

NJSC Kazakh National Research Technical University named after K.I. Satpayev
Institute of Automation and Information Technologies
Department of Software Engineering

Working educational program
CURRICULUM PROGRAM

"Machine Learning & Data Science"
PhD

in the field of Information and Communication Technologies under the
Educational Program
"8D06102- Machine Learning & Data Science"

2nd edition
in accordance with the State Standard of Higher Education 2022

Almaty 2022

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The program is drawn up and signed by the parties:
From KazNRTU named after K.I. Satpayeva:

1. Director of the Institute of Automation and Information Technologies (IAaIT), Doctor of Technical Sciences, Professor
2. Head of the Department of Software Engineering (SE), Ph.D., Associate Professor



R.K. Uskenbaeva

A.N. Moldagulova

3. Deputy Director of IAaIT, PhD



A.B. Kasymova

4. Member of the educational and methodological group of the department of SE, PhD

N.K. Mukazhanov

Qualification:

Level 8 of the National Qualifications Framework
8D06 Information and communication technologies

Professional competencies: Artificial Intelligence, Data Science

Brief description of the program:

1 Goals

The main focus of the doctoral program is on in-depth study of software development technologies in the field of artificial intelligence, data analysis and machine learning.

The program is aimed at preparing a scientist who is able to independently conduct scientific research, develop complex software solutions, work in a team, and be well versed in modern aspects of data science. The educational program is built taking into account current trends in machine learning and data processing using artificial intelligence methods in conjunction with the manufacturing sector.

The development of the educational program was carried out on the basis of 3 documents defining directions and specializations in the field of IT - SWEBOK, the purpose of which is to combine knowledge in software engineering; SE2004 - training manual for training specialists in university programs in the field of software engineering; CC2005 - guidelines for the development of training programs for IT professionals. A team of international IT specialists has identified a set of areas of study and a set of disciplines that provide quality training in IT (CC2005), as well as the thematic composition of disciplines and a set of knowledge necessary and sufficient for IT specialists (SWEBOK, SE2004).

This educational program " Machine Learning & Data Science " was developed on the basis of the main regulatory documents:

- State compulsory standard of technical and vocational education, approved by Decree of the Government of the Republic of Kazakhstan dated August 23, 2012 No. 1080 (as amended as of August 15, 2017) . Footnote. Clause 1 as amended by the Decree of the Government of the Republic of Kazakhstan dated 04/25/2015 No. 327 (put into effect from 09/01/2016); dated 05/13/2016 No. 292 (put into effect from 09/01/2017).

- Industry Qualification Framework (IQF). Industry: information and communication technologies. Approved by Minutes No. 1 of December 20, 2016 of the meeting of the Industry Commission in the field of information, informatization, communications and telecommunications.

- Law of the Republic of Kazakhstan “On Education” dated July 27, 2007 No. 319-III ZRK;

- IEEE SWEBOK pooling knowledge on software engineering;
- CC2005 guidelines for the development of training programs for IT specialists;
- SE2004 training manual for training specialists in university programs in the field of software engineering.

The program is designed to implement the principles of democratic education management, expanding the boundaries of academic freedom and the powers of

educational institutions, which will ensure the training of elite, highly motivated personnel for innovative and knowledge-intensive sectors of the economy.

The educational program was developed based on an analysis of the labor functions of software engineers, system administrators, and data analysts, as stated in professional standards.

Representatives of Kazakh companies in the field of software product development participated in the development of the educational program.

2 Types of work activity

The program is aimed at the following areas of professional activity:

- Data analysis
- Machine learning
- Artificial intelligence

Types of work activity:

- design and engineering;
- production and technological;
- experimental research;
- organizational and managerial;
- operational;
- scientific

3 Objects of professional activity

The objects of professional activity are:

- Computers, complexes, systems and networks;
- Computer systems for information processing and management;
- Automated control systems;
- Computer software;
- Systems and complexes for intelligent data analysis

PASSPORT OF THE EDUCATIONAL PROGRAM

1 Scope and content of the program

The educational program for the preparation of a Doctor of Philosophy (PhD) has a scientific and pedagogical orientation and involves fundamental educational, methodological and research training and in-depth study of disciplines in relevant areas of science for the system of higher and postgraduate education and the scientific field.

