Advances in Intelligent Systems and Computing 1129

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Advances in Information and Communication

Proceedings of the 2020 Future of Information and Communication Conference (FICC), Volume 1

Springer

Advances in Intelligent Systems and Computing

Volume 1129

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Example of the Use of Artificial Neural Network in the Educational Process

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Abstract. An example of an artificial neural network intended for use in the educational process (in such disciplines as "The socio-political importance of artificial intelligence systems", "History and philosophy of science", etc.) is presented. The neural network provides automatic processing of critical reviews written by students for pseudoscientific works, presented in abundance in the current periodical press. This makes it possible to transfer such an innovative form of study as the writing of critical reviews by students to the distance learning mode. An additional function of this neural network is testing of students in order to identify individuals with a psychological type that is appropriate to the scientist in the true meaning of the word.

Keywords: Hirsch index · Pseudoscience · Critical thinking · Passionarity · Neural network · Profanation of science

1 Introduction

Currently in Kazakhstan there is a clear oversupply of higher education institutions [1]. At the beginning of the 2017/2018 academic year, 127 higher educational institutions operated in the republic with a population of about 18 million (or 1 university for a little over 140 thousand people). For comparison, in countries that are recognized leaders in the field of higher education, there are 650–700 thousand people per university [2]. For example, in the UK there are 89 universities for 60.4 million people, in Finland for 5.2 million - 20 universities. The excess of higher education institutions in Kazakhstan is partly due to objective reasons, since the mass consciousness continues to see higher education as a social elevator.

The massive nature of higher education (university students are more than 50% of those of the corresponding age group [3]) leads to a sharp drop in the quality of educational services, and to a significant drop in the level of university science. Attempts by the Ministry of Education and Science of Kazakhstan to rectify the

K. Arai et al. (Eds.): FICC 2020, AISC 1129, pp. 420–430, 2020.
https://doi.org/10.1007/978-3-030-39445-5_31

situation, unfortunately, often cause the opposite effect, at least, if we speak about the effectiveness of research activities in Kazakhstan's universities. In particular, the introduction into widespread use of such a scientometric indicator as the Hirsch index led to a sharp increase in the number of pseudoscientific works published by university professors for the sake of formal reporting, for the sake of membership in dissertation councils, the ability to qualify for budget funding, etc. [4–6].

Improving the quality of scientific works performed by university professors in the current conditions is a very urgent task, since the primary focus on formal indicators not only leads to an increase in the number of pseudoscientific publications [6], but also the use of relevant materials as the basis for graduation, master's and doctoral dissertations that de facto corrupts students and serves as a breeding ground for corruption.

However, numerous pseudoscientific works presented in the current literature can be considered, including, as a well-defined resource for developing critical thinking skills [4, 5]. Namely, the writing of critical reviews is a promising form of academic work, especially if we take into account that under current conditions, writing essays, which traditionally remain an important part of the educational process, has already become a profanation [4].

The purpose of this work is to develop an artificial neural network (ANN) that provides a parallel solution to the following tasks: the development of critical thinking among students, countering the growth of pseudoscientific publications and dissertations (both master's and doctoral), as well as identifying among students with pronounced passionarity and other personal qualities necessary for the implementation of fruitful scientific activities in modern conditions. It is assumed that the developed ANN will be the basis for the artificial intelligence system of the same purpose.

2 Program Development and Results

Recall that by Gumilev [7] refers to passionarity as a characterological dominant, an unbreakable inner desire (conscious or, more often, unconscious) for activities aimed at the realization of a goal (often illusory).

As experience with young scientists shows, in modern conditions passionarity is often much more serious than formal competences (for example, there are plenty of examples where a budding young scientist threw science at the occurrence of some or other obstacles) the factor of passionarity for achieving success in science is demonstrated by its entire history [8].

Thus, Tycho de Brahe, who spent all his personal fortune on astronomical exploration, as well as many other Enlightenment figures who are ready for many personal sacrifices to attain Truth, should be referred to the clearly expressed passionaries.

The developed ANN is focused on analyzing the content of critical reviews written by undergraduates on pseudoscientific works. In developing assignments, emphasis was placed on criticizing pseudoscientific works, however, neural networks based on this principle can also be used to analyze critical reviews of publications of any type (i.e., including truly scientific, but containing some miscalculations or elements conscientious delusions).

