ESTIMATION OF RECYCLING CAPACITY OF MULTI-STOREY BUILDING STRUCTURES USING ANN

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UDK: 004.8.032.26:502.174.1
DOI:10.14415/konferencijaGFS2017.096

Summary: *Artificial intelligence in construction can be used at all stages of design and construction, from the earliest stages to the final stages of demolition and estimation of recycling capacity. This paper presents a model for the estimation of amount of material (concrete and reinforcement). The model is based on artificial intelligence and estimation of amount of material is performed using ANN. For research purposes, different models are tested and model that provides acceptable predictions is chosen and tested on a real sample. Prediction accuracy is up to 13%.*

Keywords: *artificial intelligence, neural networks, construction, reinforcement, concrete*

1. INTRODUCTION

The application of artificial intelligence in the construction industry is becoming more frequent with the development of software packages and computers. Over time, the application has become possible in all phases of realization of the building, from the earliest planning stages to the latest stages of demolition and recycling capacity planning. Artificial intelligence can be applied in the control of designs in the form of control materials planned to be embedded in the building, in estimation of cost and time of the construction of buildings, in prediction of recycling capacity etc.

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One of the most interesting areas of artificial intelligence that has been applied in practice is the development of artificial neural networks, which are considered to be the greatest technological process in recent decades. Artificial neural networks are well demonstrated in situations where the ability to identify hidden connections and patterns is crucial for successful predictions.

Considering very complex problems that may arise in the construction industry, the application of neural networks is more than justified. In this work, we carried out an analysis was of certain parameters which characterize the object for the purpose of predicting the amount of reinforcement and concrete. Estimation of the quantity of material has a multiple use. In the earliest stages of planning, the contractor can easily and quickly assess the costs, while in the latest stage of planning and demolition, artificial neural networks can be used to estimate the quantity of recycling capacity. This way it is possible to save money because the recyclable materials can be re-used for building new buildings, and environmental pollution is reduced because these materials are not disposed on landfills. Also, it reduces the exploitation of natural resources needed for construction. In order to estimate the recycling capacity (reinforcement and concrete) many different models of artificial neural networks were performed. These models have been tested on real samples and those which give the satisfactory prediction accuracy were chosen.

2. THE USE OF ARTIFICIAL INTELLIGENCE IN THE CONSTRUCTION INDUSTRY

In literature, there can be found several different definitions about neural networks. By the definition of Jacek M. Zurad, the "Artificial neural system (NN), are the cell systems that can gain, store and use experiential knowledge." [9]. "Neural networks are systems consisting of a large number of simple elements in parallel linked, whose function is defined by the structure of the network itself, with bond strength between elements and processing that is performed in the network nodes themselves, ie. in elements for information processing. "[8].

In literature we can find the most of artificial neural network for estimating the cost of building projects, while those for estimation deadlines execution of works or in combination deadline and costs appear less frequently. There is almost no mention of the amount of material in the planning, construction, renovation and demolition in the context of estimation.

Also, in literature we can often find the comparative analysis of artificial neural networks with other models to solve the same problem, and combination of them with models of other types of artificial intelligence, for example SVMs or Fazzy logic.

In the following text, several the most important researches in the field of artificial intelligence or artificial neural networks will be briefly shown, and all of them have helped and influenced to come to the research presented in this paper.

Peško (2013) [5] in his doctoral dissertation gave a model for estimating the cost and time of construction of urban roads based on two types of models he compared. The models were based on artificial intelligence, and predictions made by ANN and SVMs model were compared. For data processing, two types of normalization, min-max and z-score, were used. The database has been formed on the basis of 166 projects of urban roads. The conclusion was that the SVMs models gave a more accurate prediction and are also easier for formation. Kim et al (2004) [3] published a study that is based on the estimation of costs based on three models and they made a comparative analysis. The models were based on a multiple regression analysis MRA, artificial neural network ANN and reasoning based on cases of CBR. The survey was conducted on 530 projects for residential building constructed in the period from 1997 to 2000 in Seoul. The measurement of accuracy of the model was performed using the absolute error. The best prediction was obtained by applying the ANN, and the disadvantage of this method compared to the CBR model MRA is slow finding the optimal network using an iterative procedure.

Sonmez (2004) [10] made a conceptual model for estimation of different buildings built in the USA in the period between 1975 and 1995. He compared the models made by regression analysis and ANN. Validation was performed on the basis of square error and absolute error expressed in percentage. Also, the advantages and disadvantages of those models were defined as well as comments regarding the simultaneous use of these two models, which may lead to better results if they are used together.

Mučenski et al (2013) [11] published a paper that writes about the estimation of recycling capacity - the amount of concrete and rebar for residential buildings made in the skeletal system. In the set for training 95 projects were found, with 9 input and 2 output data. The models were based on ANN in Matlab. Z-score normalization of data was used. The resulting percentage error and the actual value in this paper is 9.10%.

