status:	Elective	
Precondition courses: None		
Educational goal Acquisition of advanced knowledge of information and coding theory in communication systems and principles of coding and decoding.		
Educational outcomes (acquired knowledge): Upon completion of the course, students are capable to understand the professional and scientific literature in which information theory and coding are studied and are able to make a personal contribution to the investigation of this subject.		
Course content/structure Motivation and history of coding theory. Basic concepts of coding theory. The concept of communication channel. Noisy communication channel. The notion of redundancy. Shannon communication system (encoder, communication channel, decoder). Properties of code function. Block codes. Code space. Code length. Codeword. Distance of codewords. Good code. Shannon's theorem on the existence of good code. Linear codes. Distance of codewords of linear code. Construction of linear codes. Linear code generator matrix. Coding of linear codes. Decoding of linear codes. Dual and self-dual code. Syndromic decoding. Hamming code. Encoding and decoding of Hamming codes. Cyclic codes, definition and properties. Decoding of cyclic codes. Reed-Solomon codes. Decoding of some classes of Reed-Solomon codes using factorization of bivariate polynomials.		
Literature 1. Hall J. I. (2010), *Notes on Coding Theory*, Department of Mathematics Michigan State University 2. Huffman W. C., Pless V. (2003), *Fundametals of Error Correcting Codes*, Cambridge University Press, New York 3. van Lint J. H. (1992), *Introduction to Coding Theory*, Springer-Verlag Berlin Heidelberg		
Number of active teaching classes (weekly)	Lectures: 4	Practical classes: 3
Teaching methods Classes are conducted frontally, realized through lectures and mentoring, consultations and study and research work.		
Knowledge evaluation (maximum 100 points)		
Pre-examination obligations: 40; Final exam: 60.		

Course:	**Applied group theory**
Course id:	
Number of ECTS: 6	
Teacher:	Duško Bogdanić
Course status:	Elective, first year, second semester

Precondition courses: Mathematical knowledge from the previous level of study

Educational goal

The aim of the course is to acquaint students with various applications of modern group theory, from application in cryptography / computing, to application in the study of the phenomenon of symmetry in chemistry. As part of this course, GAP and MAGMA software packages for solving computational problems in group theory will be covered. Special attention will be paid to problems from group theory that originate from cryptography.

Educational outcomes (acquired knowledge):

After attending the course, the student will be ready to:

- understands basic concepts and methods from classical group theory,
- to get acquainted with the applications of groups in cryptography (eg to understand the basic applications in asymmetric cryptography),
- to get acquainted with the applications of groups in solving the problem of classification of crystal structure in chemistry,
- to master the basic and advanced concepts of GAP and MAGMA software packages,
- to be able to develop advanced programs for computing various invariants of finite groups.

Course content/structure

Basic concepts and methods of group theory, basic cryptographic algorithms based on factorization of natural numbers, symmetric groups and their application in chemistry (crystal structure), software packages GAP and MAGMA.

Literature

- J. Rose, A Course on Group Theory, Cambridge University Press, 2012.
- J. Buchmann, Introduction to Cryptography, Springer, 2013.
- D. Bishop, Group Theory and Chemistry, The Clarendon Press, Oxford, 1993.

Number of active teaching classes (weekly)	Lectures: 4	Study research work: 3

Teaching methods

Classes are conducted through lectures and / or mentoring, consultations, seminars, study and research work. Within the study and research work, complex tasks are solved, so that the candidates can understand the given material, which they could later apply in practice. Special attention is paid to solving examples from cryptography.

Knowledge evaluation (maximum 100 points)