Critical reviews written by undergraduates of the Almaty University of Power Engineering and Telecommunications (AUPET) were used as the primary material for the development of the ANN as part of the practical tasks of the innovation discipline "Artificial Intelligence as a Driver of the Fourth Technological Revolution". Performance of just such tasks is provided for by the work program for this discipline, developed in parallel with the textbook [9].

As an experiment, the task was performed remotely, which allowed to fully cover the entire flow of the Institute of Space Engineering and Telecommunications AUPET.

The analysis of the texts of the reviews allowed us to choose groups of words, phrases and speech turns, expressing the degree of critical thinking on the text of the reviewed publication. Review analysis also showed that undergraduates are clearly divided into several groups according to the degree of readiness to critically interpret publications in the open press, according to the degree of readiness to defend their point of view, etc. Direct analysis of the texts also showed that there is a well-defined correspondence between the nature of the words used, phrases and speech patterns, and the categories to which students can be attributed.

It should be noted that the question of assessing psychological qualities in terms of identifying the propensity for fruitful scientific work is not for the first time put. Thus, an experimenter who is an adherent of a scientific hypothesis often unknowingly introduces a distortion in the interpretation of the data, providing confirmation of this hypothesis. This effect is called the "Pygmalion Effect" (this is a special phenomenon in psychological science, which consists in the fact that a person's expectations regarding another object or situation largely determine the specifics of his own actions, interpretation of the behavior of others, which allows these expectations to be realized).

One of the professional competencies of a researcher is the ability to create an image of a future research, the so-called ability to anticipate, predict. This contributes to the systematization and structuring of scientific ideas, as well as the possibility of its implementation. It is also appropriate to emphasize that an important tool of scientific knowledge, along with analysis, synthesis, classification, induction, deduction, is also reflection. A.V. Karpov defined reflection as meta-ability: "Reflection … manifests itself as the representation in the human mind of the mechanisms and forms of voluntary control over the processes of information generation, its development and functioning. … The ability to reflect can be understood as the ability to reconstruct and analyze a plan understood in a broad sense to build your own or someone else's thoughts; as the ability to distinguish in this regard its composition and structure, and then to objectify them, to work out according to the goals set" [10].

You can talk about the so-called professional reflection as the process of implementation of the internal mental activity of the subject - the reflective activity in relation to scientific activity, the subject of scientific knowledge, which is based on professional activity as an ergatic system, which is represented by a variety of subject-object and self-subject relations.

The subject of analysis of professional reflection are: "The image of the object of professional activity" and "The image of the subject of professional activity." The psychological criterion for the success of scientific research is the formation of an attitude towards oneself as the subject of a chosen activity: the professional and emotional orientation of an individual determine each other.

The researcher realizes emotional intentions, which, as a rule, are unsaturated. According to B.I. Dodonov, it can be a whole range of emotional states:

- altruistic: the scientist wants to help humanity;
- communicative: research for the implementation of scientific dialogue, the search for interdisciplinary connections;
- gloric: studies for recognition;
- praxical: dedication to this business;
- frightening: overcoming various obstacles that lie in the way of the research;
- romantic: the pursuit of science to all that is unknown;
- gnostic: the desire to find something new in the familiar, to create your innovative product;
- aesthetic: a sense of the beauty of the truth of the study;
- hedonistic: science creates mental comfort;
- acquisitic: the accumulation of theories, attitudes, principles, etc.

The listed personal aspects of the researcher are determinants of true science, the absence of these personal indicators leads to pseudoscience.

The classification according to the degree of critical attitude towards pseudoscientific texts is presented in Table 1, examples of indicative words and phrases are also presented there.

Table 1. Classification of indicative words and phrases according to the degree of critical attitude of students to the material of pseudoscientific work.

Classification/description of the feature	Characteristics of used expressions/examples of indicative phrases
Understanding the content of the work while rejecting the very idea of criticism/The rejection of the question of the need for criticism from the "younger"	The desire of the author to focus on the positive aspects of the work *The material is presented logically, the results were reviewed, studies were conducted, the results show, these options allow, the conclusions reflect, the conclusions are justified, there is no doubt about the relevance, etc.*
Departure from answer/expressed desire to get away from a sharp discussion of the shortcomings; understanding of the importance of criticism of flaws in the desire not to carry out this criticism personally	Statements with positive semantic color dominate over negative ones (positive ones have a tinge of doubt, negative ones reflect a desire to criticize insignificant flaws) *- It would be, in my opinion, it would be possible, the average scientific value, but the authors did, the article is consistent, the topic is relevant, the relevance of the article is beyond doubt, meets all the requirements, problems in the article are solved, the article is structured, framed in accordance with the requirements, material it is stated logically,*

