

**Federal State Autonomous Educational Institution of Higher Education "Moscow
Institute of Physics and Technology
(National Research University)"**

APPROVED
**Head of the Phystech School of
Applied Mathematics and
Informatics**
A.M. Raygorodskiy

Work program of the course (training module)

course:	Math Basics for Artificial Intelligence/Математические основы искусственного интеллекта
major:	Applied Mathematics and Informatics
specialization:	Modern State of Artificial Intelligence/Современные методы искусственного интеллекта “Pusk” Online and Supplementary Education Centre Chair of Machine Learning and Digital Humanities
term:	1
qualification:	Master

Semester, form of interim assessment: 1 (fall) - Exam

Academic hours: 60 AH in total, including:

lectures: 30 AH.

seminars: 30 AH.

laboratory practical: 0 AH.

Independent work: 90 AH.

Exam preparation: 30 AH.

In total: 180 AH, credits in total: 4

Author of the program: R.G. Neychev, senior professor

The program was discussed at the Chair of Machine Learning and Digital Humanities 05.03.2020

Annotation

Understanding Machine Learning requires fundamental knowledge in mathematical areas such as linear algebra, calculus, optimization, probability and statistics. The Math Refresher course focuses, through practical examples and assignments, on revising the necessary topics that will allow students to join future Machine Learning courses and gain thorough knowledge about modern Artificial Intelligence.

1. Study objective

Purpose of the course

1. Acquire a solid foundation for key mathematical concepts.
2. Get ready to understand Machine Learning algorithms.

Tasks of the course

1. Overview of main topics in Linear Algebra, Optimization Methods, Calculus and Probability Theory.
2. Practical experience in applying mathematical methods in practical tasks.

2. List of the planned results of the course (training module), correlated with the planned results of the mastering the educational program

Mastering the discipline is aimed at the formation of the following competencies:

Code and the name of the competence	Competency indicators
Gen.Pro.C-1 Address current challenges in fundamental and applied mathematics	Gen.Pro.C-1.2 Consolidate and critically assess professional experience and research findings
Pro.C-1 Become part of a professional community and conduct local research under scientific guidance using methods specific to a particular professional setting	Pro.C-1.2 Understand the verification process of software models used to solve related scientific problems
	Pro.C-1.3 Use practical knowledge of scientific argumentation when analyzing a research subject area
Pro.C-2 Understands and is able to apply modern mathematical apparatus and algorithms, the basic laws of natural science, modern programming languages and software; operating systems and networking technologies in research and applied activities	Pro.C-2.1 Demonstrate expert knowledge of research basics in the field of ICTs, philosophy and methodology of science, scientific research methods, and apply skills to use them

3. List of the planned results of the course (training module)

As a result of studying the course the student should:

know:

- Understanding terminology, main concepts in Linear Algebra, Calculus, Optimization and Probability Theory.
- How to solve systems of linear equations and convex optimization problems.

be able to:

- Apply skills to solve a well-designed computational problem.
- Implement the solution in code.

master:

- Methods of theoretical problems solving.

4. Content of the course (training module), structured by topics (sections), indicating the number of allocated academic hours and types of training sessions

4.1. The sections of the course (training module) and the complexity of the types of training sessions

№	Topic (section) of the course	Types of training sessions, including independent work			
		Lectures	Seminars	Laboratory practical	Independent work
1	Linear Algebra basics	8	8		22
2	Calculus basic	6	6		22
3	Optimization basics	8	8		23
4	Probability Theory basics	8	8		23
AH in total		30	30		90
Exam preparation		30 AH.			
Total complexity		180 AH., credits in total 4			

4.2. Content of the course (training module), structured by topics (sections)

Semester: 1 (Fall)

1. Linear Algebra basics

Euclidean spaces.

Vectors. Scalar product. Norms, length and distances. Angles and Orthogonality.

Vector spaces.

Linear independence. (Orthogonal) basis. The dimensionality of a space.

Matrices/

Matrix arithmetics. Determinant. Trace. Rank. Matrix norm. Matrix inverse.