Research work: 40; Oral exam: 60 points

Course: **Course id:** **Number of ECTS: 10**	**Logical frameworks, modeling and reasoning about systems**	
Teacher:	Dragiša Žunić	
Course status:	Elective, first year, second semester	
Precondition courses: none		
Educational goal Acquisition of fundamental knowledge in the domain of formal reasoning. Ability to model the system using logical formal systems, which at the same time allow reasoning about the properties of the observed object system. Developing abstract thinking in the complex domain of formal reasoning.		
Educational outcomes (acquired knowledge): Knowledge of relevant concepts and results from logic and formal reasoning; developed abstract thinking in the context of automatic reasoning and verification, the ability to model simpler systems, as well as reasoning about them. Initial involvement in scientific research.		
Course content/structure 1. Introduction and basic terms and concepts. 2. Formalisms and formal systems. 3. Reasoning in the statement of account. Tautology, satisfaction, SAT. Normal forms, DPLL procedure. Resolution method. Determination. 4. Predicate calculus. Resolution, determination. SMT. 5. Logical frameworks. LF, LLF and CLF. ΛΠ-calculus. Linear logic. 6. Interactive proof of the theorem Coq. Calculus of constructions. Evident Abella. G logic.		
Literature ● J. Harrison, Hadbook of practical logic and automated reasoning, Cambridge Univ. Press, 2009. ● F. Pfeenning, Logical frameworks, in Handbook of automated reasoning,pp.1063–1147, 2001. ● I. Cervesato, Logical frameworks - why not just classical logic? (online) 1999. ● P. Janičić, Matematička logika u računarstvu, Matematički Fakultet u Beogradu, 2007. ● R. Harper, Practical foundations for programming languages, Cambridge University Press, 2016. ● F. Marić, Automatsko rezonovanje (beleške), Matematički Fakultet Beograd, 2018.		
Number of active teaching classes (weekly)	Lectures:	Study research work: 3
Teaching methods The lectures present the theoretical part of the material, followed by examples with the appropriate application of software. The student independently studies parts of literature and research, which he discusses with the teacher in consultations.		
Knowledge evaluation (maximum 100 points)		
Final exam - 60 points, pre-exam obligations - 40 points (homework, seminar work, participation in projects).		

Course: **Course id:** **Number of ECTS: 10**	**Algebraic programming**
Teacher:	Duško Bogdanić
Course status:	Elective, first year, first semester

Precondition courses: none

Educational goal

By symbolic computation we mean the part of mathematics and computing that deals with the development of algorithms and software for manipulating mathematical objects that can be adequately represented on a computer. The aim of this course is to introduce students to the software packages GAP and MAGMA, computer systems designed to solve the problem of symbolic computing in the field of algebra, numerical mathematics, number theory and other branches of mathematics and computing, and their application.

Educational outcomes (acquired knowledge):

After attending the course, the student will be ready to:

- learn advanced concepts of GAP and MAGMA software packages,
- get acquainted with other available systems for symbolic calculation,
- develops software for advanced symbolic calculations,
- analyzes the complexity of symbolic computation algorithms.

Course content/structure

Algebraic programming algorithms, basic libraries of the GAP software system, basic libraries of the MAGMA software system, computer representations of mathematical objects. Development of software for advanced symbolic calculations. Analysis of the complexity of symbolic computation algorithms.

Literature

- J. Gathen, J. Gerhard, Modern Computer Algebra, Cambridge University Press, 2013.
- J.S. Cohen, Computer Algebra and Symbolic Computation: Elementary Algorithms, CRC Press, 2003.
- GAP manuals, https://www.gap-system.org/Doc/manuals.html
-

Number of active teaching classes (weekly)	Lectures: 2	Study research work: 2

Teaching methods

Classes are conducted through lectures and / or mentoring, consultations, seminars, study and research work. Within the study and research work, complex tasks are solved, so that the candidates can understand the given material, which they could later apply in practice. Special attention is paid to the development of algorithms and software in commercial systems for symbolic computing.

Knowledge evaluation (maximum 100 points)