(*continued*)

Table 1. (*continued*)

Classification/description of the feature	Characteristics of used expressions/examples of indicative phrases
	the article is written in an understandable and accessible language, can be used as theoretical material, etc. *- the topic was not disclosed, not enough informative spelling errors, grammatical errors, goals were not achieved, the article needs some work, the output is not meaningful, is not fully disclosed, there is no novelty, as a remark, no references are indicated, it requires serious work, not recommended for publication, translation inaccuracies, distant relation to the text, no conclusions, negative aspects, not fully disclosed, etc.*
Soft criticism/Ready for critical assessments of flaws in soft and smooth form.	Negative expressions prevail, focusing on the criticism of minor flaws. Positive ratings are also present, but less common *Not fully disclosed, no novelty, as a remark, no references are indicated, no literature is indicated, difficult to use the article, completely inconsistent with the content, the language of the article is not clear, the topic is not disclosed, the article needs to be improved, the conclusion is inconsistent, the goals are not achieved, there is no novelty, the author could not, do not disclose the whole scientific nature, the calculations are not justified, requires serious improvement, not recommended for publication, distant relation to the text, no conclusions, negative sides, not fully disclosed, etc.*
Tough criticism/readiness for harsh criticism of shortcomings, readiness to defend one's opinion	Reviews contain ONLY negative expressions: *Not recommended, incomprehensible, unclear, problem not disclosed, inconsistent, illogical, does not reveal the essence, does not satisfy the requirements, I do not recommend publishing, easy reading, strange manner of presentation, a number of comments, no logical conclusion, the main article is missing, the article requires self-analysis of the article requires complete substantive processing, etc.*
Misunderstanding of the essence of the reviewed work	Direct retelling of the article's test lack of indicative words and phrases

The revealed correspondence allows using well-known methods for the construction and training of ANNs [9, 11]. For the training of the neural network, reviews obtained in the course of the experiment described above were used. In parallel, for the purpose of control, students were surveyed, providing additional confirmation of their ability to develop critical assessments.

An example of one of the questionnaires is presented in Table 2. In the preamble of the questionnaire the respondents (undergraduates) were provided with the following information, which was further clarified during practical exercises.

The article "Academic unworthiness of 2018" was published on the website of the Internet resource Mirror of the Week (Ukraine). It reflects the results of the "anti-competition" conducted by the Ukrainian colleagues. This "anti-competition" is based on the idea of an outstanding physicist S. Sharapov, who proposed to distinguish academically dishonest scientists, giving them a kind of "black mark". Thus, the scientific community acquires the ability to control "its own territory". The idea was brought to life by Ukrainian activists of the Dissergate initiative; The first such "award" took place in 2016.

Respondents were asked to select only one of the presented answers, each of which corresponds to the "black marks" awarded by Ukrainian colleagues in the nominations listed below.

Table 2. The list of questions in the questionnaire proposed to undergraduates during the survey and the absolute number of undergraduates N who chose this answer.

№	Possible answer	*N*
1	"Plagiarist of the Year"- a black mark is sent to colleagues and officials who most shamelessly used other people's results	9
2	"Pseudo-scientist of the year" - nomination for those who published and defended the most malicious nonsense	5
3	"Murzilka year" - the magazine is awarded, which most eagerly published pseudoscientific works (most often for cash)	7
4	"Scandal of the Year" - for the loudest scandal in the scientific community	1
5	"Posipaka year" - awarded to organizations (for example, academic councils) for "significant contribution" to the production of plagiarists, falsifiers and fabricators	3
6	Kazakhstan is not Ukraine, we definitely don't need such "anti-competition"	8
7	I do not consider myself entitled to pass judgment on this issue, undergraduates should not even think about criticizing elders	5

The distribution of responses received in percent is presented in Fig. 1.

