Ministry of Science and Higher Education of the Russian Federation
NATIONAL RESEARCH
TOMSK STATE UNIVERSITY (NI TSU)

Institute of Applied Mathematics and Computer Science

APPROVE:
Director

_____ A. V. Zamyatin

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Work program of the discipline

Neural networks - II

in the major of training

01.04.02 Applied mathematics and informatics

Orientation (profile) of training:
Big Data and Data Science

Form of study
full-time

Qualification
master

Year of admission
2022

Code of discipline in the curriculum: B 1.P.V. 04

AGREED:
Head of OP

_____ A.V. Zamyatin

Chairman of the CMD

_____ S.P. Sushchenko

Tomsk - 2022

1. Purpose and planned results of mastering the discipline

The purpose of mastering the discipline is the formation of the following competencies:

- UK-1 - the ability to carry out a critical analysis of problem situations based on a systematic approach, to develop an action strategy;
- GPC-3 - the ability to develop mathematical models and analyze them when solving problems in the field of professional activity;
- PC-6 - the ability to manage the receipt, storage, transmission, processing of big data.

The results of mastering the discipline are the following indicators of the achievement of competencies:

IUK-1.1 Identifies a problem situation, on the basis of a systematic approach, carries out its multifactorial analysis and diagnostics.

IUK-1.2 Carries out the search, selection and systematization of information to determine alternative options for strategic solutions in a problem situation.

IUK-1.3 Suggests and justifies the strategy of action, taking into account the limitations, risks and possible consequences.

IOPC-3.3 Develops and analyzes new mathematical models for solving applied problems of professional activity in the field of applied mathematics and informatics.

IPK-6.1 Monitors and evaluates the performance of big data processing.

IPK-6.2 Uses methods and tools for receiving, storing, transmitting, processing big data.

IPK-6.3 Develops proposals to improve the performance of big data processing.

2. Tasks of mastering the discipline

– Master the apparatus for creating various topologies of artificial neural networks , as well as the technology for developing programs that use the main stages of the work of artificial neural networks (creating structures for representing neural networks, creating and evaluating a network model, training them).

– Learn to apply the conceptual apparatus of neural networks to solve practical problems of professional activity.

3. The place of discipline in the structure of the educational program

Discipline belongs to the part of the educational program formed by the participants of educational relations.

4. Semester of mastering and form of intermediate certification in the discipline

Third semester, credit.

5. Entrance requirements for mastering the discipline

Successful mastering of the discipline requires training outcomes in the following disciplines: Neural networks-1.

6. Implementation language

English.

7. Scope of discipline

The total labor intensity of the discipline is 2 credits , 72 hours, of which:
- lectures: 10 hours
- laboratory: 20 hours
 including practical training: 0 h.
The volume of independent work of the student is determined by the curriculum.

8. The content of the discipline, structured by topics

Topic 1. Optimization in training deep models

How does learning differ from pure optimization. Minimization of empirical risk. Surrogate Loss Functions and Early Stopping . Batch and mini-batch algorithms. Problems of optimization of neural networks. Bad conditioning . local minima. Plateaus, saddle points and other flat areas. Cliffs and steeply rising gradients. Long term dependencies. Inaccurate gradients. Poor correspondence between local and global structures. Theoretical optimization limits. Basic algorithms. Stochastic gradient descent. impulse method. Nesterov's method. Parameter initialization strategies. Algorithms with Adaptive Learning Rate . AdaGrad . RMSProp . Adam. Choosing the right optimization algorithm. Approximate methods of the second order. Newton's method. Conjugate gradient method. BFGS algorithm. Optimization Strategies and Metaalgorithms . Batch normalization. Coordinate descent. Pole's averaging. Pre -training with a teacher. Model design for ease of optimization. Methods of continuation and training according to the plan.

Topic 2. Convolutional networks.

Convolution operation. Motivation. Pooling . Convolution and pooling as an infinitely strong prior distribution. Variants of the basic convolution function . structured output. Data types. Efficient convolution algorithms. Random signs and unsupervised signs. Neurobiological foundations of convolutional networks. Convolutional networks and the history of deep learning.

Topic 3. Sequence modeling: recurrent and recursive networks.

Calculation graph unrolling. Recurrent neural networks. Forcing teacher and network with output recursion . Gradient calculation in a recurrent neural network. Recurrent networks as directed graphical models. Modeling context-specific sequences using RNNs. Bidirectional RNS. Encoder-decoder or sequence-to-sequence architectures. Deep recurrent networks. Recursive neural networks. The problem of long-term dependencies. Neural echo networks. Leaky blocks and other multi-timescale strategies. Adding direct links through time. Leaky blocks and a spectrum of different time scales. Removing links . Long short-term memory and other gated RNNs. Long short term memory. Other valve RNS. Optimization in the context of long-term dependencies. clipping gradients. Regularization to push the information flow . explicit memory.

Topic 4. Practical methodology.

Quality indicators . Selecting the default base model. Do I need to collect additional data? Choice of hyperparameters . Manual tuning of hyperparameters . Algorithms for Automatic Hyperparameter Optimization . Grid search. Random search. Model-based hyperparameter optimization . Debugging strategies. Example: multiple digit recognition.

Topic 5. Applications.

Large scale training for neural networks. Implementations on fast CPUs. GPU implementations. Large scale distributed implementations. Model compression. dynamic structure. Specialized hardware implementations of neural networks. Computer vision. Preprocessing. Speech recognition. Processing of natural languages. N-grams. Neural language models. Multidimensional outputs. Combining neural language models with n-grams. Neural machine translation. History reference. Other applications. recommender systems. Representation of knowledge, reasoning and answering questions.

