Ministry of Science and Higher Education of the Russian Federation

Federal State Autonomous Institution of Higher Education

"National Research Nuclear University "MEPhI"

INSTITUTE OF ENGINEERING PHYSICS FOR BIOMEDICINE

DEPARTMENT OF COMPUTER MEDICAL SYSTEMS

APPROVED НТС ИФИБ

Protocol No. 3.1

dated 30.08.2024

ACADEMIC COURSE OUTLINE

ARTIFICIAL INTELLIGENCE IN MEDICINE

Educational program track (speciality)   [1] 31.05.01 General Medicine

Semester	Labour input, credits	Total course academic, hours	Lectures, hrs.	Practical sessions, hrs.	Laboratory sessions, hrs.	In the form of practical studies, hrs.	Independent studies, hrs.	Independent studies monitoring, hrs.	Course progress, Exam/Pass-fail exam/Term
8	3	108	18	18	0		72	0	PFE
Total	3	108	18	18	0	0	72	0	

ABSTRACT

The rapid development of digital technologies and cybernetics, the use of large amounts of data, the increase in the possibilities of Internet technologies, the process of integrating information and communication technologies into various spheres of human activity have caused a large-scale digital transformation of the world community. In science, technology, medicine, education, economics, management, business and other areas, methods and means of artificial intelligence (AI) are being developed and implemented at an accelerated pace. Artificial intelligence technologies in medicine cover areas of diagnosis, treatment, rehabilitation, medical examination and are aimed at dramatically improving the quality of medical care for the population. The department "Computer Medical Systems" of the National Research Nuclear University "MEPhI" carries out fundamental and applied research in the field of oncological diagnostics using methods and means of artificial intelligence and the introduction of developments in clinical practice. The effectiveness of artificial intelligence is determined by the independence of the type of diagnostics, the size of the investigated objects (macro-, micro-, nano-) with minimal personnel, financial and time resources - the most important indicators of our time. The development of artificial intelligence systems requires an interdisciplinary approach to the education of doctors. This determines the content of the course "Artificial Intelligence in Medicine".

1.   ACADEMIC COURSE GOALS AND OBJECTIVES

The purpose of the discipline is to explain the principles of the artificial intelligence in medicine use.

2.   PLACE OF THE ACADEMIC COURSE IN THE MAIN HIGHER EDUCATION CURRICULUM

The discipline "Artificial intelligence in medicine" belongs to the section of mathematical and natural science disciplines of the MEP (main educational program).

3.   DEVELOPED COMPETENCIES AND INTENDED LEARNING OUTCOMES

Universal and/or general professional competencies:

Competency code and title	Code and title of competency-based rubrics
ОПК-10 [1] – Capable of understanding the principles of modern information technologies and using them to solve professional tasks.	З-ОПК-10 [1] – Know: - rules for working with the information systems and telecommunications network "Internet"; - main medical information systems. У-ОПК-10 [1] – Be able to: - use information systems and the "Internet" information and telecommunications network in professional activities while complying with information security rules. В-ОПК-10 [1] – Possess skills in: - practical application of information and communication technologies, telemedicine technologies, and medical information systems, considering basic information security requirements, as well as skills in using intelligent computer medical systems.

4. PEDAGOGIC POTENTIAL OF THE COURSE

Pedagogic tracks/objectives	Pedagogic goals (code)
Professional education	Establishing conditions for: formation of culture of information security (B23)
Professional education	Establishing conditions for: formation of motivation to improve the quality of medical care to the population and the desire to follow the rules and norms of interaction between the doctor, colleagues and the patient, contributing to the creation of the most favorable environment for the patient's recovery (B34)

5. ACADEMIC COURSE STRUCTURE AND CONTENT

Academic course sections, their scope, terms of study and assessment:

No.	Academic course section name	Weeks	Lectures/ Practical (seminars)/ Laboratory sessions, hrs.	Compulsory current assessment (form*, week)	Maximum grade per section**	Section assessment (form*, week)	Competency-based rubrics
	8 Semester						
1	The first section	1-8	9/9/0		25	SA-8	З-ОПК-10, У-ОПК-10, В-ОПК-10
2	The second section	9-14	9/9/0		25	SA-15	З-ОПК-10, У-ОПК-10, В-ОПК-10
	Totals for 8 Semester		18/18/0		50		
	Assessment events for 8 Semester				50	PFE	З-ОПК-10, У-ОПК-10, В-ОПК-10