The educational program for preparing a doctor in the field involves fundamental educational, methodological and research training and in-depth study of disciplines in relevant areas of science for sectors of the national economy, social sphere: information and communication technologies.

Doctoral educational programs in terms of professional training are developed on the basis of studying the experience of foreign universities and research centers that implement accredited training programs for PhDs or doctors in a specialized field.

The content of the educational program of specialized doctoral studies is established by the university independently.

The main criterion for the completion of the educational process for the preparation of Doctors of Philosophy (PhD) (doctors in the field) is the completion of at least 180 academic credits by the doctoral student, including all types of educational and scientific activities.

The duration of doctoral studies is determined by the volume of completed academic credits. When mastering the established volume of academic credits and achieving the expected learning outcomes for obtaining a Doctor of Philosophy (PhD) degree or according to the profile, the doctoral educational program is considered fully mastered.

Doctoral training is carried out on the basis of master's degree programs in two areas:

- 1) scientific and pedagogical with a period of study of at least three years;

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2) specialized with a period of study of at least three years.

Contents of the OP

- General educational complex of disciplines
- Data Analytics Disciplines
- Machine learning disciplines
- Artificial Intelligence Disciplines
- Disciplines of software development project management

Objectives of the educational program:

To provide practice-oriented training for research and production specialists in the development of software products in the field of data analysis, machine learning and artificial intelligence.

Create conditions for continuous professional self-improvement, development of social and personal competencies (broad cultural outlook, active citizenship, determination, organization, hard work, communication skills, ability to reason and make organizational and managerial decisions, mastery of modern information technologies, fluency in several languages, desire to self-development and commitment to ethical values and a healthy lifestyle, the ability to work in a team, responsibility for the final result of one’s professional activities, civic responsibility, tolerance), social mobility and competitiveness in the labor market.

2 Admission requirements

Doctoral studies accept persons who have a master's degree and work experience of at least 1 (one) year or who have completed residency training.

Admission to the number of doctoral students is carried out by the selection committees of universities and scientific organizations based on the results of the entrance exam for groups of doctoral educational programs and a certificate confirming knowledge of a foreign language in accordance with the pan-European competencies (standards) of foreign language proficiency.

When enrolling in universities, doctoral students independently choose an educational program from the appropriate group of educational programs.

Enrollment of persons for targeted training of Doctors of Philosophy (PhD) under the state educational order is carried out on a competitive basis.

The procedure for admitting citizens to doctoral studies is established in accordance with the “Standard Rules for Admission to Study in Educational Organizations Implementing Educational Programs of Postgraduate Education.”

The formation of a contingent of doctoral students is carried out by placing a state educational order for the training of scientific and teaching personnel, as well as paying for training at the expense of citizens' own funds and other sources. The state provides citizens of the Republic of Kazakhstan with the right to receive, on a competitive basis, in accordance with the state educational order, free postgraduate education if they are receiving education at this level for the first time.

At the “entrance”, the doctoral student must have all the prerequisites necessary to master the relevant professional doctoral curriculum. The list of necessary prerequisites is determined by the higher education institution independently.

In the absence of the necessary prerequisites, the doctoral student is allowed to master them on a paid basis. In this case, doctoral studies begin after the doctoral student has fully mastered the prerequisites .

3 Requirements for completion of training and obtaining a diploma

Persons who have mastered the doctoral educational program and defended their doctoral dissertation, with a positive decision by the dissertation councils of a university with a special status or the Committee for Control in the Field of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, based on the results of the examination, are awarded the degree of Doctor of Philosophy (PhD) or Doctor of Philosophy profile and is issued a state diploma with an appendix (transcript).

Persons who have received a PhD degree , to deepen scientific knowledge, solve scientific and applied problems on a specialized topic, carry out a postdoctoral program or conduct scientific research under the guidance of a leading scientist at a selected university.