Ginaydin i Gibson (2004) [1] analyzed the models based on ANN where the output data, the cost of the building, were formed in the way that they were given per m2 of the area of the building. 30 buildings of prestressed concretes in Turkey were analyzed, and the accuracy of prediction was 7%.

Wang i Gibson (2009) [2] analyzed two types of models, trying to carry out the prediction of the success of projects. The first model was based on a simple linear regression, while the second was based on artificial neural networks. They analyzed data for 62 industrial facilities and 78 multi-storey buildings. Analysis via their model showed that the projects for which it was initially done good planning have better performance upon completion.

3. CREATION OF A DATABASE FOR ANN MODELS

The key part of the analysis in the application of artificial intelligence is a database that needs to be well prepared. Although the model training process based on artificial intelligence can be described as approximating functions (correlation between the input and output data), the real "power" is in good generalization. This includes the model's ability not to make a mistake in the regression when entering data that were not used during the training model (a subset for validation). For a good model, valid data base is certainly a necessary condition, but not sufficient. A good model has a good ability of generalization [5]. Four main objectives, i.e. characteristics that a database should possess are: sharing, availability, evolvability and integrity [4].

Quality of ANN depends on the quality of input data used to train the network, as well as on its structure.

This paper analyzes the database formed on the basis of several key parameters of the objects. These parameters also define the main characteristics of the object which are the subject of analysis in this paper. Collected data for buildings are input data for the analysis and prediction by ANN. Database has been established on the Bill of quantities for 100 projects of residential buildings in Novi Sad. It is important to note that the information taken for the database are derived from design for building permit. Buildings that have been analyzed are multistory buildings made in skeleton structural system. Buildings transfer loads to the ground through the foundation slab. The applied solution is also the most common solution foundation in Novi Sad due to the high level of ground water and soil quality. Objects in the database don't have dilatation or have only one dilatation, as is the case for most residential buildings. Database which is the basis of that analysis for prediction of the amount of material was formed on the assumption that amounts of concrete and reinforcement depend on the following characteristics of the building: the complexity of the structure, the type of floor structure and the type of supporting floor structure mode such quality parameters and total gross area, average gross floor area, transverse raster, the number of walls of the stiffeners, the longitudinal raster of the pillars, the transverse raster of the pillars of quantitative parameters. The parameters mentioned are input parameters for building neural networks. Output values will be the amount of concrete and reinforcement. The complexity of the construction is divided into three parameters (simple, complex and complex medium basis in terms of variety and modified structure in height). As a part of the collected data about buildings, there are two types of the basic floor structure and those are: monolithic reinforced concrete slab, which has been assigned the value of 1 in the primary data base, and a semi-prefabricated construction type "FERT", which has been assigned the value of 2. Type of supporting floor structure is directly on poles or on-line beams. The first mode is assigned the number 1 while the second mode is assigned the number 2. *Table 1* shows the extreme values (range) of qualitative parameters.

Table 1. Extreme values of input and output qualitative data

	Type	**Database**	
		min	max
Input data	Total gross area [m^2]	1.000	7.500
	Average gross floor area [m^2]	200	1.500
	Transverse raster	13	27
	Number of stiffening walls [kom]	0	13
	Longitudinal raster [m]	2	7
	Transverse raster [m]	2	6
Output data	Quantity of concrete [m^3]	28.500	248.000
	Quantity of reinforcement [kg]	420	3.800

For the building of the ANN model it is necessary to normalize the data in the database. Normalization means that all information in the primary database bring the same level of importance in order to process information in some of the software solutions. Also, some

of the input parameters are quantitative and some are qualitative, so they can be used as equal, normalization is more than justified in this case. For the purpose of this study, Z Score data normalization method was performed, whose application is presented in detail in the PhD thesis of Igor Peško 2013 [5].
Software that will process the respective database using the ANN is a Dell Statistica 8 [6]. For the valid application of neural networks it is necessary to divide a database ons three subsets: training, testing and validation. The software uses a subset for testing to avoid cases retraining network, and database validation has a control function for prediction on real sample.
Before forming the subsets for training and validation/testing,it is necessary to ensure the homogeneity of the samples. One of the objects from the database on the surface deviates significantly from the majority of the data that are included in the primary database. For the output data to be more accurate, this object will be dropped from database because it can move ranges of prediction. After these corrections , database is homogeneous, it has 99 samples and is further divided in subsets of training, validation and testing. For other characteristics of buildings is not significantly different from the majority sub.
Subsets of validation and testing include 10 buildings. The basic database of 99 buildings is divided into intervals within the amount of concrete and the amount of reinforcement. From the interval with the most reps, more samples for subsets of validation and testing will be taken. This approach to selecting data subsets serves to normalize the range of parameters for extreme values remained the same database. This way, the data for testing and validation themselves are within the range of the set for training.