9. Ongoing evaluation

The ongoing evaluation of the discipline is carried out by monitoring attendance, performing laboratory work, tests on lecture material, doing homework and is recorded in the form of a control point at least once a semester.

10. The procedure for conducting and criteria for evaluating the intermediate certification

The basis of training is a course of lectures read by the teacher, as well as laboratory work performed by the student.

Intermediate certification and credit is carried out on the basis of an interview, subject to the successful completion of earlier laboratory work.

The results of the test are determined by the marks "excellent", "good", "satisfactory", "unsatisfactory".

The final assessment of the knowledge of the student in the discipline is carried out according to a 5-point system and includes:
- 60% of the result obtained in the test;
- 40% of the results of the current academic performance.

The formula for calculating the final grade:

$$И = \ 0,4 \ \frac{P_1 + P_2}{2} + 0,6Э \tag{1}$$

where, P1, P2 are the digital equivalents of the first and second control points, respectively; E is the digital equivalent of the exam grade.

Assessment according to the traditional system	Criterion
Excellent	The theoretical content of the course was mastered completely, without gaps the necessary practical skills of working with the mastered material were formed, all the training tasks provided for by the training program were completed, the quality of their implementation was estimated by a number of points close to the maximum.
Good	The theoretical content of the course has been mastered completely, without gaps, some practical skills in working with the mastered material are not sufficiently formed, all the training tasks provided for by the training program have been completed, the quality of none of them has been assessed with a minimum number of points, some types of tasks have been completed with errors.
Satisfactorily	The theoretical content of the course has been partially mastered, but the gaps are not significant, the necessary practical skills for working with the mastered material are basically formed, most of the training tasks provided for by the training program have been completed, some of the completed tasks may contain errors
unsatisfactory	The theoretical content of the course has not been mastered, the necessary practical work skills have not been formed, the completed training tasks contain gross errors, additional independent work on the course material will not lead to a significant improvement in the quality of the training tasks.

11. Educational and methodological support

a) Electronic training course on the discipline at the electronic university " Moodle " - https://moodle.tsu.ru/course/view.php?id=00000

b) Estimated materials of the current control and intermediate certification in the discipline.

c) Plan of seminars / practical classes in the discipline.

d) Guidelines for laboratory work.

e) Guidelines for the organization of independent work of students .

12. List of educational literature and Internet resources

a) basic literature:

1.   Joel Grace. Data Science: Data science from scratch. 2nd edition. ISBN 978-5-9775-6731-2, St. Petersburg: BHV-Petersburg, 2021

2.   Sebastian Raska, Vahid Mirjalili . Python and machine learning. ISBN 978-5-907203-57-0, Moscow: Dialectics, 2020

3.   Ameet V. Joshi. Machine Learning and Artificial Intelligence. ISBN 978-3-030-26621-9.Springer Nature Switzerland AG, 2020

4.   Denis Rothman. Artificial Intelligence by Example. second edition. ISBN 978-1-83921-153-9. Packt Publishing, 2020

5.   Stuart Russel, Peter Norvig. artificial intelligence. A Modern Approach. 4th edition. ISBN : 978-0-13-461099-3. Hoboken : Pearson , 2021

6.   Ian Goodfellow, Joshua Bengio , Aaron Courville . Deep learning. Second color edition, revised. ISBN 978-5-97060-618-6 . M. : DMK Press , 2018

7.   Roman Shirkin . artificial intelligence. The Complete Beginners' Guide to Artificial Intelligence. ISBN: 9798609154415 . Amazon KDP Printing and Publishing, 2020

8.   François Chollet   Deep Learning with Python. ISBN 978-5-4461-0770-4 . St. Petersburg : Peter, 2018

b) additional literature:

1.   Andrew Glassner . Deep learning without math. Volume 1. Basics. ISBN 978-5-97060-701-5. Moscow: DMK Press, 2020

2.   Andrew Glassner . Deep learning without math. Volume 2. Practice ISBN 978-5-97060-767-1. Moscow: DMK Press, 2020

c) Internet resources:

www.MachineLearning.ru is a professional wiki resource dedicated to machine learning and data mining

MMRO - Mathematical Methods of Pattern Recognition

Konstantin Vorontsov. The course "machine learning" of the data analysis school of Yandex.

Igor Kuralenok . Course "machine learning" Lectorium .

Roman Shamin. Course "Machine learning and artificial intelligence in mathematics and applications". REC of the Mathematical Institute. V. A. Steklov RAS

13. List of information technologies

a) licensed and freely distributed software:

- For the acquisition of practical skills - freely distributed environments with open source Python (https://www.python.org/) and RStudio (https://www.rstudio.com/) ;

- For project -group and remote work - Russian software Mind (https://mind.com/) .

- publicly available cloud technologies (Google Docs , Yandex disk, etc.).

b) information reference systems:

– Electronic catalog of the TSU Scientific Library – http://chamo.lib.tsu.ru/search/query?locale=ru&theme=system

– TSU electronic library (repository) – http://vital.lib.tsu.ru/vital/access/manager/Index

14. Logistics

When mastering the discipline, computer classes of the IPMKN TSU are used with access to the resources of the Scientific Library of TSU, including domestic and foreign periodicals and the Internet.

15. Authors information

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