Research work: 40; Oral exam: 60 points

Course: **Course id:** **Number of ECTS: 10**	**Intelligent tutoring systems**	
Teacher:	Boban Vesin	
Course status:	Elective, second year, third semester	
Precondition courses: none		
Educational goal The course focuses on the challenges and opportunities arising from the introduction of technologies in learning and teaching, assuming that the technologically rich context of learning and teaching is qualitatively different from that without technologies. The course will focus on the design of technologies for innovative learning practices.		
Educational outcomes (acquired knowledge): The main goal of the course is to train doctoral students in the field of technology enhanced learning (TEL). Students are expected to gain advanced knowledge of the state of the techniques used in TEL, in terms of theories, methods and technology. At the end of the course, students are expected to be able to apply the acquired knowledge in the analysis of user needs in formal and informal learning settings and in the design of new technologies. It will also develop the competencies needed to participate in and establish research in the field.		
Course content/structure Learning and lecturing with advanced technologies, learning contexts, intelligent tutoring systems, cognitive tools, meta-cognitive tools, student knowledge assessment methodologies, personalization and adaptation in distance learning systems, technologically advanced learning, mobile learning, knowledge sharing, gamification, strategies learning, the use of artificial intelligence techniques in the teaching process.		
Literature ● Klašnja-Milićević, A., Vesin, B., Ivanović, M., Budimac, Z. Jain, L.C., E-learning systems: Intelligent techniques for personalization (Vol. 112). Springer. 2016 ● Bower, M., Design of technology-enhanced learning: Integrating research and practice. Emerald Group Publishing. 2017. ● Lajoie, S.P. and Azevedo, R., Teaching and learning in technology-rich environments. Informa UK Limited, 2017.		
Number of active teaching classes (weekly)	Lectures: 3	Practical classes: 3
Teaching methods Classes are conducted through lectures and / or mentoring, consultations, seminars, study and research work. Within the study and research work, complex tasks are solved, so that the candidates can understand the given material, which they could later apply in practice. Special attention is paid to solving real examples from business practice, where modelling is performed using appropriate software tools.		
Knowledge evaluation (maximum 100 points)		
Research work: 40; Oral exam: 60 points		

Course: **Course id:** **Number of ECTS: 10**	**Fuzzy logic and fuzzy systems**	
Teacher:	**Marija Paunović**	
Course status:	Elective, second year, third semester	
Precondition courses: None		
Educational goal Enabling students to develop abstract thinking and acquire advanced knowledge related to the selected area within the methods and techniques for modelling uncertainty, imprecision and vagueness. Depending on the orientation of the candidate and the narrow scientific field that will be the subject of the doctoral dissertation, different methodological concepts will be considered, which will be the basis for scientific research.		
Educational outcomes (acquired knowledge): Gaining knowledge about the possibilities of applying methods and fuzzy techniques in solving real problems in engineering and managerial practice and master the appropriate skills using selected modelling approach and available software tools in building a complex management system based on fuzzy logic.		
Course content/structure Fuzzy and ordinary sets. Fuzzy arithmetic. Approximate reasoning. Uncertainty measures. Fuzzy systems. Fuzzy Databases. Fuzzy shape recognition, Fuzzy clustering. Neuro-fuzzy systems. Decision theory. Engineering applications. Applications of fuzzy systems in other disciplines. Practical classes: Modelling uncertainty. Determining membership functions. Using a computer-fuzzy toolbox. Part of the course is conducted through independent study research work, which includes active monitoring of primary scientific sources, organization and performance of experiments and statistical data processing, numerical simulations, writing papers in the field.		
Literature J. Klir, B. Yuan, Fuzzy Sets and Fuzzy Logic – Theory and Applications, Prentice Hall, 1995. R. R. Yager, D. Filev, Essential of Fuzzy Modelling and Control, Wiley, 1994 E. Cox, The Fuzzy Systems Handbook, Academic Press, London, 1994. Grabisch M., Nguyen H. Walker E. A. Fundamentals of Uncertainty Calculi with Application to Fuzzy Inference, KluwerAcademicPublishers, Dordrecht-Boston-London, 1995.		
Number of active teaching classes	Lectures: 3	Study research work: 3
Teaching methods Teaching is performed through lectures and / or mentoring, consultations, seminars, study and research work. Within the study and research work, complex tasks will be solved, which they could later apply. Special attention is dedicated to solving real problems from business practice, where modelling is performed using appropriate software tools.		
Knowledge evaluation (maximum 100 points)		
Research and study work: 40; Oral exam: 60 points		

Course:	**Direct search optimization**
Course id:	
Number of ECTS: 10	
Teacher:	Milena V. Radenković
Course status:	Elective, second year, third semester

Precondition courses: none

Educational goal

Introduction to the class of zero-order optimization methods that does not require product information and does not construct an approximate model of the optimality criterion, ie show that in numerical optimization the algorithms of the direct search method are only functions for ranking the countable set of criterion values.

Educational outcomes (acquired knowledge):

Possibility of successful application in various theoretical and applied analyses and optimization of nonlinear models of functions in the description of systems of various physical characteristics, economic, organizational, business, information, technical, ..., i.e. success of application to optimization problems with non-smooth functions that are often encountered in experimental analysis and design of diverse (non) technical systems.

