Artificial neural networks as a tool for creating a road information model

S S Shaburov¹, T L Dmitrieva¹ and A B Chernyago¹
¹Irkutsk National Research Technical University, 664074, 83, Lermontov street, Irkutsk, Russian Federation
E-mail: sss1941@yandex.ru

Abstract. The possibility of creating an information model of the highway on the basis of existing design documentation using artificial neural networks is considered. It is supposed to interconnect all the most popular formats of road design documentation data for quick and accurate search for the required parameters, further update them using GIS technologies, as well as use at the construction and operation stages. The end result may be some semblance of a digital twin of a selected stretch of road.

1. Introduction
To organize production processes related to the construction, reconstruction and overhaul of a highway, you need to strictly follow the developed work plan. The main document, which contains all the necessary information on volumes, finances, supply of resources and the timing of work, is the project documentation (PD). PD is drawn up at the design stage, in accordance with regulatory documents, as well as on the basis of standard design solutions. Modern approaches to the formation of this documentation involve the use of various information technologies: these are text editors, programs for working with spreadsheets, specialized computer programs to help in the compilation of statements, calculations of structural strength, general automation, budgeting, CAD systems for computer-aided design and etc. Such a set of different software significantly speeds up the design process. At the same time, it should be noted that today a course has been taken to introduce technologies based on the information model of technical objects (or BIM technologies), which allow not only to increase labor productivity in the design, construction and operation of structures, but also to significantly improve the technical-economic indicators of the latter [1]. This is achieved by the intelligent behavior of individual systems controlled by these technologies.

However, the massive centralized introduction of BIM technologies in Russia requires significant material, including technical and human resources and will take a certain period of time. Until this moment, it is necessary to take certain steps to maximize the digitalization of already existing PD, on the basis of which construction work will be carried out. This paper proposes one of the possible solutions to this problem based on the creation, using artificial neural networks (ANN), of an information model of the road based on its PD data and updating the data with GIS systems. This model should include the entire process of the road life cycle and be accessible to all participants involved in project development, construction and operation [2].

2. Material and research methods
To work with text data, it is proposed to apply word vectorization (a class of approaches for formalizing words and documents using vector representation) [3]. As output neurons, a sample was taken from the database of various key names of the sheets used in the PD, and as input data, the set of obtained variations in the form of a text corpus, obtained by comparing each word of a vector that gives the coordinates of words corresponding to the name of these sheets. Thus, words are formalized by dense vectors, where the vector represents the projection of the word into a continuous vector space. Training data includes different spellings of the statements. Their names, or rather, each of their words, are encoded as a sequence of integers.

The search for the required data occurs in two stages: at the first, the list of the required parameter is revealed, and at the second its value. Recalculation of values at a certain site is carried out using the principles of a standard algorithm, with the help of which a set of key parameters of the road is subsequently organized.

After the computer finds the parameters of the road from the PD, it is possible to build its information model based on all the data obtained, the available geographic and attributive information. A set of attribute information is also included in the test data of some statements.

It should be noted that in the construction of roads, specialists are already widely using modern technologies. During the survey, high-performance methods of collecting information about the terrain are used: GIS technologies, aerospace digital photogrammetry, satellite navigation systems, laser scanning, geophysical methods [4].

If you use, for example, during construction control, the collection of information during the construction phase, you can update the information model of the road, supplementing it with data from the outside. And by modeling the condition, strength and reliability of a road structure, predicting its condition in advance, one can create a kind of digital twin.

A digital twin means a complex of digital technologies that use the approaches of statistical analysis, machine learning, chemistry, physics, control theory, reliability theory, queuing theory, numerical modeling, optimization. At the same time, the digital twin is not limited to collecting data obtained at the stage of product development and manufacturing, continuing to collect and analyze data during the entire life cycle of a real object [5].

3. Research results and their discussion
During the construction of a linear facility, the contractor performing the work and construction control need to constantly monitor the progress of construction and monitor the closure (registration) of the work performed - acts of hidden work, executive documentation of the contractor, etc. The data contained in the PD must coincide with the data presented in the executive documentation, for this, the search for the necessary information in the PD for supervision must be done directly at the place of work. But such a search is not always convenient to carry out, often holding a printed volume of PD. The most practical and convenient search for design solutions, if there is Internet access, is from laptops, tablet computers or mobile devices.

