Federal State Autonomous Educational Institution of Higher Education
"Russian Peoples' Friendship University named after Patrice Lumumba"

Academy of Engineering
(name of the main educational unit (POU) - developer of the EP HE)

COURSE SYLLABUS

ARTIFICIAL NEURAL NETWORKS (REINFORCEMENT LEARNING) / ИСКУССТВЕННЫЕ НЕЙРОННЫЕ СЕТИ (ОБУЧЕНИЕ С ПОДКРЕПЛЕНИЕМ)
(name of discipline/module)

Recommended by the Didactic Council for the Education Field of:

27.04.04 CONTROL IN TECHNICAL SYSTEMS
(code and name of the area of training/specialty)

The discipline is mastered as part of the implementation of the main professional educational program of higher education:

DATA SCIENCE AND SPACE ENGINEERING
(name (profile/specialization) EP HE)

2024

1. GOAL OF DISCIPLINE MASTERING

The discipline “Artificial Neural Networks (Reinforcement Learning)” is included in the master’s program “Data Science and Space Engineering” in the direction 27.04.04 “Control in Technical Systems” and is studied in the 3rd semester of the 2nd year. The discipline is implemented by the Department of Mechanics and Control Processes. The discipline consists of 4 sections and 10 topics and is aimed at studying methods for constructing automatic control systems based on artificial neural networks, mastering methods for solving basic control problems using neural networks, neural network architectures

The goal of mastering the discipline is to teach students methods of constructing artificial neural networks.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline “Artificial Neural Networks (Reinforcement Learning) / Искусственные нейронные сети (обучение с подкреплением)” is aimed at developing the following competencies (parts of competencies) in students:

Table 2.1. List of competencies formed in students when mastering the discipline (results of mastering the discipline)

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
GC-1	Able to critically analyze problem situations based on a systematic approach and develop an action strategy	GC-1.1 Analyzes the task, highlighting its basic components;; GC-1.2 Identifies and ranks the information required to solve the task;; GC-1.3 Searches for information to solve a given problem using various types of requests;;
GC-7	Able to search for the necessary sources of information and data, perceive, analyze, remember and transmit information using digital means, as well as using algorithms when working with data received from various sources in order to effectively use the information received to solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data	GC-7.1 Searches for the necessary sources of information and data, perceives, analyzes, remembers and transmits information using digital means, as well as using algorithms when working with data received from various sources in order to effectively use the received information to solve problems;; GC-7.2 Evaluates information, its reliability, builds logical conclusions based on incoming information and data;; GC-7.3 Proficient in modern digital technologies, methods of searching, processing, analyzing, storing and presenting information (in the field of management in technical systems) in the conditions of the digital economy and modern corporate information culture.;
PC-1	Able to formulate goals and objectives of scientific research in the field of aerospace systems control, select methods and means for solving professional problems	PC-1.1 Knows methods and means of solving scientific research problems in the field of artificial intelligence systems and robotic systems;; PC-1.2 Able to formulate the purpose and objectives of scientific research in the professional field;; PC-1.3 Knows techniques for formulating the goals and objectives of scientific research, knows how to choose methods and means of solving problems of professional activity.;
PC-4	Capable of participating in scientific research and development of design solutions in the field of ballistics, dynamics and spacecraft flight control	PC-4.1 Familiar with the basic methods and approaches used to solve problems in the field of artificial intelligence and robotic systems;; PC-4.2 Knows methods for solving professional problems in the field of artificial intelligence and robotic systems;; PC-4.3 Able to apply mathematical methods and modern information technologies when conducting scientific research.;

3. PLACE OF DISCIPLINE IN THE STRUCTURE OF HE EP

Discipline “Artificial Neural Networks (Reinforcement Learning) / Artificial Neural Networks (Reinforcement Learning)” refers to the part formed by the participants in educational relations of block 1 “Disciplines (modules)” of the educational program of higher education.

As part of the educational program of higher education, students also master other disciplines and/or practices that contribute to achieving the planned results of mastering the discipline “Artificial Neural Networks (Reinforcement Learning)”.

