Appendix 1

MINISTRY OF EDUCATION AND SCIENCE OF THE RUSSIAN FEDERATION
NATIONAL RESEARCH
TOMSK STATE UNIVERSITY

Institute of Applied Mathematics and Computer Science

APPROVE:
Director
_____________A. V. Zamyatin

Evaluation materials of the current control and intermediate certification in the discipline
(Evaluation tools by discipline)

Neural networks - I

in the major of training

01.04.02 Applied mathematics and informatics

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

Tomsk-2024

ET was implemented:
Candidate of Physics and Mathematics Sciences, Associate Professor,
Associate Professor of the Department
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Evaluation tools were approved at a meeting of the educational and methodological commission of the Institute of Applied Mathematics and Computer Science (EMC IAMCS).

Protocol dated 20.05.2024 № 2

Chairman of the EMC IAMCS,
Dr. tech. Sciences, Professor S.P. Sushchenko

Evaluation tools (ET) are an element of the system for assessing the formation of competencies among students in general or at a certain stage of its formation.

The ET is developed in accordance with the work program (WP) of the discipline .

1. Competencies and training outcomes, obtained upon the discipline mastery

Competence	**Competence indicator**	**Code and name of planned training outcomes that characterize the stages of competency formation**	**Criteria for evaluating training outcomes**			
			Excellent	Good	Satisfactorily	unsatisfactory
UK-1. Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy	IUK-1.1 Identifies a problem situation, on the basis of a systematic approach, carries out its multifactorial analysis and diagnostics.	OP-1.1.1. The student will be able to: - find and use sources of additional information to improve the level of general and professional knowledge; - to select and process information on the chosen research topic; correctly quote and make references to the sources used in written works; - be able to apply natural science and mathematical knowledge for the application of neural network technology in the field of scientific and engineering problems.	90-100 points	70-89 points	50-69 points	0-49 points
	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.					

OPK-3. Able to develop mathematical models and analyze them when solving problems in the field of professional activity	IOPC-3.3 Develops and analyzes new mathematical models for solving applied problems of professional activity in the field of applied mathematics and informatics	OP-3.3.1. - be able to choose the topology of a neural network for solving an applied problem. OP-3.3.2. The student will be able to: - develop and issue a program code in accordance with the established requirements; - to form a training data set for machine learning of a neural network model; - develop a test data set to test the operation of the created software application; - to accelerate the process of machine learning for a specific computer architecture; - to conduct computer experiments on training and testing the developed neural network model; - to adapt the neural network model for practical application based on computer experiments; - to compare the obtained results with known domestic and foreign analogues.	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.	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.	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	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.
PC-6. Able to manage the receipt, storage, transmission, processing	IPK-6.1 Monitors and evaluates the performance of big data processing	OP-6.1.1 The student will: - Know the principles of planning and				

of big data	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	organizing analytical work using neural network technologies OP-6.1.2 The student will be able to: - Conduct analytical research and develop applications using neural network technologies in accordance with customer requirements OP-6.2.1 The student will be able to: - Prepare data for analytical work on the study of big data using neural networks OP-6.2.2. The student will be able to: - be able to develop algorithms for neural network processing of big data. OP-6.3.1 The student will be able to: - Carry out procedures for identifying, forming and coordinating requirements for the results of analytical work using neural network technologies				

2. Stages of competency formation and types of evaluation tools

No.	Stages of competency formation (discipline sections)	Code and name of training outcomes	Type of evaluation tool (tests, assignments, cases, questions, etc.)
1.	Sections 1. Introduction to neural networks 2. Linear algebra for neural networks 3. Probability theory and information theory for neural networks. 4. Numerical methods for neural networks. five. Fundamentals of machine learning for neural networks. Performing laboratory work No. 1. "Solving problems in the design of neural networks".	RD 1 The student will be able to apply natural science and mathematical knowledge for using neural network technologies in the field of scientific and engineering problems.	Questioning in the classroom, analysis of problems, preparation for laboratory classes, public defense of laboratory work No. 1.
2.	6. Neural networks of direct distribution. 7. Regularization for neural networks. Performing laboratory work No. 2. " Designing a fully connected neural network for a multiclass classifier"	RD 2 The student will have the ability to develop implementation tools using neural network technologies	Survey in the classroom, preparation for laboratory classes, public defense of laboratory work No. 2.

