Development of repository of deep neural networks for the analysis of geospatial data

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Abstract. The article proposes a solution for organizing a storage of artificial neural networks in a digital spatial data infrastructure system. Based on the analysis of world experience, a register of key storage cases was created, which made it possible to create an effective solution for analyzing large arrays of spatial data. The structure of the neural network sets the format of the input data and the type of the output signal. It is shown that the use of neural networks for solving design problems requires dividing the storage of the ontological model into machine learning, data and task modules. The introduction of deep learning models into the repository will allow not only to form an ANN system capable of solving urgent problems in the field of analysis of different types of big data, but also to solve the problem of choosing an effective model by building a system of recommendations that optimize the choice of algorithms.

1. Introduction
Making managerial decisions in the field and responding to local and global environmental and economic problems should be based on the use of big data, which contains information about their spatial structure, as well as information about natural resources and population.

In this context, it is important to form the spatial data infrastructure (SDI) of the regions of Russia, focused on improving the efficiency of diagnostics of the state of natural-social-production systems (NSPS) and forecasting the development of natural and natural-man-made emergencies through the deployment of a system of federal, regional and municipal geoportals.

The formation of a universal information infrastructure is relevant for solving the problem of objective remote monitoring of objects and resources on the territory of Russian regions to ensure the country's information connectivity. Digital SDI, based on new effective methods, approaches and algorithms for the analysis of spatial data, represent a tool for optimizing the business processes of the largest corporations in the country, whose economy is geographically distributed. The role of geoportals in providing information support for the integrated development of the pioneer regions of the country - Siberia, the Arctic, the Far East is especially relevant [5].

Today, digital spatial data infrastructures (SDI) are an effective solution for creating a software system that will optimize the work of projects aimed at improving the country's economy. This class of information systems includes modules for storing, analyzing, presenting and distributing spatial data and interacts with external objects, consumers and providers of the necessary data.
The module for the analysis and synthesis of spatial data is an integral component of the project-oriented SDI, which can work both on traditional computations and on software computations based on a hybrid application of fuzzy logic, artificial neural networks (ANN) and simulation [1-2].

At the beginning of the XXI century, the emerging developments in the field of machine learning, its methods and principles include several stages of nonlinear data analysis for their extraction, transformation and classification. Research in the development of deep learning methods and algorithms has influenced the solution of a number of scientific problems associated with the automatic analysis of big data.

The use of neural network models should have a problem-oriented focus: the processes of creating an analyzer architecture, choosing its parameters, formulating requirements for the form of output data, combining arrays of training, validation and test samples should determine the features of the problem being solved. An important element is also the quality of documentation for use and flexible configuration of the model [3].

These provisions determine the need to form a deep neural network storage in an SDI system, a systematized storage that provides access to a standardized description of machine learning models, as well as tools for choosing the most effective solution in this area and testing the algorithm for its application.

2. Functional requirements for deep neural network storage

Analysis of the strengths and weaknesses of currently functioning ANN storages, as well as performance criteria for the SDI-oriented spatial data analysis subsystem, makes it possible to form a register of key options using a deep neural network storage:

- Navigation through the catalog of system models, which are characterized by division according to the type of tasks, the size of the analyzed data and their architecture.
- Selecting and configuring a model using a recommendation system that allows you to efficiently and visually search for an effective structural solution and customize it for solving design problems using a graphical interface.
- Obtain information about a deep neural network model, including meta descriptions, performance metrics, architecture type, hyperparameter tuning tips, practical examples.
- Representation of deep learning models in the form of a graphical diagram with the ability to visually edit the structure of the model online through a thin client.
- Open access to pre-trained versions of the model for the purpose of their direct application for solving problems or subsequent tuning.
- Storing models in a common format for displaying deep neural networks, which will allow them to be translated into representations used by modern machine learning structures.
- Interaction with an application programming interface that allows automatic data exchange, including the import and export of deep models, obtaining information about the state of the database.
- Identification and authentication for access to the repository in order to restrict the rights to use and modify models and display data about them.

The development of a deep neural network repository should be based on an ontology that provides a formalized description of entities, as well as connections between them [4,6]. The relevance of this provision is determined by the assumption that the process of applying deep learning to solving design problems can only be supported if the acquired knowledge and rules are collected in a system for which suitable interaction tools have been created. It is recommended to use formal languages to describe the ontology.

Effective use of deep neural networks for solving design problems requires decomposition of the ontological storage model into the domain of machine learning models, data and tasks.
Such a systemic organization will allow to give an exhaustive formalized definition of the studied area of knowledge, will allow to form the basis for creating a platform solution for the consolidation, storage, selection and effective use of deep neural network models for solving problem-oriented problems.