* – abbreviated name of assessment

** – 100 maximum points per semester including a pass/fail exam and (or) an exam

Abbreviated current assessment forms and section assessment

Abbreviation	Full name
SA	Summative assessment
PFE	Pass/fail examination

SYLLABUS

Weeks	Topics / Content	Lect., hrs.	Pr./sem., hrs.	Lab., hrs.
	8 Semester	18	18	0
1-8	**The first section**	9	9	0
1	**LECTURE 1. INTRODUCTION. ARTIFICIAL INTELLIGENCE IN MEDICINE.**	All		
		2	0	0
	Basic concepts. Terminology. Information. Measuring	Online		
	information. Information systems. Medical Informatics. Digital medicine: a modern stage. Artificial intelligence(AI): history, main directions - pattern recognition, knowledge bases, expert systems. Rapid development of applied intellectual interdisciplinary systems in the XXI century. The state of work. The exceptional importance of AI in medicine in solving complex problems with large amounts of data on the stages of diagnosis, treatment, reabilitation, and medical examinations. The role of intelligent systems - computer systems for supporting medical decision - making.Strategy of interdisciplinary education in the field of artificial intelligence. Discussion of approaches to the problems of artificial intelligence. Examples of the use of AI in the clinical practice of the FMBA of Russia. (Developments of the Department of Computer Medical Systems of MEPhI). The purpose and objectives of the course.	0	0	0
2 - 6	**LECTURES 2-6. COMPUTER MEDICAL SYSTEMS: EVOLUTION FROM TRADITIONAL COMPUTER SCIENCE TECHNOLOGIES TO HIGH-TECH AND INTELLIGENT ARCHITECTURES.**	All		
		10	0	10
	Topic 1. Computers. Terminology. Architecture. Classification.	Online		
	Micro-mini-super computers. Servers. Workstations. Personal computers (PCs). Computer peripherals. Connecting a webcam, transmitting data from the camera over the network, organizing audio and video calls and consultations. The main characteristics of computers. Technical, software, information, computer support. Principles of creating presentations and working with a word processor (Microsoft Word). Practical advice for future doctors. Electrical and information security when working with a computer. Examples of modern computers. Prospects for the development of computers (quantum, biological (molecular), neuro – computers) Topic 2. Medical information systems (MIS). Basic concepts. Terminology. Purpose of the MIS. Variety of IIA classifications. Classification of IIAs by management levels: clinical, institutional, territorial, and federal levels. Classification of MIS by the nature of the tasks to be solved: information-search, diagnostic, therapeutic, information-measuring and control, predictive systems. The generalized structure of the MIS. Subsystems of MIS. Tasks of clinical MIS. Examples of MIS. Computer medical history. Automated workplace (AWP) of a doctor. Topic 3. Databases. Basic concepts. Terminology. Data. Databases (DB). Appointment. Data structures (hierarchical, network, relational, object-oriented). Database management	0	0	0

