Scientific personnel training in convolutional neural networks for the implementation of research projects of the MegaScience class

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Abstract. Megascience projects require an all-inclusive interdisciplinary approach. Because of that scientific personnel engaged in projects of this type must possess relevant required interdisciplinary skills. Artificial intelligence in particular convolutional neural networks has a wide range of applications, and it could be used to solve complicated problems in all kinds of various fields of science. Thus, the understanding of the principles of neural networks’ working is a necessary skill for scientific personnel. In this paper, we’re considering practical examples and fields of applications of neural networks in the real world.

1. Introduction
Scientific personnel requires adequate training of various skill to successfully participate in research projects. Megascience projects are usually big international projects and they have following distinctive features:

- These are complex physics and research facilities.
- Projects requiring significant financial costs.
- Participation of multiple countries.
- Requirement for processing and storage of high amounts of data.
- Demand for new effective intelligent data processing algorithms, for example, involving neural networks.

These big and complex projects demand from participants knowledge in various fields, including intelligent data processing. Projects of this type generate big amounts of data which needs to be processed. Data processing may be a complicated intellectual process which requires adequate artificial intelligence algorithms to automate it. Effective processing algorithms would decrease project costs. In order to effectively introduce complex data processing algorithms into the workplace, it’s not only necessary to have experts trained specifically in this field but also for all participating personnel to have a basic understanding of principles involved.

Data processing algorithms of various nature have been developed in different fields of applying over the years, for example:

- Bayesian networks for accident risk assessment [1].
- Petri nets for risk assessment in business [2].
- Information retrieval algorithms [3, 4].
- Big data processing [5].
- Agent-based technologies [6, 7].
- Models for structuring data [8].
- Competence evaluation in knowledge management systems [9].
- Association rules mining [10].
- Life cycle visualization [11].
- Visual scene analysis [12].
- Cognitive architectures [13] and their semantic maps [14].
- Strategies for forming competences [15].

However, in recent years neural networks and artificial intelligence, in general, takes on an increasingly important role in life and science.

Leaders of countries and corporations pay more and more attention to the technologies of artificial intelligence.

One of the modern generalized solutions for various tasks of intelligent data processing is neural networks. In recent years the general interest for neural networks, especially convolutional, is growing which can be seen from google search statistics (figure 1).

![Google search trends for artificial intelligence and convolutional neural networks](image1.jpg)

**Figure 1.** Google search trends for artificial intelligence and convolutional neural networks [16].

Each year more and more neural network algorithms are developed for solving various tasks. A few types of tasks already have a more or less standardized approach to solving them.
2. Neural Networks

Neural networks are an important method of intelligent data processing. A neural network consists of many connected entities called neurons (figure 2). Each neuron performs a basic transformation over values inputted into it and outputs a value. Parameters of the transformation are called weights. In a neural network, neurons are connected to each other so the output values of neurons are fed as input values of the other neurons. A group of neurons called input neurons take their input values from neural network input, and another group called output neurons provide their output as neural network final output.

Neurons’ weights can be adjusted so the output values (given certain input values) match the desired values for solving a particular task, for example, for determining whether a fingerprint provided by a sensor is real or a forgery.

The process of finding the necessary values is usually referred to as training (figure 2). In order to train a neural network, a training dataset is composed. The training dataset consists of examples of input data $x_1, \ldots, x_n$ and corresponding desired output values $y_1, \ldots, y_n$.

During training for each input example from $x_1, \ldots, x_n$ neural network using current weight values $w_1, \ldots, w_m$ produces predictions $y^*_1, \ldots, y^*_n$ for output values $y_1, \ldots, y_n$. Next, these predictions are compared to the true output values, and the weights are adjusted so the predictions match true values more closely. After this neural network produces the predictions using these new weights, the described above process repeats and thus, in an iterative process, the network is trained to solve the given task until the necessary performance (for example, accuracy threshold) is reached.

