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: Complex Networks/Сложные сети
major: Applied Mathematics and Informatics
specialization: Advanced Methods of Modern Combinatorics/Продвинутые методы современной комбинаторики
Phystech School of Applied Mathematics and Informatics
Chair of Discrete Mathematics
term: 2
qualification: Master

Semester, form of interim assessment: 3 (fall) - Grading test

Academic hours: 45 AH in total, including:
lectures: 15 AH.
seminars: 30 AH.
laboratory practical: 0 AH.

Independent work: 45 AH.

In total: 90 AH, credits in total: 2

Author of the program: A.V. Leonidov, doctor of physics and mathematical sciences, professor

The program was discussed at the Chair of Discrete Mathematics 05.03.2020

Annotation

The aim of the course is to acquaint students with the theory of complex networks and its applications to the description of the properties of complex networks in nature, the economic and social spheres, and problems related to the field of artificial intelligence.

1. Study objective

Purpose of the course

mastering basic concepts in the field of complex networks.

Tasks of the course

- mastering by students of basic knowledge (concepts, concepts, methods and models) in the field of complex networks;
- acquisition of theoretical knowledge and practical skills in the field of complex networks;
- providing advice and assistance to students in their own theoretical research in the field of complex networks.

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
UC-1 Use a systematic approach to critically analyze a problem, and develop an action plan	UC-1.2 Search for solutions by using available sources
Gen.Pro.C-1 Address current challenges in fundamental and applied mathematics	Gen.Pro.C-1.3 Understand interdisciplinary relations in applied mathematics and computer science and apply them in professional tasks
Gen.Pro.C-2 Iimprove upon and implement new mathematical methods in applied problem solving	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form
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-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-2.2 Demonstrate practical experience of applying methods and digital signal processing algorithms, using the Internet, abstracting, referencing, searching for bibliographic sources, and working with scientific sources

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

As a result of studying the course the student should:

know:

fundamental concepts, laws, theories of complex networks;
modern problems of the corresponding sections of complex networks;
concepts, axioms, methods of proofs and proofs of the main theorems in the sections included in the basic part of the cycle;
basic properties of the corresponding mathematical objects;
analytical and numerical approaches and methods for solving typical applied problems.

be able to:

understand the task at hand;
use your knowledge to solve fundamental and applied problems;
evaluate the correctness of the problem setting;
strictly prove or disprove the statement;
independently find algorithms for solving problems, including non-standard ones, and analyze them;
independently see the consequences of the results obtained;
Accurately present mathematical knowledge in the field orally and in writing.

master:

skills of mastering a large amount of information and solving problems (including complex ones);
skills of independent work and mastering new disciplines;
culture of setting, analyzing and solving mathematical and applied problems that require the use of mathematical approaches and methods for their solution;
the subject language of complex networks and the skills of competently describing the solution of problems and presenting the results obtained.

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	Dynamic evolution of complex networks	3	6		12
2	Classification of complex networks	4	8		11
3	Complex networks in problems of economics and finance	4	8		11
4	Phase transitions on random networks	4	8		11
AH in total		15	30		45
Exam preparation		0 AH.			
Total complexity		90 AH., credits in total 2			

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

Semester: 3 (Fall)

1. Dynamic evolution of complex networks

Comparative analysis of the percolation transition for the Bethe lattice and scale-invariant graphs

2. Classification of complex networks

Critical indices of the percolation transition for the Bethe lattice

3. Complex networks in problems of economics and finance

Relationships linking critical indicators.

4. Phase transitions on random networks

Properties of the one-dimensional Ising model

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

Standard classroom.

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

Main literature

1. Сложные технические системы (оценка характеристик) [Текст] : учебное пособие для вузов / И. Г. Железнов .— М. : Высшая школа, 1984 .— 120 с.

Дискретная математика [Текст] : учеб. пособие для вузов / А. Н. Макоха, П. А Сахнюк, Н. И. Червяков .— М. : Физматлит, 2005 .— 368 с. - Библиогр.: с. 366-368. - ISBN 5-9221-0630-9 (в пер.) .— Полный текст (Доступ из сети МФТИ / Удаленный доступ).

Additional literature

1. Нейронные сети [Текст] : полный курс / С. Хайкин ; пер. с англ. Н. Н. Куссуль, А. Ю. Шелестова ; под ред. Н. Н. Куссуль .— 2-е изд., испр. — М. : Вильямс, 2006 .— 1103 с.

2. Нейронные сети: история развития теории [Текст]. Кн. 5 : учеб. пособие для вузов / под общ. ред. А. И. Галушкина, Я. З. Цыпкина .— М. : ИПРЖР, 2001 .— 840 с.