	systems DBMS. Classification of DBMS (by structure, method of placement, method of access to databases, type of stored data). Characteristics and selection of the DBMS. User problems. Popular relational databases (SQLite, MySQL, PostgreSQL, Oracle, etc.). Principles of creating databases.Examples of medical databases. Topic 4. Knowledge bases. Basic concepts. Terminology. Knowledge. Terminological problems. The importance of knowledge bases (KB) as the foundation of intelligent medical systems. Structuring of knowledge. The process of creating a knowledge base. The stages of the design BL. Examples of practical application of medical BZ in oncological diagnostics (histology, cytology, hematology) - developments of the Department of Computer Medical Systems of MEPhI. Topic 5. High-tech medical systems (IUDs). Basic concepts. Terminology. Distinctive features of the Navy. The field of application of the modern Navy. Classification of the IUD. Diagnostic IUDs. Therapeutic IUDs. Examples of IUDs. Diagnostic tomographic complex of PET/CT. Da Vinci robotic surgical complex. Topic 6. Intelligent medical systems (IMS). The architecture of the IMS. Principles of building systems for recognizing medical objects, reference knowledge bases, and expert systems. Neural network architectures in medicine. Discussion of modern approaches to the creation of IMS. Examples from clinical practice.			
7 - 8	**LECTURES 7-8. APPLICATION OF MATHEMATICAL STATISTICS FOR MEDICAL DATA PROCESSING.** Basic concepts of probability theory and mathematical statistics. Laws of distribution of random variables. The role of mathematical statistics in medicine. Principles of statistical processing of medical data. Examples of statistical data analysis packages MS Excel; SPSS (Statistical Package for Social Science), Statistics, PSPP; STATISTICA. Practical examples of statistical data analysis in the field of oncology (developments of the Department No. 46 "Computer Medical Systems" of MEPhI).	All		
		4	0	6
		Online		
		0	0	0
9-14	**The second section**	9	9	0
9 - 11	**LECTURES 9-11. SYSTEMS OF DIGITAL PROCESSING OF MEDICAL IMAGES. PRINCIPLES OF CONSTRUCTION.** Topic 1. Image. Basic concepts. Terminology. Non-identity of the object and its image. The classification of images is based on linear dimensions, time variation, continuity, space dimension, and the physical nature of signal generation. Practical examples. Vision. The human eye. Light-sensitive cells. The rods and cones. Spectral sensitivity of the eye. The visibility curve. Color in medicine. Practical examples. The RGB color model. An experiment to determine the RGB coordinates of monochromatic radiation for different wavelengths. Negative coordinates in RGB. Models XYZ,	All		
		4	0	8
		Online		
		0	0	0

	HSV, Lab. Practical examples. Topic 2. Technical means of forming, registering and reproducing images. Practical examples. Digital camera. X-ray machine. ULTRASOUND, CT, MRI, PET-CT systems. A television (computer) monitor. Multimedia projector. The CMYK color model. The printer. The resolution of the image in terms of space and signal level. Digital image. Sampling, quantization, and encoding of the image signal. Pixel. Archiving images. Image file formats. Raster and vector formats. Lossless and lossy image compression. Topic 3. Image processing. The stages of image recognition: pre-processing, description, and classification. The tasks of pre-processing the images. Image enhancement. Filtering noise and interference. Compensation for uneven background. Change the brightness and contrast. Non-linear contrast. Gamma correction. Color correction. Underline borders. Blurry masking. The concept of an object in an image. Selection of objects. The selection boundaries. Segmentation. Methods for describing the object. Color, morphological, and textural characteristics of objects. Methods of image classification. Practical examples.			
12	**LECTURE 12. TELEMEDICINE**	All		
	Evolution of distributed computing systems.Methods of data transmission over physical lines. The concept of the open	2	0	0
		Online		
	systems approach, standartization problems, multi-level approach, protocol stack. Global computing networks, access methods, current state and near-term prospects. Internet: a brief history, principles of construction, addressing, basic applications. The main trends in the development of programming languages. Classification and brief description of modern programming languages. Local area networks, types of link layer protocols, technical means used by LAN. The main provisions of the law on telemedicine; the basic principles of building telemedicine systems on the example of the telemedicine system Rosatom-FMBA-MEPhI	0	0	0
13 - 14	**LECTURES 13-14. INTERDISCIPLINARY TECHNOLOGIES OF ARTIFICIAL INTELLIGENCE IN CLINICAL PRACTICE. ONCOMORPHOLOGY. JOINT EXPERIENCE OF THE MEPhI RESEARCH INSTITUTE. ROSATOM, N. N. BLOKHIN NATIONAL RESEAR**	All		
		6	0	6
		Online		
	Topic 1. Oncomorphology. Basic concepts. Terminology. Classification of diagnostic research methods in oncomorphology. Histological methods. Cytological methods. Histological diagnostics is the "gold diagnostic standard". Routine diagnostics. Urgent (intraoperative) diagnosis. Digital systems of oncomorphology. Interdisciplinary nature of work in the field of creating intelligent systems of oncodiagnostics. Interdisciplinary problems and ways to solve them. Topic 2. Strategy for the development of intelligent systems of	0	0	0

| | oncomorphology – clinical, research, educational, informational, telemedicine. Features of the strategy. Analysis of digital system architectures. ATLANT is a basic artificial intelligence system in digital oncomorphology. Intelligent histological diagnostic systems (HD). Object environment of digital DG systems:type of histological material, type of preparation, type of digital images. Methods of preparation of drugs. Hardware architecture of digital DG systems. Practical examples.