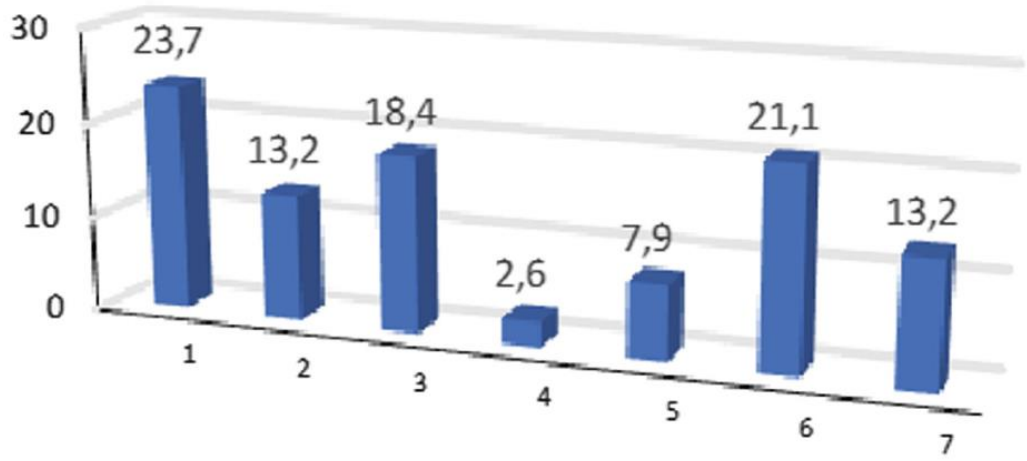

Fig. 1. The percentage distribution of answers on the options.

A trained neural network allows classifying students according to the signs that determine their readiness for scientific work. We emphasize that in modern conditions one of the most essential features is the willingness to overcome obstacles (created by both the conservatism of a significant part of the teaching staff and the bureaucratic routine) and other character traits, which together form a passionate psycho type [12].

To implement the artificial neural network of the proposed type, the programming language Python was used, with the open neural network library for deep learning Keras. It is a superstructure over the Deeplearning4j, TensorFlow and Theano frameworks. This library is aimed at efficient work with the networks of in-depth training, at the same time designed to be compact, modular and expandable. It was created as part of the ONEIROS research effort (the Open-ended Neuro-Electronic Intelligent Robot Operating System) [13]. TensorFlow was used as a backend, which is an open software library for machine learning developed by Google for solving the problems of building and training a neural network with the goal of automatically finding and classifying images, achieving the quality of human perception. It is used both for research and for the development of Google's own products [14].

The developed system is focused on working with textual samples (review texts), therefore, a preliminary processing of the training sample for the created deep artificial neural network in a convenient form was carried out. The available sample of reviews was divided into 5 groups according to the degree of understanding of the material under review in accordance with the classification criteria reflected in Table 1.

The training sample reviews were placed in one csv file. The structure of a csv file is a string consisting of two columns separated by an "@" sign. The first column contains the review itself in one line, the second indicates the group to which this review belongs. Later, the Keras library was used to preprocess text: using the Tokenizer function (the tokenize module is a lexical scanner for Python source code implemented in Python). The scanner of this module returns comments as tokens; the words in the sample were replaced with digits that could be used by artificial neural network.

The implemented network is a sequential recurrent artificial neural network consisting of three layers. Schematically such a neural network is shown in Fig. 2.

The first input layer is a fully connected layer consisting of 256 neurons, with the type of activation ReLu (Fig. 3). This activation function has the name "rectifier" (rectifier, by analogy with a one-half-period rectifier in electrical engineering). Neurons with this activation function are called ReLU (rectified linear unit). The ReLU has the following formula f (x) = max (0, x) and implements a simple threshold transition at zero.

Consider the positive and negative sides of ReLU.

Positive sides:

- The calculation of sigmoids and hyperbolic tangent requires demanding operations, such as exponentiation, while ReLU can be implemented using a simple threshold transformation of the activation matrix at zero. In addition, the ReLU is not saturated.
- The use of ReLU significantly increases the rate of convergence of stochastic gradient descent (in some cases up to 6 times) compared with sigmoid and hyperbolic tangent. It is believed that this is due to the linear nature and the lack of saturation of this function [15].