Course content/structure

1. Linear search, non-gradient and gradient methods.
2. Pattern methods of direct search, coordinate method, method with positive spanning sets of search directions in the conditions of fulfilment of global mechanisms based on the application of the criteria of sufficient decline.
3. Simplex direct search methods, matrix model of Nelder-Mead method in theory and application.
4. Multidirectional search method.
5. Optimization of nonlinear function models, Software solutions.

Literature

- J.E.Dennis and R.B.Schnabel, Numerical Methods for Unconstrained Optimization and Nonlinear Equations, SIAM, Philadelphia, 1996.
- J.Nocedal and S.J.Wright, Numerical Optimization, Springer, 2006.
- E.Polak, Computational Methods in Optimization, A Unified Approach, Academic Press, New York, 1971.

Number of active teaching classes	Lectures: 4	Study research work: 3

Teaching methods

Lectures and / or mentoring, consultations, laboratory exercises, homework assignments, preparation of seminar paper, participation in projects.

Knowledge evaluation (maximum 100 points)

Final exam - 60 points, pre - exam obligations - 40 points (homework, seminar work, participation in projects).

Course:	**Computer modeling of natural and technical processes**
Course id:	
Number of ECTS: 10	
Teacher:	Goran Keković
Course status:	Elective, second year, third semester

Precondition courses: none

Educational goal

The aim of the course is to acquaint doctoral students with the applications of linear algebra, differential equations, probabilities and statistics, for the production of mathematical models of physical and technical processes in a broader sense and the adoption of methods for identifying parameters of linear and nonlinear models; as well as basic methods of working with stochastic processes, and with systems that depend on random events.

Educational outcomes (acquired knowledge):

Upon successful completion of the course, the doctoral student will be able to: 1. based on numerical data and time series to assess the type and order of models of a given physical process, 2. determine the structure of the model, 3. identify the parameters of the model or otherwise optimize the model; 4. write a program to simulate a given physical process.

- determine the structure of the model
- from the measured data identifies the parameters of the model or otherwise optimizes the model
- writes a program for simulation of a given physical process

Course content/structure

Theoretical classes:

Theory of dynamical systems, differential and differential equations, hysteresis dynamics; Linear and nonlinear dynamical systems; Physical and numerical models of dynamical systems; stochastic systems; model parameterization; random event processes, queuing systems; statistical identification and parameter optimization; process simulation. Areas of application in engineering: CAD, CAM systems, modelling in biotechnology and medicine.

Practical classes:

Computational exercises. Laboratory exercises. Research project.

Literature

- .Richard Durrett : Essentials of stochastic processes, 2nd ed. Springer, 2012.
- Tokunbo Ogunfunmi : Adaptive Nonlinear System Identification: The Volterra and Wiener Model Approaches, Springer; 2007.
- Shapiro, V. Solid modeling, Elsevier, 2001.
- Hatcher, A. Algebraic topology, Cambridge university, 2002.

Number of active teaching classes	Lectures: 4	Study research work: 3

Teaching methods

Lectures and / or mentoring, consultations, laboratory exercises, preparation of seminar papers, development and defence of research projects.

Knowledge evaluation (maximum 100 points)

Final exam - 60 points, pre - exam obligations - 40 points (seminar work, participation in projects).

Course:	**Adaptive systems for business decision making**

Course id:	
Number of ECTS: 10	
Teacher:	Boban Vesin
Course status:	Elective, second year, third semester

Precondition courses: none

Educational goal

Classical approaches in data analysis are based on a static (or predefined) procedure for collecting and processing data. Modern approaches deal with adaptive methods that are almost always used in practice. The aim of the course is for students to learn how to design systems that adaptively collect and process data in order to make decisions independently or in cooperation with people. The course applies basic principles from machine learning, artificial intelligence, databases and parallel processing to real problems in security, personalization, forecasting, transparency and privacy.

Educational outcomes (acquired knowledge):

After attending the course, the student will be ready to:

- understand adaptive data analysis, as well as identify general problems in decision making.
- uses the SQL query language
- plans adaptive data collection.
- identifies software security issues and how to troubleshoot them.
- be able to provide guarantees of safety and reliability.
- addresses issues of discrimination and fairness that may arise.
- uses large-scale data processing tools such as Tensor-flow
- solves problems with extremities, as well as with incomplete and / or unprocessed data.