Table 3.1. List of components of EP HE that contribute to achieving the planned results of mastering the discipline

Cipher	**Name of competency**	**Previous disciplines/modules, practices***	**Subsequent disciplines/modules, practices***
GC-7	Able to search for the necessary sources of information and data, perceive, analyze, remember and transmit information using digital means, as well as using algorithms when working with data received from various sources in order to effectively use the information received to solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data	History and Methodology of Science; Information Technology in Mathematical Modeling; Research work / Scientific research work;	Undergraduate practice / Pre-graduate practice;
GC-1	Able to critically analyze problem situations based on a systematic approach and develop an action strategy	History and Methodology of Science; *Artificial Neural Networks (Deep Learning)***; *Artificial Neural Networks (Deep Learning)***; Research work / Scientific research work;	Undergraduate practice / Pre-graduate practice;
PC-1	Able to formulate goals and objectives of scientific research in the field of aerospace systems control, select methods and means for solving professional problems	Research work / Scientific research work; *Artificial Neural Networks (Deep Learning)***; *Artificial Neural Networks (Deep Learning)***; Advanced Methods of Space Flight Mechanics;	Undergraduate practice / Pre-graduate practice;
PC-4	Capable of participating in scientific research and development of design solutions in the field of ballistics, dynamics and spacecraft flight control	Research work / Scientific research work; History and Methodology of Science; Advanced Methods of Earth Remote Sensing;	Undergraduate practice / Pre-graduate practice;

* - to be filled out in accordance with the competency matrix and SUP EP VO

** - elective disciplines/practices

4. SCOPE OF DISCIPLINE AND TYPES OF STUDY WORK

The total labor intensity of the “Artificial Neural Networks (Reinforcement Learning)” discipline is “5” credit units.

Table 4.1. Types of educational work by periods of mastering the educational program of higher education for full-time study.

Type of educational work	**TOTAL,**ac.ch.		**Semester(s)**
			3
Contact work, ac.ch.	*36*		*36*
Lectures (LC)	18		18
Laboratory work (LR)	18		18
Practical/seminar sessions (SZ)	0		0
Independent work of students, ac.ch.	*108*		*108*
Control (exam/test with assessment), academic degree.	*36*		*36*
Total labor intensity of the discipline	**ac.ch.**	***180***	*180*
	credit units	***5***	*5*

5. CONTENT OF DISCIPLINE

Table 5.1. Contents of the discipline (module) by type of academic work

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
Section 1	Introduction to reinforcement learning.	1.1	Structure of a reinforcement learning algorithm.	LK, LR
		1.2	Agent. Policy function. Value function.	LK, LR
		1.3	Model. Types of reinforcement learning environments: deterministic, stochastic with complete and incomplete information, discrete and continuous, episodic and non-episodic, single-agent and multi-agent.	LK, LR
Section 2	Theoretical foundations and methods of reinforcement learning	2.1	Markov chains and Markov processes. Markov decision process.	LK, LR
		2.2	State value functions, Q-function. Bellman equation and optimality. Derivation of the Bellman equation.	LK, LR
		2.3	Dynamic programming. Monte Carlo methods and game theory.	LK, LR
		2.4	Learning from Temporary Differences. TD forecasting. TD training.	LK, LR
		2.5	Q training. SARSA algorithm. (State-Action-Reward-State-Action)	LK, LR
Section 3	Reinforcement Learning Software	3.1	Software packages for implementing neural networks. Tensor Flow	LK, LR
Section 4	Development of artificial neural networks. Symbolic regression methods	4.1	Genetic programming, Cartesian genetic programming, network operator method, variational methods of symbolic regression	LK, LR

* - to be filled out only for full-time education: LC – lectures; LR – laboratory work; SZ – practical/seminar classes.

