Faculty of «Computer technology and cybersecurity»
Department of «Mathematical and computer modeling»

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**8D06105**

**Data Science**

# CATALOGUE OF ELECTIVE DISCIPLINES

**2023-2027 year of admission**

2023 y.

The catalogue of elective disciplines for the EP pf the MCM department is developed on the basis of the working curriculum of the EP "8D06105 Data Science".

The catalogue of elective disciplines was discussed at a meeting of the department of Mathematical and computer modeling

minutes No. 8 from «10» 02 2023 y.

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## 1 TERMS AND ABBREVIATIONS

1. 1 Educational program is a single set of basic characteristics of education, including goals, results and content of training, the organization of educational process, ways and methods for their implementation and criteria for assessing learning outcomes.
The content of educational program of higher education consists of three cycles of disciplines - general education disciplines (hereinafter - GED), basic disciplines (hereinafter - BD) and core disciplines (hereinafter - CD).
The cycle of GED includes disciplines of the compulsory component (hereinafter - CC), the university component (hereinafter - UC) and (or) the component of choice (hereinafter - COC). BD and CD include disciplines of UC and COC.

1. 2 Catalogue of elective disciplines (CED) is a systematic annotated list of all COC disciplines, for the entire training period, containing a brief description indicating the purpose of study, a summary of main sections and expected learning outcomes. CED reflects the prerequisites and postrequisites of each academic discipline. It should provide the students with the possibility of an alternative choice of elective disciplines for the formation of an individual educational trajectory.

On the basis of educational program and CED, the students develop individual curricula with the help of advisers.

1. 3 Individual curriculum (IC) is a curriculum formed by the students independently with the help of an advisor for each academic year on the basis of the educational program, the catalogue of elective disciplines or modules;

IC defines an individual educational trajectory of each student separately. It includes disciplines and types of educational activities (internship, experimental research, forms of final certification) of the compulsory component (CC), the university component (UC) and the component of choice (COC).

1. 4 Advisor is a teacher who performs the functions of an academic mentor of a student (according to the appropriate educational program) and assists in choosing a learning path (creating an individual curriculum) and mastering the educational program during the training period.

1. 5 The university component is a list of compulsory educational disciplines determined by the university independently for the mastering of the educational program.

1. 6 The component of choice is a list of academic disciplines and the corresponding minimum amounts of academic credits offered by the university and independently chosen by students in any academic period, taking into account their prerequisites and postrequisites.

1. 7 Elective disciplines are educational disciplines that are a part of the university component and the component of choice in the framework of established academic credits, introduced by organizations of education reflecting the individual preparation of students and taking into account the specifics of socio-economic development, the needs of a particular region and established scientific schools.

1. 8 Postrequisites are the disciplines and (or) modules and other types of academic work, the study of which requires knowledge, skills and competencies acquired at the end of the study of this discipline and (or) modules;

1. 9 Prerequisites are the disciplines and (or) modules and other types of educational work containing knowledge, abilities, skills and competencies necessary for the mastering of the studied discipline and (or) modules;

1. 10 Competencies are the ability of the practical use of acquired knowledge and skills in professional activities.

## 2 ELECTIVE DISCIPLINES

| № | Cycle of discipline | Name of discipline | Semester | Number of credits | Prerequisites |
|---|---|---|---|---|---|
| ***1 year*** | | | | | |
| 1 | CD COC | Nonlinear optimization problems of machine learning | 1 | 4 | |
| | | Deep learning in applied mathematics | 1 | 4 | |
| 2 | CD COC | Advanced deep learning problems | 1 | 4 | |
| | | Game simulation and applications | 1 | 4 | |
| 3 | CD COC | Applied statistical analysis | 1 | 4 | |
| | | Enumerative combinatorics | 1 | 4 | |