Topic 3. Principles of building intelligent clinical systems of histological oncological diagnostics (hereinafter referred to as SYSTEMS) when performing procedures for recognizing tumors, forming knowledge bases and implementing expert technologies.
The main principle is that the methods of conceptual construction of SYSTEMS correspond to the scheme of classical (traditional) training of a pathologist.
Principles of the procedure of recognition. Automatic mode of recognition of tumor characteristics at the stage of analysis of digital images of macropreparations. Interactive (with the participation of a doctor) mode of recognition of the nosological affiliation of the tumor at the crucial stage-the analysis of digital images using reference knowledge bases and expert systems of micro-drugs. Quantitative system of signs in the analysis of macropreparations. Quantitative system of signs (by scaling method) at the stage of analysis of micro-preparations. Practical examples.
Principles of formation of reference (reference) knowledge bases SYSTEMS. Knowledge. Knowledge requirements: structuring information about standard samples – unique samples of histological micro-preparations with the expert's determination of the characteristics of the composition and properties of micro-preparations.
A conceptual model of knowledge. Elements of the knowledge model: characteristics of the composition and properties of histological micro-preparations; types of reference samples (information about the structure of nosological forms) for this organ. Characteristics of the composition and properties of standard samples of histological micro-preparations of tumors (for example, the thyroid gland). Characteristics: general properties of histological material, tissue and cell structures. The structure of nosological forms: norm, pathology; pathology: tumor, non-tumor; tumor: benign, malignant.
Examples of practical development of reference knowledge bases for intelligent clinical systems of histological cancer diagnostics. Reference databases of histological micro-preparations for eight organs – thyroid gland, mammary gland, pancreas, stomach, lymph nodes, esophagus, kidneys, colon.
Principles of implementation of expert systems. A model for conducting measurements in systems using expert technologies. The composition of the structural elements of the model. Log in | | | |

to the expert system. The object of measurement (histological micropreparation). Registration of the measurement object by the microscope-camera-computer system. Measurement of the characteristics of microimages - qualitative informative signs of tissue and cellular structures with the participation of a pathologist. Determination of the closest cases (the procedure for determining the variants of the greatest similarity of the measured characteristics of the tissue and cell structures of the micro-product under study with similar characteristics of standard samples in the reference knowledge base). Comparative statistical analysis (determining the frequency of occurrence of a set of characteristics of the object under study and the type of reference samples from the reference knowledge base). The output of the expert system (the recommended set of diagnoses according to the probabilistic rating scale). Practical examples.

Topic 4. Information about effectiveness of implementation of artificial intelligence systems in digital oncomorphology ATLANT at the medical units of the FMBA of Russia in cities with seven nuclear power plants.

Topic 5. Directions of development of intellectual technologies in medicine. basic provisions. problems and solutions. Integrated systems of diagnostic (by diagnostic methods), and therapeutic (by treatment methods) knowledge bases and expert systems to support management decision-making. Intelligent systems for molecular diagnostics and nanotechnology – the Foundation for personalized medicine. Information systems of genetic certification of the population. Artificial intelligence technologies in the field of improving the quality of doctors. Information and legal systems in medicine. Examples of reference knowledge bases on histological, cytological, and hematological preparations for morphological oncodiagnostics (Developed by the Department of Computer Medical Systems of MEPhI together with the N. N. Blokhin National Research Medical Center of Oncology, FMBA of Russia, and RMAN-PO).
Intelligent systems for 3D molecular diagnostics of tumors using atomic force microscopy (AFM). (Development of the Nanotechnology Laboratory of the V. N. Orekhovich Institute of Biomedical Chemistry together with the Department of Computer Medical Systems of the MEPhI National Research Nuclear University).