Course content/structure

Decision problems, adaptive systems, privacy, neural networks, graphical models, referral generation systems, big data, genetic algorithms, Bayesian network.

Literature

- Dimitrakakis, C. Ortner, R., Decision making under uncertainty and reinforcement learning.
- Chalmers University of Technology, 2018.
- Dwork, C. and Roth, A., The algorithmic foundations of differential privacy. Foundations and Trends in Theoretical Computer Science, 2014
- Klašnja-Milićević, A., Vesin, B., Ivanović, M., Budimac, Z. and Jain, L.C., E-learning systems: Intelligent techniques for personalization (Vol. 112). Springer. 2016

Number of active teaching classes	Lectures: 4	Practical classes: 3

Teaching methods

Classes are conducted through lectures and / or mentoring, consultations, seminars, study and research work. Within the study and research work, complex tasks are solved, so that the candidates can understand the given material, which they could later apply in practice. Special attention is paid to solving real examples from business practice, where modelling is performed using appropriate software tools.

Knowledge evaluation (maximum 100 points)

Research work: 40; Oral exam: 60 points

Course: **Course id:** **Number of ECTS: 10**	**Decision support systems**	
Teacher:	**Marija Paunović**	
Course status:	Elective, second year, third semester	
Precondition courses: None		
Educational goal Advanced knowledge related to modern disciplines and methods that deal with decision-making. Depending on the orientation of the candidate and the narrow scientific field that will be the subject of the doctoral dissertation, different methodological concepts will be considered, which will be the basis for further scientific research.		
Educational outcomes (acquired knowledge): Student is familiar with a number of important methods, models and techniques in the field of decision-making and have knowledge in the research areas of decision-making for further scientific research. The student has mastered software tools to support decision making.		
Course content/structure Introduction to decision theory, Decision making process. Aspects of probability and statistics in decision theory. Aspect of fuzzy logic and system in decision theory. Decision tree technique. Utility theory. Game theory. Multi-attributive utility. Multicriteria decision making and analysis. Group decision making. Delphi technique. Technologies for the development of decision support systems. Optimization models for decision making. Application of artificial intelligence in decision support systems. Expert systems. Patterns and decision making. Decision support software.		
Literature 1. Qudrat-Ullah, H, Spector, J.M, Davidsen, P. Complex Decision Making: Theory and Practice, Springer, 2010 2. Murty K. Optimization models for decision making, Springer-Verlag US, 2010 3. Miescke, K-J, Liese, F. Statistical Decision Theory: Estimation, Testing, and Selection, Springer-Verlag New York, 2008 4. Павличић, Д. Теорија одлучивања, ЦИД, Економски факултет Београд, 2004. 5. Adam, F, Humphreys, P. Encyclopedia of decision making and decision support technologiec, Information Science Reference, 2008		
Number of active teaching classes	Lectures: 4	Study research work: 3
Teaching methods Teaching is performed through lectures and / or mentoring, consultations, seminars, study and research work. Within the study and research work, complex tasks will be solved, which they could later apply. Special attention is dedicated to solving real problems from business practice, where modelling is performed using appropriate software tools.		
Knowledge evaluation (maximum 100 points)		
Research and study work: 40; Oral exam: 60 points		

Course: **Course id:** **Number of ECTS: 10**	**Study research work on the preparation of the Accession paper for the Doctoral dissertation**
Teacher:	Mentor
Course status:	Mandatory, second year, fourth semester

Precondition courses: 90 ECTS

Educational goal

Preparing students for independent scientific research work on the preparation of the approach paper, as well as on the future preparation of the doctoral dissertation. With the help of a mentor, the student observes, presents the methodology and solves a specific current problem with scientific research methods, with the application of theoretical and applied knowledge acquired during the study.

Educational outcomes (acquired knowledge):

Successful first steps have been taken in training students for independent scientific research work in the elective field: It can analyze the available and available scientific literature and can give a comparative overview of known solutions, with their advantages and disadvantages. Can present initial hypotheses, list basic research methods and describe the form of expected scientific contribution and expected scientific results. Preliminary analysis should imply the student's ability to make significant scientific contributions in the field of study in the course of independent research.