Such a search will be most effective when using cloud services using a ready-made software environment on remote servers. In this work, a platform for working with neural networks and working with databases will be created on the basis of the PaaS (Platform as a Service) cloud service. This method will allow the use of portable devices when processing the necessary data at a construction site.

As an example, a search was made in the existing PD "list of intersected utilities", in which it was necessary to find the value of the gauge of the wire above the road.

The search is carried out by means of ANN based on the received sound information (voice). When organizing a search in project documentation, the goal is to accurately determine the meaning of the text being laid by the consumer with the output of the data of the desired value. ANN Learning Paradigm: Supervised Learning. Standard algorithms are supposed to determine, from the values found by the ANN, the missing data by mathematical and geometric calculations (where possible). Thus, an information model of the road is created, which can be used by any participant in the construction.
Neuroph Studio is Java Neural Network development environment on top of NetBeans Platform based on Neuroph framework, a type of neural network - Rumelhart's multilayer perceptron with three trainable layers.

A search for the required statement is organized (Fig. 1). To train the neural network, the activation function was chosen - sigmoid (1):

\[ A = \frac{1}{1 + e^{-x}} \]  

(1)

In comparison with the hyperbolic tangent (2):

\[ f(x) = \tanh(x) = \frac{2}{1 + e^{-2x}} - 1, \]  

(2)

for our purposes, it approximates the desired function better.

As can be seen in Fig. 1, the required list was found in the design documentation with a rather small error, the search success was 92.9%.

In the found list, positions are highlighted that are equal to the number of output neurons, with the subsequent creation of an array of data of these positions to search and select a specific desired value - the size of the wire above the road (Fig. 2).

**Figure 1.** The result of the search for the dimension value at 0.17 kilometer with its vector representation.
Thus, a trained ANN can successfully solve problems in ~ 93% of cases when organizing a search for the necessary values of the parameters of a highway in the PD. Further training of the ANN will improve this result.

Another useful direction in the study of the use of ANN in the construction of linear facilities will be the use of these technologies to compare the positions from the consolidated bill of quantities (CBOQ) used to calculate the estimated cost of construction, with positions from the collections of HPES and FER for automatic compilation of estimates for each type works.

It is assumed that all project documentation, together with an estimate block, which, like all other related documents, including as-built documentation (at the construction stage), will be in the Common Data Environment (CDE - a single source of reliable information for all project participants) [6,7]. But for this, it is necessary, by converting everything into electronic format, to provide all tabular data in a single software module for working with spreadsheets. Then the work with the estimated normative database of the GESN-2001 (the state element budget norms), FER-2001 (federal unit rates) will be associated with the consolidated bill of quantities (CBOQ) and other tabular data (Fig. 3).
Figure 3. Comparison of different variants of writing the scope of work (left) with positions from the collection of FER (right). ANN determines the position and, where required, an addition to the main position with the assignment of coefficients to the required values.

Figure 3 shows how, with different spelling of the types of work in the CBOQ, trained on more than 30 examples of various PD, the ANN compared them with the same prices (positions) from the FER collection. Under certain conditions for comparing positions from the CBOQ, for example, when it is necessary to make an addition to the main position or a coefficient to this position, the algorithm provides for such an operation when drawing up an estimate.

Further study of improving the supervision of the construction of a road based on verification by PD involves the development of an algorithm for constructing a model of the technological process of operation (MTPO) of the road (for example, the stage of repair) based on a digital model of the road (DMR) - a reference model obtained at the stage of development of the design and working documentation. Comparison of the existing situation with the DMR and MTPO. The result will be a generated report.

4. Conclusion
The trained ANN can successfully solve problems in ~ 93% of cases when organizing the search for the necessary values of the parameters of the road in the PD, automatically compare the estimate with the specified types of work, which allows using this technology in combination with the use of cloud services for the fastest possible verification of the parameters of a linear object under construction.

BIM is becoming an indispensable attribute in the new paradigm of the state contract system, or rather, in the implementation of life cycle contracts (LCC). LCC implies that a road contractor must not only build an object, but also ensure its long-term operation [8].

Thus, information modeling of roads is more and more in demand. Maximum digitalization of existing and future projects is one of the most pressing issues of the present time. And here the global BIM model of an object can be obtained on the basis of the existing software support, including all documentation packages. One of the steps in this direction can be an information model created on the basis of design documentation, which allows organizing effective control of the timing and cost of work at linear facilities, linking all this with the work schedule, improving the quality of design, construction and operation of these facilities [9].
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