3. Typical control tasks or other materials necessary for the assessment of educational training outcomes

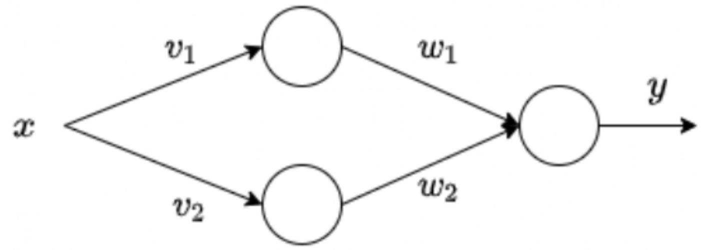
3.1. Typical tasks for conducting ongoing monitoring of progress in the discipline

Laboratory work No. 1 "Solving problems in the design of neural networks."

The aim of the work is to design a multilayer neural network using stochastic gradient descent with a given learning rate and activation function. It is necessary to iterate the training of the network with a given loss function and calculate the value of the synaptic coefficient after its adjustment; perform the design of a neural network with stochastic neurons, the output of each stochastic neuron is a discrete random variable described by the distribution, it is necessary to find the mathematical expectation of the network output when a given value is applied to the input .

Task #1

The multilayer neural network, the scheme of which is shown in the figure, is trained using stochastic gradient descent with the learning rate parameter $\alpha = 0.1$.



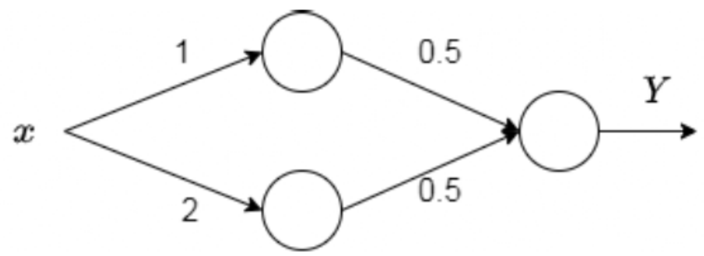
The activation characteristic of the output neuron is linear, the activation characteristics of the remaining neurons have the form:

$$f(h) = \begin{cases} h, & h \geq 0, \\ 0, & h < 0. \end{cases}$$

At the current training iteration, τthe synaptic coefficients of all neurons in the network are equal to 0.5, and the biases of all neurons are zero. The training example is fed to the network input $x = 2$, which corresponds to the desired output value $\sigma = -1$. Perform one iteration of training the network with a quadratic loss function $L(v_1) = \frac{1}{2}(\sigma - y)^2$ and calculate the value of the synaptic coefficient v_1 after it has been adjusted.

Task #2

At the input of a neural network with stochastic neurons (the circuit and synaptic coefficients of the network are shown in the figure, the biases of all neurons of the network are zero), some non-random number *x is fed* .



The output of each stochastic neuron is a discrete random variable described by the distribution

$$P[Y = -1] = 1 - p(h),$$
$$P[Y = 1] = p(h).$$

where Y is the output of the neuron, h is the potential (activation) of the neuron.
Find the mathematical expectation of the network output when the value is fed to its input $x = 0.5$, if

$$p(h) = \begin{cases} 0, & h \leq -1, \\ 0.5(h+1), & -1 < h \leq 1, \\ 1, & h > 1. \end{cases}$$

Laboratory work No. 2 "Designing a fully connected neural network for a multiclass classifier"

The purpose of the work is to write a program in Python and R that builds and trains fully connected feed-forward neural networks that solves multiclass classification problems (samples received from the teacher), it is required to select a non-redundant network architecture that works with an acceptable error level and visualize the process of model training. The results of the work should be included in the report.

Topics of surveys in the classroom:

Linked to the material of previous lectures, as well as the personal experience of students. Students can offer options for solving the problem set by the teacher, as well as solution tools.

Sample questions:

1. Which of the following neural network models is best suited for predicting time sequences?

a) Single-Layer Perceptron	b) CNN
c) LSTM	d) Multi-layer Perceptron

2. What is the name of several examples from the training set that are used to simultaneously calculate the gradient and weights of the network?