3.1 Requirements for key competencies of doctoral graduates:

1) have an idea:

- about the main stages of development and paradigm shifts in the evolution of science;
- about the subject, ideological and methodological specifics of natural (social, humanitarian, economic) sciences;
- about scientific schools of the relevant field of knowledge, their theoretical and practical developments;
- about scientific concepts of world and Kazakhstani science in the relevant field;
- on the mechanism for introducing scientific developments into practical activities;

- about the norms of interaction in the scientific community;
- about the pedagogical and scientific ethics of the research scientist;

2) *know and understand:*

- modern trends, directions and patterns of development of domestic science in the conditions of globalization and internationalization;
- methodology of scientific knowledge;
- achievements of world and Kazakhstani science in the relevant field;
- (realize and accept) the social responsibility of science and education;
- fluent foreign language for scientific communication and international cooperation;

3) *be able to:*

- organize, plan and implement the scientific research process;
- analyze, evaluate and compare different theoretical concepts in the field of study and draw conclusions;
- analyze and process information from various sources;
- conduct independent scientific research characterized by academic integrity, based on modern theories and methods of analysis;
- generate your own new scientific ideas, communicate your knowledge and ideas to the scientific community, expanding the boundaries of scientific knowledge;
- choose and effectively use modern research methodology;
- plan and predict your further professional development;

4) *have the skills:*

- critical analysis, evaluation and comparison of various scientific theories and ideas;
- analytical and experimental scientific activities;
- planning and forecasting research results;
- oratory and public speaking at international scientific forums, conferences and seminars;
- scientific writing and scientific communication;
- planning, coordinating and implementing scientific research processes;
- systematic understanding of the field of study and demonstrate the quality and effectiveness of the selected scientific methods;
- participation in scientific events, fundamental scientific domestic and international projects;
- leadership management and team management;

- responsible and creative attitude towards scientific and scientific-pedagogical activities;
- conducting patent searches and experience in transferring scientific information using modern information and innovative technologies;
- protection of intellectual property rights to scientific discoveries and developments;
- free communication in a foreign language;

5) *be competent:*

- in the field of scientific and scientific-pedagogical activities in conditions of rapid updating and growth of information flows;
- in conducting theoretical and experimental scientific research;
- in setting and solving theoretical and applied problems in scientific research;
- in conducting a professional and comprehensive analysis of problems in the relevant field;
- in matters of interpersonal communication and human resource management;
- in matters of university training of specialists;
- in conducting examination of scientific projects and research;
- in ensuring continuous professional growth.

3.2 Requirements for research and development work for a student in the Doctor of Philosophy (PhD) program:

- 1) compliance with the main issues of the doctoral educational program on which the doctoral dissertation is being defended;
- 2) is relevant and contains scientific novelty and practical significance;
- 3) is based on modern theoretical, methodological and technological achievements of science and practice;
- 4) is based on modern methods of data processing and interpretation using computer technology;
- 5) is carried out using modern scientific research methods;
- 6) contains research (methodological, practical) sections on the main protected provisions.

3.3 Requirements for organizing practices:

The internship is carried out with the aim of developing practical skills in scientific,

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scientific-pedagogical and professional activities.

The doctoral educational program includes:

- 1) teaching and research practice - for students in the Doctor of Philosophy program;
- 2) industrial practice – for students in a specialized doctoral program.

During the period of teaching practice, doctoral students, if necessary, are involved in conducting classes in undergraduate and graduate courses.

The doctoral student's research practice is carried out with the aim of studying the latest theoretical, methodological and technological achievements of domestic and foreign science, as well as consolidating practical skills, applying modern methods of scientific research, processing and interpreting experimental data in dissertation research.

The doctoral student's practical training is carried out with the aim of consolidating the theoretical knowledge acquired during the training process and improving the professional level.

The content of research and production practice is determined by the topic of the doctoral dissertation.

4 Working curriculum of the educational program

4.1.

5 Descriptors of the level and scope of knowledge, abilities, skills and competencies

The third level descriptors within the Comprehensive Qualifications Framework of the European Higher Education Area (CQ-EHEA) reflect learning outcomes that characterize the student’s abilities:

- 1) demonstrate a systematic understanding of the field of study, mastery of skills and research methods used in the field of software development;
- 2) demonstrate the ability to think, design, implement and adapt a substantial research process with a scientific approach;
- 3) contribute with their own original research to expand the boundaries of the scientific field, which deserves publication at the national or international level;
- 4) critically analyze, evaluate and synthesize new and complex ideas;
- 5) communicate your knowledge and achievements to colleagues, the scientific community and the general public;
- 6) promote, in academic and professional contexts, the technological, social or cultural development of society based on knowledge.