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 test papers, as this simplifies the final assessment of the subject.
2. To prepare for the final certification in the subject, it is best to use the lecture materials.

SUPPLEMENT

Assessment funds for course (training module)

major:	Applied Mathematics and Informatics
specialization:	Advanced Methods of Modern Combinatorics/Продвинутые методы современной комбинаторики
	Phystech School of Applied Mathematics and Informatics
	Chair of Discrete Mathematics
term:	2
qualification:	Master

Semester, form of interim assessment: 3 (fall) - Grading test

Author: A.V. Leonidov, doctor of physics and mathematical sciences, professor

1. Competencies formed during the process of studying the course

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2. Competency assessment indicators

As a result of studying the course the student should:

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modern problems of the corresponding sections of complex networks;
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the subject language of complex networks and the skills of competently describing the solution of problems and presenting the results obtained.

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

1. Calculate the probability of multi-edge formation in the configuration model.
2. Within the framework of the configuration model, show that only one component can exist in a random graph.
3. Prove Harrari's theorem for a balanced network.
4. Calculate the value of Katz's prestige for the count of Florentine marriages.

5. Calculate the modularity of a linear graph of N vertices, cut along one of the edges so that the original graph is split into components of M and N-M nodes. Find a cut that maximizes modularity.

6. Describe the methodology and results of the article on corporate ownership.

7. Describe the generalization of the stochastic block model to the case of weighted graphs.

8. Show that for a finite random scale-invariant graph with exponent γ the average number of nodes in the random search problem is proportional to 1 / M3 − γ, where M is the maximum degree of the graph vertices.

9. Calculate the variance for the numbers of loops in a random undirected multigraph.

10. Describe the formation of the language in the model of the preferred attachment of the formation of the semantic network.

4. Evaluation criteria

1. Classification of complex networks and their main characteristics. Scale-invariant networks.
2. Examples of complex networks in nature and society.
3. The structure of clusters in complex networks.
4. Percolation transition.
5. Percolation of vertices and edges.
6. Dynamic evolution of complex networks.
7. Spread of epidemics.
8. Stability of complex networks in relation to external influences.
9. The problem of optimal transport in complex networks.
10. Diffusion on complex networks.
11. Complex networks in the problems of economics and finance.
12. Socioeconomic interactions in terms of complex networks.
13. Networks of influence on financial markets.
14. Fluctuation properties of complex networks.
15. Endogenous and exogenous fluctuations.
16. Phase transitions on random networks.

- the mark "excellent (10)" is given to a student who has shown comprehensive, systematized, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice when solving specific problems, free and correct justification of the decisions

- the mark "excellent (9)" is given to a student who has shown comprehensive, systematized, in-depth knowledge of the curriculum of the discipline and the ability to apply them in practice in solving specific problems, free and correct justification of the decisions

- the mark "excellent (8)" is given to a student who has shown comprehensive systematized, deep knowledge of the curriculum of the discipline and the ability to apply them in practice in solving specific problems, and the correct justification of the decisions made

- the mark "good (7)" is given to a student if he firmly knows the material, expresses it competently and to the point, knows how to apply the acquired knowledge in practice, but makes some inaccuracies in the answer or in solving problems;

- the mark "good (6)" is given to a student if he knows the material, presents it competently and in essence, knows how to apply the knowledge gained in practice, but makes some inaccuracies in the answer or in solving problems;

- the mark "good (5)" is given to a student if he knows the material, and essentially expounds it, knows how to apply the knowledge gained in practice, but makes some inaccuracies in the answer or in solving problems;

- the mark "satisfactory (4)" is given to a student who has shown a fragmented, scattered nature of knowledge, insufficiently correct formulations of basic concepts, violation of the logical sequence in the presentation of the program material, but at the same time he owns the main sections of the curriculum necessary for further education and can apply the obtained knowledge by model in a standard situation;

- the mark "satisfactory (3)" is given to a student who has shown a fragmentary, scattered nature of knowledge, insufficiently correct formulations of basic concepts, violation of the logical sequence in the presentation of program material, but at the same time he has fragmentary knowledge of the main sections of the curriculum necessary for further education and can apply the knowledge gained by the model in a standard situation;

- the mark "unsatisfactory (2)" is given to a student who does not know most of the main content of the curriculum of the discipline, makes gross mistakes in the formulation of the basic concepts of the discipline and does not know how to use the knowledge gained in solving typical practical problems

- grade "unsatisfactory (1)" is given to a student who does not know the formulations of the basic concepts of the discipline.

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

.During the differential credit, students can use the discipline program