

**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:	Computer Vision/Компьютерное зрение
major:	Applied Mathematics and Informatics
specialization:	Contemporary Combinatorics/Современная комбинаторика “Pusk” Online and Supplementary Education Centre Chair of Discrete Mathematics
term:	2
qualification:	Master

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

Academic hours: 75 AH in total, including:

lectures: 45 AH.

seminars: 30 AH.

laboratory practical: 0 AH.

Independent work: 75 AH.

Exam preparation: 30 AH.

In total: 180 AH, credits in total: 4

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

The program was discussed at the Chair of Discrete Mathematics 05.03.2020

Annotation

This course succeeds the Machine Learning course and aims to introduce students to the contemporary state of Computer Vision. The biological inspiration and theoretical foundations of Computer Vision algorithms are enhanced with comprehensive practical assignments. The course covers materials from early visual classification models to the latest achievements in Computer Vision approaches and narrows the gap between different sub-areas of Artificial Intelligence.

1. Study objective

Purpose of the course

- Learn how to apply Computer Vision techniques in practice
- Get familiar with both fundamental and most recent approaches in Computer Vision
- Get hands on experience in Computer Vision problems solutions

Tasks of the course

- Computer Vision problem statement and ability to develop the general pipeline of the solution
- Choose relevant approach and model for particular problem
- Ability to apply the Computer Vision techniques to the real world problems
- Essential experience with PyTorch framework

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-3 Able to organise and lead a team, developing a team strategy to achieve a goal	UC-3.2 Consider the interests, specific behavior, and diversity of opinions of team members/colleagues/counterparties
	UC-3.4 Plan teamwork, distribute tasks to team members, hold discussions of different ideas and opinions
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
	Gen.Pro.C-1.1 Apply fundamental scientific knowledge, new scientific principles, and research methods in applied mathematics and computer science
Gen.Pro.C-2 Improve upon and implement new mathematical methods in applied problem solving	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
Gen.Pro.C-4 Combine and adapt current information and communications technologies (ICTs) to meet professional challenges	Gen.Pro.C-4.2 Apply ICTs to solve the task in hand, to draw conclusions, and to evaluate the obtained results
Gen.Pro.C-5 An understanding of current scientific and technical problems in the field of informatics and computer technology, and is able to formulate professional tasks in scientific language	Gen.Pro.C-5.1 An understanding of the current state of research within his/her professional thematic area
	Gen.Pro.C-5.2 Able to assess the relevance of research in informatics and computer technology and its practical relevance
	Gen.Pro.C-5.3 A good command of the professional terminology used in modern scientific and technical literature, and is able to present the results of scientific work orally and in writing as part of professional communication
	Gen.Pro.C-6.1 Able to analyse the problem, plan the solution, suggest and combine ways of solving it
	Gen.Pro.C-6.2 Capable of developing and upgrading software and hardware for information and automated systems

Gen.Pro.C-6 Capable of selecting and/or developing approaches to solving typical and new problems in informatics and computer technology, taking into account the characteristics and limitations of different solution methods	Gen.Pro.C-6.3 Able to use research methods to solve new problems by applying knowledge from different fields of science (technology)
	Gen.Pro.C-6.4 Proficient in analytical and computational solution methods, and understands and takes into account in practice the limits of applicability of the solutions obtained
	Gen.Pro.C-6.5 Able to independently acquire, develop and apply mathematical, natural science, socio-economic and professional knowledge to solve non-standard problems, including in new or unfamiliar environments and in an interdisciplinary context

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

As a result of studying the course the student should:

know:

- basic methods and algorithms for analyzing a single image;
- examples of computer vision problems arising in the real world;
- existing heuristic methods of analysis, classification and image search.

be able to:

- understand the task at hand; use your knowledge to research images;
- independently find algorithms for solving problems, including non-standard ones, and analyze them;
- independently see the consequences of the results obtained.

master:

- skills of mastering a large amount of information and solving problems (including complex ones);
- skills of independent work and mastering new disciplines;
- the culture of setting, analyzing and solving practical problems of computer vision.

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	Computer Vision problem statements: classification, detection, segmentation	10	6		15
2	R-CNN -> Fast -> Faster structure, main ideas, metrics and performance	8	6		15
3	YOLO v1 -> v3 main ideas	10	6		15
4	Upsampling methods: poolings, transposed convolutions	9	6		15
5	Mask R-CNN approaches	8	6		15
AH in total		45	30		75
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: 3 (Fall)

1. Computer Vision problem statements: classification, detection, segmentation

Metrics in CV: IoU, mAP Main datasets: PASCAL VOC, ImageNet, COCO, OpenImages
Variational Autoencoders: structure, loss function, training process

2. R-CNN -> Fast -> Faster structure, main ideas, metrics and performance

Focal Loss Non Maximum Suppression algorithm Generative Adversarial Networks: structure, loss function, training process