Course content/structure

With the support of the mentor, the student uses the acquired knowledge, but still studies and researches the selected scientific field, the content of which depends on the specifically considered problem. The paper should show that the student has extensive knowledge and understanding of the problems in the part of the study area that he studied in doctoral studies, so that based on a broader overview of references will give a comprehensive analysis of observed research tasks in a given field, as well as known ways to solve these problems. Based on a critical review of known solutions, the student should identify the task of independent research, set goals, initial hypotheses and scientific methods used, explain their choice and present the results of their research, for example, modification of known algorithm, approach, model and / or method. , a new algorithm, approach, comparative analysis of the used algorithms and clear conclusions about the advantages and disadvantages of each of them in solving the set scientific-research task.

Literature

The general characteristic of literature analysis should be reflected in the systematic chronological approach of presenting relevant references in the field of research, starting from fundamental works in the formation of the field, to contemporary results published in leading international scientific journals, other scientific journals, conference proceedings, published doctoral dissertations. and books of textbook and / or monograph character. Relevant reference literature should set the framework for the development of the considered scientific field, ie the framework for the current and future development of the research field.

Number of active teaching classes		Study research work: 10

Teaching methods

Consultations with the mentor in all phases of work, with active monitoring and study of new results of relevant scientific journals, conference proceedings, technical reports of faculties and institutes and doctoral dissertations of other authors in the considered field of research.

Knowledge evaluation (maximum 100 points)

Research work on the preparation of the Accession Paper for the Doctoral Dissertation 50 points. Active participation in the scientific gathering 50 points.

Course: **Course id:** **Number of ECTS: 20**	**Preparation and defense of the Accession paper for the doctoral dissertation**
Teacher:	Mentor
Course status:	Mandatory, second year, fourth semester

Precondition courses: 90 ECTS

Educational goal

Preparing students for independent scientific research work on the preparation of the approach paper, as well as on the future preparation of the doctoral dissertation. With the help of a mentor, the student observes, presents the methodology and solves a specific current problem with scientific research methods, with the application of theoretical and applied knowledge acquired during the study.

Educational outcomes (acquired knowledge):

Successful first steps have been taken in training students for independent scientific research work in the elective field: It can analyse the available and available scientific literature and can give a comparative overview of known solutions, with their advantages and disadvantages. Can present initial hypotheses, list basic research methods and describe the form of expected scientific contribution and expected scientific results. Preliminary analysis should imply the student's ability to make significant scientific contributions in the field of study in the course of independent research.

Course content/structure

With the support of the mentor, the student uses the acquired knowledge, but still studies and researches the selected scientific field, the content of which depends on the specifically considered problem. The paper should show that the student has extensive knowledge and understanding of the problems in the study area that he studied in doctoral studies, so that based on a broader overview of references will provide a comprehensive analysis of observed research tasks in a given scientific field, as well as known ways to solve these problems. Based on a critical review of known solutions, the student should identify the task of independent research, set goals, initial hypotheses and scientific methods used, explain their choice and present the results of their research, for example, modification of known algorithm, approach, model and / or method. , a new algorithm, approach, comparative analysis of the used algorithms and clear conclusions about the advantages and disadvantages of each of them in solving the set scientific-research task.

Literature

The general characteristic of literature analysis should be reflected in the systematic chronological approach of presenting relevant references in the field of research, starting from fundamental works in the formation of the field, to contemporary results published in leading international scientific journals, other scientific journals, conference proceedings, published doctoral dissertations. and books of textbook and / or monograph character. Relevant reference literature should set the framework for the development of the considered scientific field, ie the framework for the current and future development of the research field.

Number of active teaching classes		Study research work: 10

Teaching methods

Consultations with the mentor in all phases of work, with active monitoring and study of new results of relevant scientific journals, conference proceedings, technical reports of faculties and institutes and doctoral dissertations of other authors in the considered field of research.

Knowledge evaluation (maximum 100 points)

Written and positively graded Accession paper 50 points and its oral defence 50 points.