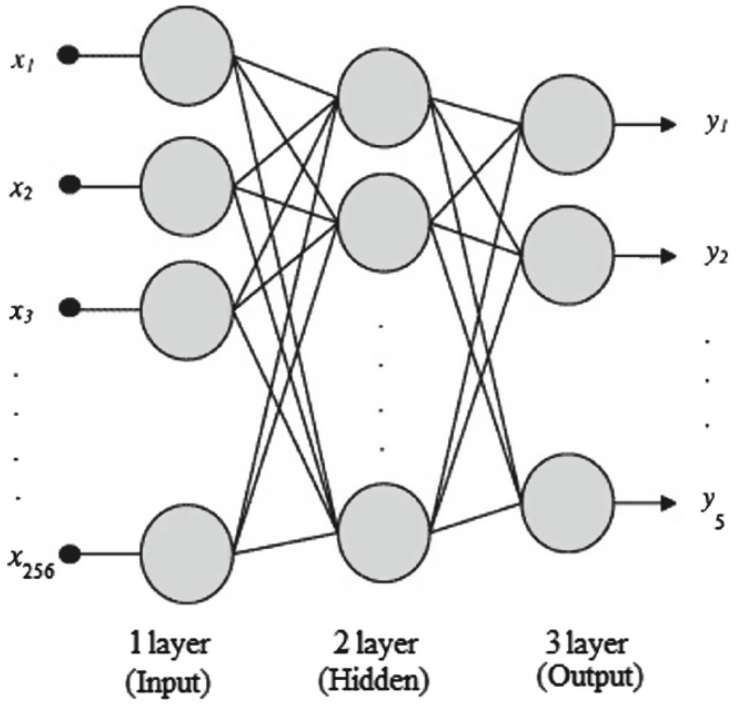

Fig. 2. The scheme of the primary version of the artificial neural network.

Negative sides:

Unfortunately, ReLUs are not always reliable enough and can fail ("die") in the learning process. For example, a large gradient passing through a ReLU can lead to such an update of the balance that the neuron is never activated again. If this happens, then, from now on, the gradient passing through this neuron will always be zero. Accordingly, this neuron will be irreversibly disabled. For example, if the learning rate is too high, it may turn out that up to 40% of the ReLUs are "dead" (that is, never activated). This problem is solved by choosing the appropriate learning rate, which in this paper was chosen empirically.

The second layer of the constructed network is a layer of regulation with the probability of neuron shutdown of 50%. The output layer consists of 5 neurons corresponding to the number of defined categories. The activation type for the output layer is Softmax, the total sum of the outputs of all 5 neurons of the output layer is 1, which corresponds to the classification procedure.

The SoftMax function (soft maximum function) is often used in neural networks as an activation function when solving a classification problem. Softmax is defined by the following formula: $\sigma(z)_i = \frac{e^{z_i}}{\sum_{k=1}^{N} e^{z_k}}$, where z_i – the value at the output of the i-th neuron before activation, and N - the total number of neurons in the layer.

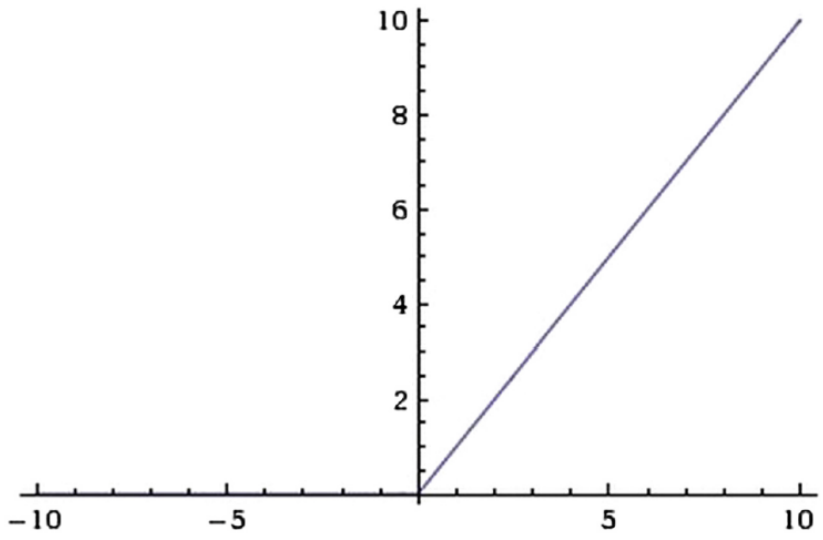

Fig. 3. ReLu activation function.

As a function of the error when compiling the model of an artificial neural network, categorical cross-entropy[1] was chosen, which is well suited for the case when at the output of an artificial neural network there are probabilities of the appearance of a class

[1] Cross-entropy is one of many possible loss functions (another is the loss of the SVM loop). These loss functions are usually written as J (theta) and can be used in gradient descent, which is an iterative basis for moving parameters (or coefficients) to optimal values.