Systems of linear equations.

Gaussian elimination. Linear regression.

Matrix decomposition.

Eigenvalues and eigenvectors Principal Components Analysis.

2. Calculus basic

Univariate functions.

Monotonicity. Convexity. Limit of a function.

Extrema of a function.

First and second derivatives. Chain rule. Extrema.

Integration.

Standard antiderivatives. Change of Variable and Integration by Parts. Definite Integral.

3. Optimization basics

Convex set.

Cone.

Constrained Optimization and Lagrange Multipliers.

Convex optimization.

Numerical optimization.
Gradient Descent.

4. Probability Theory basics

Basic Probability.
(Conditional) probability and Independence. Bayes' theorem.
Discrete Random variables.
Common discrete distributions and their properties.
Random variables properties.
Expectation, variance, covariance and correlation.
Continuous Random variables.
Density. Common continuous distributions and their properties.
Statistics.
Descriptive vs inferential statistics.
Parameter estimation. Method of maximum likelihood.

5. Description of the material and technical facilities that are necessary for the implementation of the educational process of the course (training module)

A standard classroom.

6. List of the main and additional literature, that is necessary for the course (training module) mastering

Main literature

1. Курс аналитической геометрии и линейной алгебры [Текст] : учебник для вузов / Д. В. Беклемишев .— 12-е изд., испр. — М. : Физматлит, 2008, 2009 .— 312 с.

Additional literature

Литература есть на кафедре:

Ian Goodfellow, Yoshua Bengio & Aaron Courville. Deep Learning (Adaptive Computation and Machine Learning series). The MIT Press, 2016

7. List of web resources that are necessary for the course (training module) mastering

<http://dm.fizteh.ru/>

8. List of information technologies used for implementation of the educational process, including a list of software and information reference systems (if necessary)

Multimedia technologies can be employed during lectures and practical lessons, including presentations.

9. Guidelines for students to master the course

1. It is recommended to successfully pass the test papers, as this simplifies the final certification in the subject.
2. To prepare for the final certification in the subject, it is best to use the lecture materials.

Assessment funds for course (training module)

major: Applied Mathematics and Informatics
specialization: Modern State of Artificial Intelligence/Современные методы искусственного интеллекта
“Pusk” Online and Supplementary Education Centre
Chair of Machine Learning and Digital Humanities
term: 1
qualification: Master
Semester, form of interim assessment: 1 (fall) - Exam
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1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
Gen.Pro.C-1 Address current challenges in fundamental and applied mathematics	Gen.Pro.C-1.2 Consolidate and critically assess professional experience and research findings
Pro.C-1 Become part of a professional community and conduct local research under scientific guidance using methods specific to a particular professional setting	Pro.C-1.2 Understand the verification process of software models used to solve related scientific problems
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Pro.C-2 Understands and is able to apply modern mathematical apparatus and algorithms, the basic laws of natural science, modern programming languages and software; operating systems and networking technologies in research and applied activities	Pro.C-2.1 Demonstrate expert knowledge of research basics in the field of ICTs, philosophy and methodology of science, scientific research methods, and apply skills to use them

2. Competency assessment indicators

As a result of studying the course the student should:

know:

- Understanding terminology, main concepts in Linear Algebra, Calculus, Optimization and Probability Theory.
- How to solve systems of linear equations and convex optimization problems.

be able to:

- Apply skills to solve a well-designed computational problem.
- Implement the solution in code.

master:

- Methods of theoretical problems solving.

3. List of typical control tasks used to evaluate knowledge and skills

Example Lab assignment

1. Gram–Schmidt process implementation .

Implement Gram–Schmidt orthogonalization process for the provided set of vectors.

2. Constrained optimization problem solving.

Solve the provided optimization problem with the hard constraints using Lagrange multipliers method.

4. Evaluation criteria

Questions:

1. What is the Taylor series?
2. Describe the convex function properties
3. What is the difference between first order and second order gradient methods?
4. How many unique pairs can be selected from the set of N elements?
5. Describe linear space properties
6. What are the properties of the scalar product?
7. Are metric and scalar product related?
8. What is conditional probability?