## 3 DESCRIPTION OF ELECTIVE DISCIPLINES

| Description of discipline | |
|---|---|
| Name of the discipline | Nonlinear optimization problems of machine learning |
| The aim of study of a discipline | • Basic iterative methods of nonlinear optimization;<br>• Convergence of iterative nonlinear optimization methods;<br>• Development of algorithms and programs for nonlinear optimization methods;<br>• Conducting computational experiments and data analysis. |
| Brief course description (main sections) | Nonlinear optimization methods are widely used in solving practical problems of production and science. With the advent of machine learning, the importance of nonlinear optimization methods has increased many times over. Because one of the main foundations of machine learning is nonlinear optimization.<br>Doctoral students will learn to use the method of constructing an iterative nonlinear optimization scheme; get acquainted with the method of proving the convergence of iterative optimization schemes; will develop algorithms for solving the problem of nonlinear optimization, as well as build a software product. They will learn how to conduct computational experiments by choosing parameters for damping the computational process. They will also be able to analyze the result and evaluate the accuracy of the developed method. |
| Expected Learning Outcomes (knowledge, abilities, skills and competencies acquired by students) | Will receive:<br>Knowledge in the development of iterative nonlinear optimization methods;<br>Understanding the convergence of iterative nonlinear optimization methods;<br>Application of software development and numerical calculations;<br>Analysis of the results of numerical calculations;<br>Synthesis of using the damping parameter to increase the convergence rate of nonlinear optimization methods;<br>Evaluate the accuracy of the developed numerical methods of nonlinear optimization based on numerical experiments. |

| Description of discipline | |
|---|---|
| Name of the discipline | Deep learning in applied mathematics |
| The aim of study of a discipline | The offered course is devoted to the methods of "deep learning" - a new generation of neural network machine learning methods that have caused a rapid surge in development in a number of applied areas. First of all, the course is aimed at developing research skills for doctoral students in solving applied problems using deep neural networks. |
| Brief course description (main sections) | As part of the course, it is planned to highlight:<br>• Deep Learning (1. Basic architectures and layers, 2. Specific optimization methods (Mommentum SGD, RMSprop, ada *, etc.) 3. General pipeline for solving applied problems, 4. Solving the simplest problems in practice (NotMnist))<br>• Deep learning in image analysis (1. Overview of basic tasks 2. Convolutional networks, Pooling 3. Specific architectures - AutoEncoders, Siamese, Stacked 4. Applied heuristics: Batch Normalization, Dropout, DropConnect, added noize, 1x1 convolution 5. “Zoo of models”, Additional training of networks, Fine-tuning)<br>• Deep learning in word processing (1. Brief overview of the subject area 2. Reduction of applied problems to Deep Learning 3. Convolutional and recurrent networks in word processing, GRU, LSTM 4. Specific architectures: Text Convolution, Recurrent, Encoder-Decoder, 5. Situational heuristics, nudging dataset) |
| Expected Learning Outcomes (knowledge, abilities, skills and competencies acquired by students) | The discipline forms the following skills:<br>1.solving the problem of production and technological activities using deep learning methods at a professional level, including problem statement, basic solution, prototyping and implementation.<br>2. an understanding of the main areas of application of deep learning methods, features and tricks in each such area.<br>3.in-depth understanding of one of the main applications of deep learning |

| Description of discipline | |
|---|---|
| Name of the discipline | Advanced deep learning problems |
| The aim of study of a discipline | familiarization with modern approaches to the construction, training and use of recognition and classification systems based on machine learning methods and deep learning neural networks. |
| Brief course description (main sections) | - familiarization with the classification of problems of indexing, recognition and classification of signals and images, and methods for their solution;<br>- familiarization with the classification of machine learning tasks;<br>- the acquisition of theoretical knowledge and practical skills by students in the field of researching data analysis tasks and their solution using machine learning methods;<br>- familiarization with the basic principles of building and training deep learning networks;<br>acquisition of practical skills for effective design and construction of classifiers based on deep learning networks. |
| Expected Learning Outcomes (knowledge, abilities, skills and competencies acquired by students) | As a result of studying the discipline, the student must:<br>be able to:<br>- to draw correct conclusions from the comparison of the results of theory and experiment; - to select from practical problems their formulation for machine learning;<br>- work with modern software systems for solving machine learning problems;<br>- to plan the optimal computational experiment;<br>- correctly assess the degree of reliability of the solution found;<br>- conduct training of algorithms, avoiding retraining;<br>- choose algorithms based on the characteristics of the task data.<br>own:<br>- skills of independent work in modern software systems;<br>- skills of mastering a large amount of information;<br>- programming skills for solving data analysis problems;<br>- culture of setting goals; - the culture of the experiment;<br>- visualization tools to demonstrate the results obtained. |