In the process of mastering the educational program, a Doctor of Philosophy must have the following key competencies.

A – knowledge and understanding:

A1 – Programming languages and systems used for data analysis and building intelligent systems;

A2 – Models, methods and types of data analysis;

A3 – Principles and types of artificial intelligence;

A4 - machine learning methods

A5 – Techniques for modeling, composition and decomposition of systems;

A6 – Methods for designing data processing processes;

A7 – Methods and organization of scientific activities;

A8 – Data processing models;

A9 – Basic approaches, tools and models for managing project activities;

B – application of knowledge and understanding:

B1 - Analysis of the subject area, determination of goals, objectives and methods for achieving the planned result of the project/research;

- B2 - Determining deadlines for completing tasks, creating specifications of requirements and technical specifications;
- B3 - Formalization of tasks, determining the priority of their implementation;
- B4 - Selection of optimal methods and models for solving problems;
- B5 - Planning the stages of the project;
- B6 - Domain modeling;
- B7 - Determination of functional and operational requirements for system components;
- B8 — Maintaining protocols of project implementation;
- B9 — Generation of reporting documentation;
- B10 - Creation of data mining systems;
- B11 — Creation of decision-making systems based on Artificial Intelligence models

C – formation of judgments:

- C 1 — About trends in IT
- C 2 - On the applicability of tools and technologies to solve the problem
- C 3 — On the adequacy of the designed model
- C4 - On the effectiveness of the methods and models used
- C5 - About models, methods and algorithms for intelligent data processing

D – personal abilities :

- D 1 - Ability to set goals and plan ways to achieve them
- D 2 — Ability to conduct project/operational activities
- D3 - Ability to conduct scientific research
- D 4 — Ability to organize the work of the IT department
- D5 - Ability to organize work on collecting, storing and processing information used in the field of professional activity

ECTS Diploma Supplement

The application was developed according to the standards of the European Commission, Council of Europe and UNESCO/CEPES. This document serves only for academic recognition and is not an official confirmation of an educational document. Not

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valid without a higher education diploma. The purpose of completing the European Annex is to provide sufficient information about the diploma holder, the qualifications he has received, the level of this qualification, the content of the training program, the results, the functional purpose of the qualification, as well as information about the national education system. The application model used to transfer grades uses the European Credit Transfer or Transfer System (ECTS).

The European Diploma Supplement provides an opportunity to continue education at foreign universities, as well as confirm national higher education for foreign employers. When traveling abroad for professional recognition, additional legalization of an education diploma will be required. The European Diploma Supplement is completed in English upon individual request and is issued free of charge.

7 Description of disciplines

English for Research Purposes

CODE – LNG301

CREDIT – 6 (0/0/3)

PREREQUISITE – ENGLISH LEVEL C2/B2

PURPOSE AND OBJECTIVES OF THE COURSE

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Introduce students to the world of scientific writing to more effectively develop their scientific writing skills.

BRIEF DESCRIPTION OF THE COURSE

The course aims to develop writing, reading and speaking skills, and to communicate progress in their research to support ideas rather than simply summarizing other people's work, and to encourage students to take a variety of approaches to their own learning.

KNOWLEDGE , ABILITIES, SKILLS AT COMPLETION OF THE COURSE

Understand basic information and language of scientific presentations; understand how the material is organized, listen to the main points of scientific speech, review the text to understand its main idea, style and purpose; predict the content of a text, scan text for specific information, take notes and use them to write summaries, analyze the structure of a research paper, recognize the cohesion of paragraphs, organize information logically, write research papers in an area of study, participate in discussion, offer and respond to opinions.

Scientific Python

CODE – LNG301

CREDIT – 6 (2/0/1)

PREREQUISITE – ENGLISH LEVEL C2/B2

PURPOSE AND OBJECTIVES OF THE COURSE:

The purpose of studying this discipline is for students to master the Python language and data processing and visualization libraries necessary in the process of scientific research and data analysis

BRIEF DESCRIPTION OF THE COURSE

Python is the most common programming language for solving data processing problems. This is due to its simplicity and intuitive syntax, which abstracts the connection with the hardware of the computer with a strong emphasis on creating high-level algorithms and data processing systems. The course provides a brief overview of the syntactic features of the language and the strengths of its application in data processing tasks.