3. Why do models based on convolutional neural networks show the best performance in classifying objects in images compared to other models?

a) They are highly optimized for handling vectors with numeric rather than categorical features	b) They have a wide range of feature space transformation tools that can be varied by the developer in the model
c)They take into account the correlation of adjacent components of the vector	d) They use significantly more ***adjustable*** parameters than other models

3.2. Typical tasks for conducting intermediate certification in the discipline . Questions for credit with an assessment:

1. What are the historical trends in neural networks. What does an increase in the data set in neural networks lead to? What does increasing the size of models in neural networks lead to? How can you improve the prediction accuracy in neural networks?
2. Describe what methods of linear algebra are used in the design of neural networks?
3. What is the essence of the principal component method?
4. Describe what methods of probability theory and information theory are used in the design of neural networks?
5. What is the chain rule? How is it used in the design of neural networks?
6. What common probability distributions do you know?
7. Bernoulli distribution.
8. categorical distribution.
9. Normal distribution.
10. Exponential distribution and Laplace distribution.
11. Dirac distribution and empirical distribution.
12. What is Bayes' Rule?
13. What structural probabilistic models do you know? How are they used in the design of neural networks?
14. What numerical methods are used in the design of neural networks?
15. Give an optimization scheme by the gradient method.
16. What is the essence of the linear least squares method? How is it applied in the design of neural networks?
17. What machine learning algorithms do you know?
18. What is Task T? What are typical machine learning tasks?

19. How is the measure of quality P measured?
20. What is experience E? Give examples.
21. Give an example of the operation of the linear regression algorithm in the design of neural networks
22. What is overfitting in machine learning? How to deal with it?
23. What is underfitting in machine learning? How to deal with it?
24. What is the essence of the no free breakfast theorem?
25. What is regularization in machine learning? How can regularization be done?
26. What machine learning settings are called hyperparameters? How can they be set using additional data?
27. What is the purpose of cross-validation? What is it used for?
28. Describe how to trade off bias and variance to minimize the mean square error.
29. What is the principle of maximum likelihood?
30. List the maximum likelihood properties.
31. Give an example of linear regression and maximum likelihood
32. What is the Bayesian approach to statistics?
33. Give an example of Bayesian linear regression.
34. How to Calculate the Posterior Maximum Score (MAP)
35. What is the essence of probabilistic supervised learning?
36. What is the essence of the support vector machine?
37. What unsupervised learning algorithms do you know?
38. What is the Principal Component Method?
39. How is k-means clustering performed?
40. What is stochastic gradient descent?
41. Building a machine learning algorithm. The curse of dimensionality.
42. How to perform regularization to achieve local consistency and smoothness.
43. What is the essence of learning manifolds.
44. Example: XOR training.
45. Training by gradient methods. cost functions. output blocks.
46. hidden blocks. Blocks of linear rectification and their generalizations. Logistic sigmoid and hyperbolic tangent. Other hidden blocks.
47. Architecture design. Properties of universal approximation and depth. Other architectural approaches.
48. Back propagation and other differentiation algorithms. Graphs of calculations. The rule of differentiation of a complex function.
49. Recursively applying the rule of differentiation of a complex function to obtain a backpropagation algorithm.
50. Computing Backpropagation in a Fully Connected MSP. Symbolic-symbolic derivatives.
51. General backpropagation algorithm. Example: Applying Back Propagation to SME Learning. Complications.
52. Differentiation beyond the deep learning community. Derivatives of higher order.
53. Fines according to the norm of parameters. Regularization of parameters in the L2 norm. L1 regularization.
54. Norm penalty as constrained optimization.
55. Regularization and underdetermined problems.
56. Replenishment of the data set.
57. Robustness relative to noise. Adding noise to output labels.
58. Teaching with the partial involvement of a teacher.
59. Multitasking learning.
60. Early stop.
61. Linking and sharing parameters. Convolutional neural networks.
62. Sparse Views.

63. Bagging and other ensemble methods.
64. thinning.
65. Competitive learning.
66. Tangent Distance, Tangent Propagation Algorithm, and Manifold Tangent Classifier.

4. Methodological materials that determine the procedures for evaluating educational training outcomes

4.1. Methodological materials for assessing the current control of progress in the discipline.

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

4.2. Methodological materials for conducting intermediate certification in the discipline.

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

The final assessment of the student's knowledge in the discipline is carried out according to a 100-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:

$$F = 0,4 \frac{P_1+P_2}{2} + 0,6\,T \quad (1)$$

where, P1, P2 are the digital equivalents of the first and second control points, respectively; T - the digital equivalent of the assessment in the test.

The points scored during the current control are taken into account during the intermediate certification. The grades "excellent", "good", "satisfactory", "unsatisfactory" are given with the number of points scored: 90-100, 70-89, 50-69 and 0-49, respectively.