[16]. The model is optimized using the method of adaptive moment estimation (Adam), the accuracy is chosen as the model metric.

There were 40 reviews in the training set. The size of the mini-sample for each epoch of learning was 18 reviews, the number of learning epochs was 15. The option of automatic separation of the sample into training and verification was also chosen. The size of the test sample was 10% of the main.

According to the results of 15 epochs of learning, the accuracy of determining the class of reviews on test data was 94.4%, in the training sample 50% (Fig. 4). The relatively low value of the accuracy of determining the class on the training sample is caused by the small size of the original sample, however, the results show that the developed tool is quite efficient and can be further brought to the level of real practical use by increasing the training sample.

```
Train on 18 samples, validate on 2 samples
Epoch 1/15
18/18 [==============================] - 2s 96ms/step - loss: 2.0089 - acc: 0.1111 - val_loss: 1.5148 - val_acc: 0.0000e+00
Epoch 2/15
18/18 [==============================] - 0s 445us/step - loss: 1.4680 - acc: 0.3889 - val_loss: 1.8863 - val_acc: 0.0000e+00
Epoch 3/15
18/18 [==============================] - 0s 389us/step - loss: 1.1337 - acc: 0.4444 - val_loss: 2.4155 - val_acc: 0.0000e+00
Epoch 4/15
18/18 [==============================] - 0s 389us/step - loss: 0.9287 - acc: 0.6667 - val_loss: 2.7458 - val_acc: 0.0000e+00
Epoch 5/15
18/18 [==============================] - 0s 445us/step - loss: 0.6838 - acc: 0.8889 - val_loss: 3.0558 - val_acc: 0.5000
Epoch 6/15
18/18 [==============================] - 0s 445us/step - loss: 0.6847 - acc: 0.8889 - val_loss: 3.3143 - val_acc: 0.5000
Epoch 7/15
18/18 [==============================] - 0s 445us/step - loss: 0.5302 - acc: 0.8889 - val_loss: 3.5213 - val_acc: 0.5000
Epoch 8/15
18/18 [==============================] - 0s 445us/step - loss: 0.4458 - acc: 0.9444 - val_loss: 3.6991 - val_acc: 0.5000
Epoch 9/15
18/18 [==============================] - 0s 445us/step - loss: 0.3468 - acc: 0.9444 - val_loss: 3.8344 - val_acc: 0.5000
Epoch 10/15
18/18 [==============================] - 0s 445us/step - loss: 0.3257 - acc: 0.9444 - val_loss: 3.9366 - val_acc: 0.5000
Epoch 11/15
18/18 [==============================] - 0s 389us/step - loss: 0.2584 - acc: 1.0000 - val_loss: 4.0200 - val_acc: 0.5000
Epoch 12/15
18/18 [==============================] - 0s 445us/step - loss: 0.2476 - acc: 1.0000 - val_loss: 4.0929 - val_acc: 0.5000
Epoch 13/15
18/18 [==============================] - 0s 389us/step - loss: 0.2384 - acc: 1.0000 - val_loss: 4.1628 - val_acc: 0.5000
Epoch 14/15
18/18 [==============================] - 0s 389us/step - loss: 0.2074 - acc: 1.0000 - val_loss: 4.2180 - val_acc: 0.5000
Epoch 15/15
18/18 [==============================] - 0s 389us/step - loss: 0.2080 - acc: 0.9444 - val_loss: 4.2882 - val_acc: 0.5000
```

Fig. 4. Learning outcomes of an artificial neural network.

3 Conclusion

Thus, there is a real opportunity to transfer a significant part of practical classes in such disciplines as "History and Philosophy of Science" [8] into a remote mode, in parallel testing students for aptitude for independent scientific work with the aim of recruiting staff for the implementation of scientific and technical projects and programs including interdisciplinary nature.

A completely similar tool can also be used to stimulate interdisciplinary cooperation focused on specialties related to electronics and information and communication technologies. In this case, students are invited to write critical reviews on the nature of the use of measurement methods (in terms of electronic support, for example), as well as in the use of infocommunication methods in related (and not only) fields of knowledge.

Criticism of techniques actually used in works in chemistry, nanotechnology, ecology, etc. allow students to see the points of application of their efforts, which in turn is a guarantee for fruitful project activities within the framework of the concept of the "triangle of knowledge".

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