The process of forming a storage of deep neural networks in a digital SDI system should be based on a project-oriented approach, according to which each stored deep ANN should be compared with a range of design problems within which it can be used. Systematized in the storage of deep neural networks, and the solved design problems are based on consolidated datasets, with the key role being played by arrays of spatial information.

Directions for using the intended results:

- Implementation of intelligent systems for forecasting the development of natural and man-made emergency processes based on new technologies of integration, intellectual analysis and dissemination of large geospatial data into the activities of industrial enterprises and executive authorities of the region.
- Design, development and implementation of geoportal solutions aimed at creating information support for sustainable development of ecological, socio-economic systems of regions, effectively modified for specific corporate customers on the basis of a project-oriented approach.
- Provision of services for the use of geoportal systems according to the SaaS (Software as a Service) model with the possibility of flexible configuration of the provided solution.
- Development and development of socially-oriented geoportal solutions that ensure effective dissemination of spatial data about nature, economy, social life, history and culture of Russian regions.
- Development and implementation of practice-oriented educational programs in the field of sustainable development of regional and global ecological, socio-economic systems.

The area of deep learning includes concepts and relationships that describe deep neural network models of various topologies and configurations, as well as methods for training them. Although machine learning is not limited to artificial neural networks (ANNs) and can include helper vector machines, genetic algorithms, and automatic statistics methods, it was decided to focus on deep neural network models that most significantly influenced the development of machine learning and showed promising importance. for solving problems of analysis of large spatial data, requiring the identification of complex nonlinear dependencies.

For each ANN, it is recommended to compare a meta-description that includes guidelines for applying the model, its category, a description of the design problems to be solved, and a description of the presentation of the analyzed data. For the formation of a storage of deep neural networks in a digital SDI system, both ANN models and their network-trained copies of them, ready for solving design problems and for which fine tuning strategies are given, are of interest [7].

The next section will discuss a technique for creating a deep neural network model.

3. Methods of creating a neural network model for deep learning

It is advisable to build deep models for the analysis of spatial data according to the following algorithm:

1) creating a system of requirements for the model and define its input and output, performance and accuracy parameters;
2) the definition of the basic architecture that describes the work of the classifier;
3) decomposition of layers into linear and branching structures;
4) solving the problem of reducing the classification accuracy and overfitting by configuring the hyperparameters of the deep model and adding layers of normalization, subsampling and regularization;
5) optimization of the model according to the principle "less is better", since the process of training large models requires computational resources and, more importantly, deep neural networks are prone to overfitting;

6) training the model with testing various measures of accuracy, optimization algorithms, loss functions and the number of training stages;

7) analysis of the training process of the model by calculating the relationship between the expected value and the standard deviation of the classification accuracy based on a series of experiments;

8) evaluating the quality of the result obtained by constructing error matrices and evaluating the accuracy and error metrics based on the results of the model;

9) the formulation of conclusions about the compliance of the resulting model with objective and subjective requirements.

The proposed algorithm of actions leads to obtaining a sample of a model with certain properties. If the parameters of the designed and trained model do not meet the specified requirements, it is necessary to roll back a few steps (up to the first stage, if the formulated requirements turned out to be unattainable) and repeat the algorithm of actions.

As a result, the process of searching for an effective classification model can be formalized in the form of a tree, the root node of which precedes the first stage of the search algorithm and corresponds to the formulation of the research problem. The tree nodes determine the variant of the model state at the i-th stage of the effective model search algorithm. The end nodes of the tree correspond to a specific solution to the problem of finding the optimal model, ready to use a deep classifier.

Thus, a deep model based on the application of the geosystem approach is a functional element that receives input satellite images of an area and its host geosystems. The number of inputs can vary depending on the number of levels in the model, but you need to track their increase, as this will inevitably lead to the need to increase the capacity of the model.

A deep neural network model can be distinguished by its topology, which establishes the presence in its structure of layers of the designated type and connections between them (branching, chain). The structure of the neural network sets the format of the input data and the type of the output signal. Activation and regularization functions are important characteristics of the neural network layer. The deep neural network model is also characterized by parameters (loss function, initialization and optimization algorithm) and learning strategy (with reinforcement, with a teacher, without a teacher, with partial participation of a teacher) [8].

4. Conclusions

The introduction of deep learning models into the repository will allow not only to form an ANN system capable of solving urgent problems in the field of analysis of different types of big data, but also to solve the problem of choosing an effective model by building a system of recommendations that optimize the choice of algorithms.

Each deep neural network should be tested on live web site systems to quantify its performance.

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