6. MATERIAL AND TECHNICAL SUPPORT OF DISCIPLINE

Table 6.1. Material and technical support of the discipline

Audience type	Auditorium equipment	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Lecture	An auditorium for conducting lecture-type classes, equipped with a set of specialized furniture; board (screen) and technical means of multimedia presentations.	
Computer class	A computer class for conducting classes, group and individual consultations, ongoing monitoring and intermediate certification, equipped with personal computers ([Parameter] pcs.), a whiteboard (screen) and technical means for multimedia presentations.	
For independent work	An auditorium for independent work by students (can be used for seminars and	

Audience type	Auditorium equipment	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
	consultations), equipped with a set of specialized furniture and computers with access to EIOS.	

* - the audience for independent work of students is MANDATORY!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF DISCIPLINE

Main literature:

1. Sutton Richard S., Barto Andrew G. Reinforcement learning =Reinforcement Learning. — 2nd edition. - M.: DMK press, 2020. - 552 p. — ISBN 978-5-97060-097-9.

2. Rosenblatt, F. Principles of neurodynamics: Perceptrons and the theory of brain mechanisms =Principles of Neurodynamics: Perceptrons and the Theory of Brain Mechanisms. - M.: Mir, 1965. - 480 p.3.

3. A.N.Vasiliev, D.A.Tarkhov. Neuronal modeling. Principles. Algorithms. Applications. SPb.: Publishing House Polytechnic.Univ., 2009. ISBN 978-5-7422-2272-9

4. CCAggarwal. Neural Networks and Deep Learning. A Textbook. Springer International Publishing

5. D.A. Tarkhov. Neural networks. Models and algorithms. M., Radio engineering, 2005. (Scientific series "Neurocomputers and their application", ed. A.I. Galushkin. Book 18.)

Additional literature:

1. DERumelhardt, GEHinton, RJWilliams. Learning representations by back-propagating errors. Nature, 1986, V.323, pp.533-536.

2. Caudill, M. The Kohonen Model. Neural Network Primer. AI Expert, 1990, 25-31.

3. J. J. Hopfield. Neural networks and physical systems with emergent collective computational abilities. Proceedings of National Academy of Sciences of USA, 1982, V.79, No.8, pp.2554-2558.

Resources of the information and telecommunications network "Internet":

1. EBS of RUDN University and third-party EBS, to which university students have access based on concluded agreements

- Electronic library system of RUDN University - EBS RUDN Universityhttp://lib.rudn.ru/MegaPro/Web
- EBS "University Library Online"http://www.biblioclub.ru
- EBS Lawhttp://www.biblio-online.ru
- EBS "Student Consultant"www.studentlibrary.ru
- EBS "Trinity Bridge"

2. Databases and search engines

- electronic fund of legal and regulatory technical documentationhttp://docs.cntd.ru/
- Yandex search enginehttps://www.yandex.ru/
- search systemGoogle https://www.google.ru/
- abstract databaseSCOPUS http://www.elsevierscience.ru/products/scopus/

Educational and methodological materials for students' independent work when mastering a discipline/module:*

1. Course of lectures on the discipline "Artificial Neural Networks (Reinforcement Learning) / Artificial Neural Networks (Reinforcement Learning)."

* - all educational and methodological materials for students' independent work are posted in accordance with the current procedure on the discipline page in TUIS!

8. ASSESSMENT MATERIALS AND POINT-RATING SYSTEM FOR ASSESSING THE LEVEL OF COMPETENCIES FOR A DISCIPLINE

Evaluation materials and point-rating system* for assessing the level of development of competencies (parts of competencies) based on the results of mastering the discipline"Artificial Neural Networks (Reinforcement Learning) / Искусственные нейронные сети (обучение с подкреплением)" are presented in the Appendix to this Work Program of the discipline.

* - OM and BRS are formed on the basis of the requirements of the relevant local regulatory act of RUDN University.

DEVELOPER:

Assistant professor		Saltykova Olga Alexandrovna
Position	*Signature*	*Last name I.O.*

HEAD OF DEPARTMENT:

Head of the department		Razumny Yuri Nikolaevich
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HEAD OF EP HP:

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