The course focuses on mechanisms for working with data, such as: loading, transformation, analysis, data interpretation and data visualization. The basic methods of loading and analyzing data sets based on the Pandas library , working with matrices and matrix operations based on the NumPy library , and data visualization tools Matplotlib are studied .

KNOWLEDGE, ABILITIES, SKILLS AT COMPLETION OF THE COURSE

As a result of completing the course, students will receive the necessary knowledge about the Python language. Gain knowledge in the field of programming matrix operations and working with data. They will learn to use tools for loading, filtering, processing, and interpreting data. Learn to use effective methods when writing program code in Python.

Big Data Processing

CODE – LNG301

CREDIT – 6 (2/0/1)

PREREQUISITE – ENGLISH LEVEL C2/B2

PURPOSE AND OBJECTIVES OF THE COURSE

The goal of the discipline is to master the principles and obtain practical skills in organizing and technologies for storing, transforming and analytical processing of big data. Study of various distributed computing models.

The objectives of the course are to develop skills in researching the use of tools for working with big data in information systems to solve practical problems.

BRIEF DESCRIPTION OF THE COURSE

The discipline examines the theoretical and practical aspects of using big data technologies in information systems. The lecture course examines trends in the development of infrastructure solutions for processing and storing big data.

KNOWLEDGE , ABILITIES, SKILLS AT COMPLETION OF THE COURSE

must know:

- basic principles of using big data in enterprise architecture;
- basic methods of analytical processing of big data;

should be able to:

- use MapReduce technologies and software built on the basis of software when working with big data

Advanced Neural Networks Models

CODE – LNG301

CREDIT – 6 (2/0/1)

PREREQUISITE – ENGLISH LEVEL C2/B2

PURPOSE AND OBJECTIVES OF THE COURSE:

The purpose of studying this discipline is an in-depth study of the theoretical foundations of constructing artificial neural networks, studying the mathematical model for constructing networks with backpropagation of errors, methods for optimizing training and convergence. Study of various neural network topologies.

BRIEF DESCRIPTION OF THE COURSE

Currently, artificial neural networks are widely used in machine learning tasks. This is due to innovative models and technological progress that allows them to perform trillions of operations per second using specialized processors. Artificial neural networks are built in an attempt to resemble biological prototypes. The mathematical model is based on linear algebra operations. The problems that neural network architects face are the selection of a model that best meets the requirements of the subject area and the solution of the problem. The process of modeling new topologies of artificial neural networks is a labor-intensive task, but training and optimization of such networks, as well as performance testing, is no less labor-intensive .

KNOWLEDGE, ABILITIES, SKILLS AT COMPLETION OF THE COURSE

As a result of completing the course, students will receive basic knowledge about artificial neural networks. Learn to create models of the simplest perceptron, a multilayer neural network. Explore learning models and convergence problems. Get acquainted with problems of dimensionality of feature space. This course is a theoretical foundation for continuing to apply practical skills in machine learning.

Machine Learning & Deep Learning

CODE – LNG301

CREDIT – 6 (2/0/1)

PREREQUISITE – ENGLISH LEVEL C2/B2

PURPOSE AND OBJECTIVES OF THE COURSE

The goal of the course is to master the basic theory and practice of machine learning methods based on widely used open access libraries. Learn to apply machine learning models in practical software development problems.

Main objectives of the course:

- Study the main machine learning models and the problems they solve
- Gain knowledge and practical skills in using machine learning to build classification, prediction and data clustering systems
- Explore modern deep learning models and methods
- Gain practical skills in applying deep learning models

BRIEF DESCRIPTION OF THE COURSE

The course focuses on machine learning and deep learning models. As a field within machine learning, deep learning models demonstrate a quantitative-qualitative transition in the quality of data analysis. New models and their properties require separate study and practice in tuning the metaparameters of such models.

KNOWLEDGE , ABILITIES, SKILLS AT COMPLETION OF THE COURSE

Upon completion of the course students will:

Understand

- Features of deep learning models
- Current directions of research in the field of AI

Know

- Objectives and applications of deep learning models

Be able to

- Use machine learning models

The doctoral educational program includes:

- research practice;
- industrial practice .