Abbreviated names of online options:

Abbreviation	Full name
EC	E-course
FtM	Full-text material
FtL	Full-text lectures

VM	Video materials
AM	Audio materials
Prs	Presentations
T	Tests
ERM	E-reference materials
IS	Interactive site

LABORATORY (LAB) SESSIONS TOPICS

Weeks	Topics / Content
	8 Semester
1 - 2	**Laboratory work №1** Work with a personal computer.
3 - 5	**Laboratory work №2** Database. Intelligent knowledge bases. Building an educational medical knowledge base using the graphical manager SQLitestudio. Research of DBMS operations.
6 - 8	**Laboratory work №3** Mathematical statistics. Medical data operations with the example of the program "System of statistical analysis for the recognition of blood cells."
9 - 11	**Laboratory work №4** Investigation of intelligent medical microscopic preparations processing images methods.
12 - 14	**Laboratory work №5** Artificial intelligence system ATLANT in digital oncomorphology .

6.   EDUCATIONAL TECHNOLOGIES

Most of the time in the course is devoted to practical exercises in the computer class. The lecture course uses multimedia tools for a more visual presentation of the studied solution methods.

7.   ASSESSMENT TOOLKIT

The assessment toolkit ensures verification of the intended learning outcomes achievement (competency-based rubrics) using current, midterm and interim assessment of the course.

The link between developed competencies and their assessment is presented in the following table:

Competency	Achievement rubrics	Assessment activity (Syl 1)
ОПК-10	З-ОПК-10	PFE, SA-8, SA-15
	У-ОПК-10	PFE, SA-8, SA-15
	В-ОПК-10	PFE, SA-8, SA-15

Educational achievement rubrics scales

The scale of each assessment activity varies from 0 to the maximum established point, inclusive. The final assessment of the course is performed on a 100-point scale and represents the sum of the points earned by the student in the section assessments, framework of current and interim assessment.

Sections and interim assessments are considered passed when the student achieves a minimum score equal to 60% of the maximum. The final grade is assigned only upon passing all sections and the interim assessment.

The final grade is assigned in accordance with the following scale:

Total score	Rating on a 4-point scale	Pass/fail examination	ECTS assessment
90-100	5 – «excellent»		A
85-89	4 – «good»	«pass»	B
75-84			C
70-74			D
65-69	3 – «satisfactory»		
60-64			E
below 60	2 – «fail»	«fail»	F

An "excellent" grade indicates a deep and solid mastery of the program material by a student who presents their answers consistently, clearly, and logically, is able to closely link theory with practice, and uses materials from monographic literature in their answers.

A "good" grade corresponds to a student's solid knowledge of the material, who presents their answers competently and to the point, without any significant inaccuracies.

A "satisfactory" grade corresponds to the basic level of mastery of the material by the student, in which the main material has been mastered, but its details have not been assimilated, the answers contain inaccuracies, insufficiently correct wording and logical inconsistencies.

A grade "pass" corresponds to at least a basic level of mastery of the program material, in which the student possesses the necessary knowledge, skills, and abilities, and is able to apply theoretical principles to solve typical practical problems.

A grade "fail" is given to a student who lacks a significant understanding of the curriculum material, makes significant errors in their answers, or fails all required assignments. These students are generally unable to continue their studies without additional classes.

8. ACADEMIC COURSE EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT

CORE READING:

1. 004 Ш97 Базы данных : учебник, Шустова Л.И., Тараканов О.В., Москва: ИНФРА-М, 2017

2. ЭИ Ф 34 Введение в цифровую обработку биомедицинских изображений : учебное пособие, Федотов А. А., Санкт-Петербург: Лань, 2022

3. ЭИ С 29 Компьютерное зрение. Анализ и обработка изображений : учебное пособие для вузов, Селянкин В. В., Санкт-Петербург: Лань, 2023

4. ЭИ П 95 Методы морфологического анализа изображений : учебное пособие, Чуличко в. А., Пытьев Ю. П., Москва: Физматлит, 2010

5. ЭИ Ф 34 Теория признаков распознавания образов на основе стохастической геометрии и функционального анализа : , Федотов Н. Г., Москва: Физматлит, 2010

FURTHER READING:

SOFTWARE:

No special softwares is required

LMS AND ONLINE RESOURCES

https://online.mephi.ru/

http://library.mephi.ru/

9. LOGISTICAL SUPPORT

Any special logistical support is not required

10. EDUCATIONAL AND METHODOLOGICAL RECOMMENDATIONS FOR STUDENTS

1.1. When implementing the discipline program, educational technologies are used in the form of practical exercises, laboratory work and independent work using Internet resources, methodological developments, educational, popular science and scientific literature.