For example, the training process for object detection using YOLO framework is depicted in figure 3. As can be seen, accuracy measure steadily increases over iterations of training, and training accuracy is usually higher than validation accuracy.

The method proved to be very effective in many fields of application. Various ways to organize, connect neurons, calculate the cost function, create training and testing datasets and so on were researched.

In recent years the increasing computational power of GPUs allowed neural networks to be widely and effectively used.
Figure 3. Training and validation accuracy during neural network training process.

3. Personnel Training Features
Neural networks have been successfully used to solve various tasks. As was mentioned above, neural networks can be applied in very different application fields, such as medicine, forensic science [17], aerology and so on. Here are examples of neural networks applied in various fields:

- Extreme weather event detection: finding tropical cyclones, atmospheric rivers and weather fronts using AlexNet-inspired convolutional neural network [18].
- Detecting military mines on Ground Penetrating Radar scans using convolutional neural networks [19,20].
- Spoof fingerprint detection: using a convolutional neural network to determine the liveness of a fingerprint [21].
- Artificial intelligence for board games [22].

Important to note that a lot of neural network algorithms are very general and algorithms from one field can be used and trained for a completely different field without many changes as long as input and output datatypes match. As such the breakthrough algorithm capable of playing go, for example, was later expanded to be able to play chess and shogi [22].

In research on military mine detection, authors took already developed detection system for real-life images and retrained it for radar images with good results. Thus, neural network algorithms are exceptionally versatile.

In the field of neural networks, we can observe the following tendencies:

- Transfer from domain-specific algorithms to generalized approaches.
- The increasing availability of more and more powerful hardware.
- Development of new and more effective algorithms in different application fields.
- Growing number of tools for easier use of neural networks.

So neural networks are more and more widely used in different scientific fields and with their increasing use, there’s increasing demand for training in this field.

The reason why it’s important to train experts of different fields in the area of neural networks is that these are the people who are going to make decisions about introducing AI tools into their workplace and use developed algorithms in their work. Neural networks and other AI algorithms can’t solve every problem and can make mistakes. Often people become too reliant on computer decisions, it’s important for user to understand that AI can make mistakes too and know which mistakes are more likely. Additionally, it’s important for people who make decisions to understand which tasks can be automated and how much it would cost.
Neural networks have specific peculiarities in their training and usage. Relatively common mistakes may include:

- Inaccurately chosen training goal. An optimized solution may not match the intended goal if the cost function doesn’t apply all the necessary constraints.
- Expecting algorithm to copy human behaviour. Algorithm responses don’t necessarily match human (expert) responses, for example, image classification network sometimes makes mistakes a human would never do.
- Relying too much on algorithms to produce a correct result. Since often neural network algorithms work with superhuman accuracy, human operators may develop a habit to not question the output of the algorithm.
- Rely on producing an accurate network without enough data.

Generally, there’re two levels of understanding for neural networks. First one is a low level which includes the understanding of inner workings of neural networks, development of algorithms based on them, specifics of training and application. The second level treats neural networks as a black box and focuses on solving real-life problems using ready-to-use tools, typical problems, and limitations.

Thus, we can outline two training directions:

- Machine learning expert. Programming expert capable of developing and applying neural network algorithms.
- User. Researcher capable of applying neural networks using ready-to-use tools.

We already developed a command-line neural network program, and are planning on making a lesson based on it. The program in question is patented by RosPatent [23].

4. Conclusion

We’ve demonstrated that the interest for artificial intelligence and neural networks is growing. Convolutional neural networks are an all-purpose tool for solving all kinds of different tasks in the real world. There’re many ready-to-use tools for applying neural networks in different science fields. In the application of neural networks, user can meet unexpected pitfalls and that’s why it’s important to train experts of various fields in neural networks. We outlined two possible branches of personnel training. We hope that our ideas will be used in developing of Megascience projects. We will continue to make efforts in developing teaching materials for students and researchers in the field of neural networks.

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