| Description of discipline | |
|---|---|
| Name of the discipline | Game simulation and applications |
| The aim of study of a discipline | familiarization of students with the basic concepts of game theory. As a result of mastering the course, doctoral students will be able to apply the theoretical and methodological tools of the discipline for the analysis and game-theoretic modeling of real processes. |
| Brief course description (main sections) | Content of the discipline<br>- Static games with complete information<br>- Dynamic games with complete information<br>- Statistical games with incomplete information<br>- Dynamic games with incomplete information |
| Expected Learning Outcomes (knowledge, abilities, skills and competencies acquired by students) | Planned learning outcomes:<br>- Know the basic concepts and concepts of game theory and acquire skills in applying game theory to political science practice.<br>- To be able to present a theory based on the prerequisites of rational strategic choice in game-theoretic language; correctly interpret the predictions of mathematical models of political economy; build and analyze mathematical models of socio-political systems and processes.<br>- Possess the skills of analyzing conflicts of interest from a game-theoretic point of view; the skills of determining the applicability of the model to a particular situation. |

| Description of discipline | |
|---|---|
| Name of the discipline | Applied statistical analysis |
| The aim of study of a discipline | The aim of the course is to study the main directions of development of modern applied statistical tools, including methods of correlation and regression analysis, reducing the dimension of the feature space, classifying objects, including hierarchical and iterative algorithms for cluster analysis, parametric and nonparametric classification. An important feature of the course is the wide use of illustrative examples and the use of a wide arsenal of modern tools for processing statistical information in Excel, R and Python.. |
| Brief course description (main sections) | This course covers: Simple Linear Regression, Multiple Linear Regression, Nonlinear Models, Nonparametric Regression and Generalized Additive Models (GAM), Residual Analysis; Principal Component Analysis, Multivariate Normality, Cluster Analysis, Discriminant Analysis, Multivariate Scaling, Factor Analysis, Canonical Correlation Analysis. |
| Expected Learning Outcomes (knowledge, abilities, skills and competencies acquired by students) | Postdoctoral students at the end of the course should be able to:<br>• use correlation analysis, explore the relationship of variables in a multidimensional space using modern software products<br>• use the most common statistical tests and understand their assumptions and limitations; formulate and select an appropriate testing methodology in a given situation;<br>• use most estimation methods (eg least squares, maximum likelihood);<br>• perform estimation in regression models and evaluate the proposed model;<br>• finds regression models including conditions and assumptions<br>• choose an appropriate regression model for a given task |

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|---|---|
| | • use multivariate statistical tools, and critically examine the validity of statistical analyzes<br>• execute and evaluate the results using the statistical software R. |

| **Description of discipline** | |
|---|---|
| Name of the discipline | Enumerative combinatorics |
| Pretrequisites | mastering the necessary mathematical apparatus, with the help of which theoretical and experimental models of objects of professional activity are developed and studied |
| The aim of study of a discipline | The main task of studying the discipline is the formation of doctoral students' research skills related to the use of theoretical knowledge in the field of combinatorics, and its application in engineering disciplines. The doctoral student will receive knowledge and skills in using the basic concepts and methods of combinatorics; the ability to formulate problems related to discrete objects in combinatorial terms; skills in solving typical combinatorial problems; knowledge of the basic algorithms for discrete optimization; skills in compiling and decoding ciphers, solving other problems of information theory. |
| Brief course description (main sections) | Postdoctoral students at the end of the course must have and be able to:<br>• formulate problems related to discrete objects in combinatorial terms.<br>• Skill of solving problems of enumeration combinatorics.<br>• Skill in solving linear recurrence relations.<br>• Ability to apply methods for solving extreme problems on graphs.<br>• Knowledge of the most important classes of codes and their application. |