3. YOLO v1 -> v3 main ideas

Separable convolutions MobileNet v1, v2 blocks

4. Upsampling methods: poolings, transposed convolutions

FCN, DeconvNet, SegNet U-Net architecture

5. Mask R-CNN approaches

Neural style transfer technique Model compression methods (distillation and quantization concepts) KL divergence. Relations to crossentropy

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. Методы распознавания [Текст] : учеб. пособие для вузов / А. Л. Горелик, В. А. Скрипкин .— 2-е изд., перераб. и доп. — М. : Высшая школа, 1984 .— 208 с.
2. Введение в цифровую обработку изображений [Текст]/Л. П. Ярославский, -М., Сов. радио, 1979

Additional literature

1. Обработка изображений в автоматизированных системах научных исследований [Текст]/В. А. Витих, В. В. Сергеев, В. А. Сойфер, -М., Наука, 1982

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

A student studying the discipline must, on the one hand, master the general conceptual apparatus, and, on the other, learn to apply theoretical knowledge in practice.

As a result of studying the discipline, the student must know the basic definitions and concepts.

Successful mastering of the course requires intense independent work of the student.

Independent work includes:

- reading and taking notes of the recommended literature;
- study of educational material (educational and scientific literature), preparation of answers to questions intended for self-study, proof of individual statements, properties;
- preparation for differential credit.

It is important to achieve an understanding of the studied material, and not its mechanical memorization. If you find it difficult to study certain topics, questions, you should seek advice from the lecturer.

Assessment funds for course (training module)

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“Pusk” Online and Supplementary Education Centre
Chair of Discrete Mathematics
term: 2
qualification: Master
Semester, form of interim assessment: 3 (fall) - Exam
Author: R.G. Neychev, professor

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
UC-3 Able to organise and lead a team, developing a team strategy to achieve a goal	UC-3.2 Consider the interests, specific behavior, and diversity of opinions of team members/colleagues/counterparties
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2. Competency assessment indicators

As a result of studying the course the student should:

know:

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be able to:

- understand the task at hand; use your knowledge to research images;
- independently find algorithms for solving problems, including non-standard ones, and analyze them;
- independently see the consequences of the results obtained.

master:

- skills of mastering a large amount of information and solving problems (including complex ones);
- skills of independent work and mastering new disciplines;
- the culture of setting, analyzing and solving practical problems of computer vision.

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

- Describe Computer Vision problem statements
- Describe metrics in CV
- Name main CV datasets
- Describe R-CNN structure and its development
- Name loss function in CV
- Describe NMS algorithm
- Describe YOLO main achievements and architectural decisions
- Describe different types of convolutions
- Describe U-Net structure, why is it so successful
- Neural style transfer technique
- Name types of Autoencoders
- Name most known GANs

4. Evaluation criteria

Questions for the exam

1. Prove that if m , n are two coprime integers of different parity, then the numbers $m^2 - n^2$ and $2mn$ are also coprime.
2. Write and prove the general formula for the number of different representations of a given integer n as the sum of two squares. (Representatives that are not obtained from each other by changing signs and the order of the terms are considered different.)
3. Based on the obtained formula, derive the lower bound for the maximum number of equal distances among the given n points on the plane using a regular rectangular lattice.
4. Build a regular pentagon using a compass and a ruler.
5. Build a regular 15-gon using a compass and a ruler.
6. You are given a single segment. It is required to construct using a compass and a ruler a segment of length x satisfying the equation
7. Based on the previous task, prove that a regular heptagon cannot be built using a compass and a ruler.
8. Prove that trisection of the angle is impossible.
9. Describe all possible combinations of the amounts of black and white balls in the ballot box, so that if two balls are randomly fished in a sample without returning, the probability of fishing two white balls is exactly 0.5.
10. Consider the relation on the sides a , b , c of the triangle, in which a triangle with vertices at the bases of the bisectors is isosceles. Assuming that the sides converging on side c of the large triangle are equal, reduce this relation to the following
11. In what follows, we consider the cube defined by the first of the three equations (refusing the requirement that a , b , c be sides of a triangle). Show that the resulting cube is indecomposable, that is, the polynomial that defines it does not factor.
12. In addition to this, show that our cube is nonsingular, that is, there is not a single point on its projectivization at which each direction is tangent (or the same thing at which all three first partial derivatives of the polynomial defining it degenerate).

Exam ticket examples

Ticket number 1

1. Write and prove the general formula for the number of different representations of a given integer n as the sum of two squares.
2. Prove that trisection of the angle is impossible.

Ticket number 2

1. Consider the relationship on the sides a , b , c of the triangle, in which a triangle with vertices at the bases of the bisectors is isosceles.
2. Describe all kinds of combinations of the numbers of black and white balls in the ballot box, so that if two balls are randomly fished in the sample without returning, the probability of fishing two white balls is exactly 0.5.

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 examination the student are allowed to use the program of the discipline.