Task №1

1. Describe the convex function properties.
2. What is conditional probability?

3. Describe linear space properties.

Task №2

1. What is the difference between first order and second order gradient methods?
2. How many unique pairs can be selected from the set of N elements?
3. What are the properties of the scalar product?

Assessment “excellent (10)” is given to a student who has displayed comprehensive, systematic and deep knowledge of the educational program material, has independently performed all the tasks stipulated by the program, has deeply studied the basic and additional literature recommended by the program, has been actively working in the classroom, and understands the basic scientific concepts on studied discipline, who showed creativity and scientific approach in understanding and presenting educational program material, whose answer is characterized by using rich and adequate terms, and by the consistent and logical presentation of the material;

Assessment “excellent (9)” is given to a student who has displayed comprehensive, systematic knowledge of the educational program material, has independently performed all the tasks provided by the program, has deeply mastered the basic literature and is familiar with the additional literature recommended by the program, has been actively working in the classroom, has shown the systematic nature of knowledge on discipline sufficient for further study, as well as the ability to amplify it on one’s own, whose answer is distinguished by the accuracy of the terms used, and the presentation of the material in it is consistent and logical;

Assessment “excellent (8)” is given to a student who has displayed complete knowledge of the educational program material, does not allow significant inaccuracies in his answer, has independently performed all the tasks stipulated by the program, studied the basic literature recommended by the program, worked actively in the classroom, showed systematic character of his knowledge of the discipline, which is sufficient for further study, as well as the ability to amplify it on his own;

Assessment “good (7)” is given to a student who has displayed a sufficiently complete knowledge of the educational program material, does not allow significant inaccuracies in the answer, has independently performed all the tasks provided by the program, studied the basic literature recommended by the program, worked actively in the classroom, showed systematic character of his knowledge of the discipline, which is sufficient for further study, as well as the ability to amplify it on his own;

Assessment “good (6)” is given to a student who has displayed a sufficiently complete knowledge of the educational program material, does not allow significant inaccuracies in his answer, has independently carried out the main tasks stipulated by the program, studied the basic literature recommended by the program, showed systematic character of his knowledge of the discipline, which is sufficient for further study;

Assessment “good (5)” is given to a student who has displayed knowledge of the basic educational program material in the amount necessary for further study and future work in the profession, who while not being sufficiently active in the classroom, has nevertheless independently carried out the main tasks stipulated by the program, mastered the basic literature recommended by the program, made some errors in their implementation and in his answer during the test, but has the necessary knowledge for correcting these errors by himself;

Assessment “satisfactory (4)” is given to a student who has discovered knowledge of the basic educational program material in the amount necessary for further study and future work in the profession, who while not being sufficiently active in the classroom, has nevertheless independently carried out the main tasks stipulated by the program, learned the main literature but allowed some errors in their implementation and in his answer during the test, but has the necessary knowledge for correcting these errors under the guidance of a teacher;

Assessment “satisfactory (3)” is given to a student who has displayed knowledge of the basic educational program material in the amount necessary for further study and future work in the profession, not showed activity in the classroom, independently fulfilled the main tasks envisaged by the program, but allowed errors in their implementation and in the answer during the test, but possessing necessary knowledge for elimination under the guidance of the teacher of the most essential errors;

Assessment “unsatisfactory (2)” is given to a student who showed gaps in knowledge or lack of knowledge on a significant part of the basic educational program material, who has not performed independently the main tasks demanded by the program, made fundamental errors in the fulfillment of the tasks stipulated by the program, who is not able to continue his studies or start professional activities without additional training in the discipline in question;

Assessment “unsatisfactory (1)” is given to a student when there is no answer (refusal to answer), or when the submitted answer does not correspond at all to the essence of the questions contained in the task.

5. Methodological materials defining the procedures for the assessment of knowledge, skills, abilities and/or experience

During exam the student are allowed to use the program of the discipline.