The doctoral student's research practice is carried out with the aim of studying the latest theoretical, methodological and technological achievements of domestic and foreign science, as well as consolidating practical skills, applying modern methods of scientific research, processing and interpreting experimental data in dissertation research.

The doctoral student's practical training is carried out with the aim of consolidating the theoretical knowledge acquired during the training process and improving the professional level.

The doctoral student's research work must:

- correspond to the main issues of the specialty in which the doctoral dissertation is being defended;
- be relevant, contain scientific novelty and practical significance;
- be based on modern theoretical, methodological and technological achievements of science and practice;
- be based on modern methods of data processing and interpretation using computer technology;
- be carried out using modern scientific research methods;
- contain research (methodological, practical) sections on the main protected provisions.

The experimental research work of a doctoral student must:

- correspond to the main issues of the specialty in which the doctoral dissertation is being defended;
- be relevant, contain scientific novelty and practical significance;
- be based on modern achievements of science, technology and production and contain specific practical recommendations, independent solutions to management problems of a complex, cross-functional nature;
- carried out using advanced information technologies;
- contain experimental and research (methodological, practical) sections on the main protected provisions.

Preparation and defense of a doctoral dissertation

CODE -

CREDIT – 4

PRE-REQUISITE – no

PURPOSE AND OBJECTIVES OF PREPARATION AND DEFENSE OF THE DISSERTATION

A dissertation is a qualifying scientific work in a specific specialty of an educational program for the preparation of a Doctor of Philosophy (PhD) .

The topic of the dissertation must be related to priority areas of scientific development and/or government programs, or programs of fundamental or applied research. The content of the dissertation, the goals and objectives set, and the scientific results obtained must strictly correspond to the topic of the dissertation.

The dissertation is carried out in compliance with the principles of independence, internal unity, scientific novelty, reliability and practical value.

The purpose of preparing and defending a dissertation is for the doctoral student to master the skills of independently conducting scientific research and competently presenting the research results.

The tasks of preparing and defending a dissertation are: setting research goals, theoretical and experimental research of the object, developing control algorithms and synthesizing a control system.

SUMMARY OF THE DISSERTATION

The main part of the dissertation must contain:

- choice of direction of research, including justification for the direction of research, methods for solving problems and their comparative assessment, description of the selected general methodology for conducting research work;
- setting the goal, object and subject of research, research objectives;
- the process of theoretical and (or) experimental research, including determining the nature and content of theoretical research, research methods, calculation methods, justification for the need for experimental work, operating principles of the developed objects, their characteristics;
- generalization and assessment of research results, including an assessment of the completeness of the solution to the problem and proposals for further areas of work, assessment of the reliability of the results obtained and their comparison with similar results of domestic and foreign work.

Each section of the dissertation should end with main conclusions and form the basis for the next section.

The presentation in the main part of the dissertation must be strictly substantiated, holistic and logical. Spelling, grammatical and punctuation errors should not be allowed in the dissertation. The style of presentation of the dissertation text must be correct from a scientific point of view. No one's emotional judgments and statements, expressions from fiction, everyday expressions, jargon, etc. are allowed.

ACQUIRED KNOWLEDGE , SKILLS AND SKILLS

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The dissertation is written independently, contains a set of new scientific results and provisions put forward by the author for public protection and testifies to the author's personal contribution to science. New solutions proposed by the author must be reasoned and evaluated in comparison with known solutions.

A dissertation of applied significance provides information on the practical use of the scientific results obtained by the author, confirmed by copyright certificates, patents and other official documents, and a dissertation of theoretical significance provides recommendations for the use of scientific findings.

The main content of the dissertation is published in scientific, scientific-analytical and scientific-practical publications.

The main scientific results of the dissertation for the degree of Doctor of Philosophy (PhD) are published in at least 7 (seven) publications on the topic of the dissertation, including at least 3 (three) in scientific publications recommended by the authorized body, 1 (one) in international scientific publication, which, according to the information database of the Thomson Reuters company (ISI Web of Knowledge , Thomson Reuters) non-zero impact factor or included in the Scopus database , 3 (three) in the proceedings of international conferences, including 1 (one) in the proceedings of foreign conferences.

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