1.2. When starting to study the discipline, the student should familiarize himself with the goals and objectives of the discipline, the content of the discipline's work program, recommended literary sources, methodological developments in this discipline, available on the educational portal and the website of the department.

2. Recommendations for preparing for practical exercises.

2.1. Preparation for a practical lesson includes ongoing work on educational materials using the recommended basic and additional literature.

2.2. When preparing for practical exercises, theoretical material should be worked out based on recommended literary sources related to this practical lesson.

2.3. During practical classes, give specific, clear answers to the substance of the questions, bring each task to a final solution, demonstrate an understanding of the calculations (analyses, situations) carried out, and contact the teacher in case of difficulties.

3. Independent work of students

3.1. Independent work involves the formation and assimilation of theoretical material based on the study and systematization of textbook materials, official government documents, laws, regulatory and reference materials using information retrieval systems, the Internet.

3.2. Students should be guided by the schedule of independent work defined by the work plan of the discipline and perform all scheduled tasks assigned by the teacher for independent work, and submit them within the prescribed time.

4. Recommendations on preparation and passing of certification in the discipline.

4.1. The assessment of the discipline is based on a point-rating system, which includes ongoing monitoring of academic performance, boundary control in the semester and interim assessment based on the results of mastering the discipline.

4.2. The current control involves checking the students' readiness for classes, for which various test tasks can be used. Passing the control lines is carried out in the middle and end of the semester and can be carried out in the form of test papers, surveys, etc. The stage of intermediate certification based on the results of mastering the discipline generally implies passing the test and self-preparation for it.

11. EDUCATIONAL AND METHODOLOGICAL RECOMMENDATIONS FOR TEACHERS

1.1. When implementing the discipline program, educational technologies are used in the form of lectures, practical exercises and independent work using Internet resources, methodological developments, educational, popular science and scientific literature.

1.2. In the first lesson, the teacher:

introduces students to the goals and objectives of the discipline being taught, determines its place in the educational program, and identifies interdisciplinary connections.;

clarifies the plans of practical (seminar, laboratory) classes in accordance with the work program of the discipline, taking into account the contingent and the level of training of students.;

recommends basic and additional literature for the successful development of the discipline;

brings the knowledge assessment system to the attention of students.

2. Recommendations for the preparation and teaching of the discipline

2.1. Recommendations for the preparation and conduct of practical (seminar) classes:

2.1.1. The purpose of practical (seminar) classes is to provide opportunities for in-depth study of theory, mastering practical skills and developing independent creative thinking among students. At each such lesson, students solve practical problems and demonstrate the results of homework given in the previous lesson.

2.1.2. At each such lesson, students solve practical tasks and demonstrate the results of completing the homework given in the previous lesson.

2.2. Recommendations on the organization of the management of students' independent work

2.2.1. Independent work involves the formation and assimilation of theoretical material based on the study and systematization of textbook materials, official government documents, laws, regulatory and reference materials using information retrieval systems, the Internet.

2.2.2. In the course of guiding the students' independent work, the teacher introduces them to scientific creativity, the search for and solution of urgent modern problems.

2.3. Recommendations for the control of students' knowledge

2.3.1. There is a point rating system for the discipline, which includes ongoing monitoring of academic performance and interim assessment based on the results of mastering the discipline.

2.3.2. The following types of certification are provided for in the discipline: current control, boundary control and final certification.

2.3.3. The current control involves checking the students' readiness for laboratory and practical exercises, various test tasks can be used.

2.3.4. Passing the control lines based on the results of mastering the discipline is carried out in the middle and at the end of the semester.

2.3.5. The intermediate assessment stage based on the results of mastering the discipline generally implies taking the test and preparing for it independently.

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