Course:	**Doctoral dissertation (study research work)**	
Course id:		
Number of ECTS: 30		
Teacher:	Mentor	
Course status:	Mandatory, third year, fifth semester	
Precondition courses: 120 ECTS		
Educational goal Preparing students for independent scientific research work on the preparation of the approach paper, as well as on the future preparation of the doctoral dissertation. With the help of a mentor, the student observes, presents the methodology and solves a specific current problem with scientific research methods, with the application of theoretical and applied knowledge acquired during the study.		
Educational outcomes (acquired knowledge): Successful first steps have been taken in training students for independent scientific research work in the elective field: they can analyse the available and available scientific literature and can give a comparative overview of known solutions, with their advantages and disadvantages. Can present initial hypotheses, list basic research methods and describe the form of expected scientific contribution and expected scientific results. Preliminary analysis should imply the student's ability to make significant scientific contributions in the field of study in the course of independent research.		
Course content/structure With the support of the mentor, the student uses the acquired knowledge, but still studies and researches the selected scientific field, the content of which depends on the specifically considered problem. The paper should show that the student has extensive knowledge and understanding of the problems in the part of the study area that he studied in doctoral studies, so that based on a broader overview of references will give a comprehensive analysis of observed research tasks in a given field, as well as known ways to solve these problems. Based on a critical review of known solutions, the student should identify the task of independent research, set goals, initial hypotheses and scientific methods used, explain their choice and present the results of their research, for example, modification of known algorithm, approach, model and / or method, a new algorithm, approach, comparative analysis of the used algorithms and clear conclusions about the advantages and disadvantages of each of them in solving the set scientific-research task.		
Literature The general characteristic of literature analysis should be reflected in the systematic chronological approach of presenting relevant references in the field of research, starting from fundamental works in the formation of the field, to contemporary results published in leading international scientific journals, other scientific journals, conference proceedings, published doctoral dissertations. and books of textbook and / or monograph character. Relevant reference literature should set the framework for the development of the considered scientific field, i.e. the framework for the current and future development of the research field.		
Number of active teaching classes (weekly)	Lectures:	Study research work: 20
Teaching methods Consultations with the mentor in all phases of work, with active monitoring and study of new results of relevant scientific journals, conference proceedings, technical reports of faculties and institutes and doctoral dissertations of other authors in the considered field of research.		
Knowledge evaluation (maximum 100 points)		
Study research work on the doctoral dissertation 50 points and a paper published in a scientific journal from the SCI list on which the doctoral student is the first author of 50 points.		

Course: **Course id:** **Number of ECTS: 30**	**Doctoral dissertation (drafting and defence)**	
Teacher:	Mentor and Commission for Review and Evaluation and Oral Defence	
Course status:	Mandatory, third year, sixth semester	
Precondition courses: 150 ECTS and published work in a scientific journal from the SCI list in which the doctoral student is the first author		
Educational goal The introductory work, especially the Doctoral dissertation, represents the independent scientific works of the candidate, with a scientific contribution that qualifies him as an independent scientific researcher in his further work.		
Educational outcomes (acquired knowledge): The student is qualified for independent scientific research work in the elective field: He can perform an analysis of available and available scientific literature and can give a comparative overview of known solutions, with their advantages and disadvantages. Can present initial hypotheses, list basic research methods and describe the form of expected scientific contribution and expected scientific results. Preliminary analysis should imply the student's ability to make significant scientific contributions in the field of study in the course of independent research.		
Course content/structure The introductory paper, especially the Doctoral Dissertation, should show that the student has extensive knowledge and understanding of the problems in the study area studied in doctoral studies, by providing a comprehensive analysis of the observed research tasks in a given field, based on a broader overview of references. and known ways to solve these problems. Based on a critical review of known solutions, the student should identify the task of independent research, set goals, initial hypotheses and scientific methods used, explain their choice and present the results of their research, for example, modification of known algorithm, approach, model and / or method. , a new algorithm, approach, comparative analysis of the used algorithms and clear conclusions about the advantages and disadvantages of each of them in solving the set scientific-research task.		
Literature The general characteristic of literature analysis should be reflected in the systematic chronological approach of presenting relevant references in the field of research, starting from fundamental works in the formation of the field, to contemporary results published in leading international scientific journals, other scientific journals, conference proceedings, published doctoral dissertations. and books of textbook and / or monograph character. Relevant reference literature should set the framework for the development of the considered scientific field, ie the framework for the current and future development of the research field.		
Number of active teaching classes (weekly)	Other: 10	Study research work: 20
Teaching methods Consultations with the mentor in all phases of work, with active monitoring and study of new results of relevant scientific journals, conference proceedings, technical reports of faculties and institutes and doctoral dissertations of other authors in the considered field of research.		
Knowledge evaluation (maximum 100 points)		
Written and positively evaluated Doctoral dissertation 50 points and its oral defence 50 points.		