4. BUILDING ANN MODEL FOR ESTIMATION OF AMOUNT OF CONCRETE AND REINFORCEMENT

Artificial neural networks allow choice of one or more parameters as output data which is different and vary useful from other forms of artificial intelligence who do not have this feature. One model can predict the amounth of a several different materials.
Finding the most appropriate model of artificial neural network is an iterative process and is followed through several steps. The first step is to enter normalized data into software Statistica 8 and classify samples into specific subsets of training, testing and validation. In the second step variable and fixed size are selected. Designed amount of concrete and reinforcement is selected as a variable inputs ie. parameters that will be performed prediction, while the fixed size nine input parameters mentioned in *Chapter 3* is selected. In the next stage, which is the most important one, the number of hidden layers, the weight coefficients and the type of neural network are set. The next parameter that can be set in the building of neural networks are activation functions. The activation function of the output neurons, in case of regression problems in the most of cases, is linear function. When it comes to activation functions of hidden neurons the most commonly used functions are unipolar logistic and bipolar sigmoidal [7]. Therefore, for all models were used activation functions *Logistic and Hyperbolic Tangent* for hidden neurons and for the output neurons were used activation function *Identity*. After selecting all listed parameters, network are trained and results were compared with a sample for validation. On the basis of the percent of the mean absolute percentage error, model which gives the most even

and most effective solution of predicting (together concrete and reinforcement), was chosen.

Iteration I
In the first iteration of the training MLP model of the neural network was selected, so as 50 networks for training and a number of hidden neurons is in the range of 1-20. The result gave the best network MLP 9-3-2. This network has function Tanh for hidden neurons and function Identity for output neurons (as the activation function), which is recommended for this type of analysis. This network has three hidden neurons.

Iteration II
In the second iteration the number of neural networks for training increased with 50 at 1000 and the number of hidden neurons remained in the same range of 1 until 20. Activation functions remain the same. Thus configured model as the best network gives MLP 9-2-2. This network, also, has function Tanh for hidden neurons and function Identity for output neurons (as the activation function).

Iteration III
In the context of the next iteration, and with experience in the previously formed networks, the number of networks for training is set up to 2000. Number of hidden neurons was adopted at an interval of 1-5 considering that no one network is not coming out of this range in the last two iterations. Activation functions have remained the same but except MLP type of networks, RBF type of networks is chosen too. Number of hidden neurons in RBF network is in the range of 15-30 for this iteration. In this iteration result gave the best network MLP 9-3-2.

Iteration IV
In this iteration the activation functions are varied. All the available functions for the hidden and output neurons is allowed the software to use. The remaining parameters are chosen as in the iteration III. On the basis of this modification the best network is MLP 9-2-2 with two hidden neurons. This network has function Exponential for hidden neurons and function Tanh for output neurons.

Iteration V
A mean absolute percentage error increased in the last four iterations, so, in this iteration parameters are set as in the iteration I in which the most accurate prediction was obtained. Only the number of networks for training increased in 5000. This increase of the number of networks for training also failed to reduce mean absolute percentage error.

After five iterations and modifications of artificial neural networks in several directions we can conclude that in the case of the output data (prediction of amounts of concrete and reinforcement) optimum operating parameters that must be taken in the analysis are for hidden neurons range from 1 to 5, until a sufficient number of training the neural networks is 50. Activation functions should be recommended Tanh and Identity.
On the fallowing figures (*Figure 1 and Figure 2*) are shown absolute percentage error from the correct solutions for all five iterations.

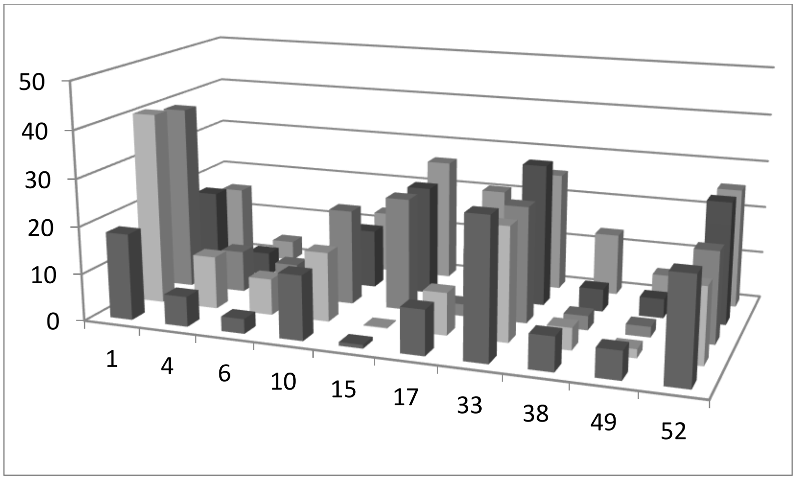

Figure 1. The percentage errors for all iterations - predict the amount of concrete

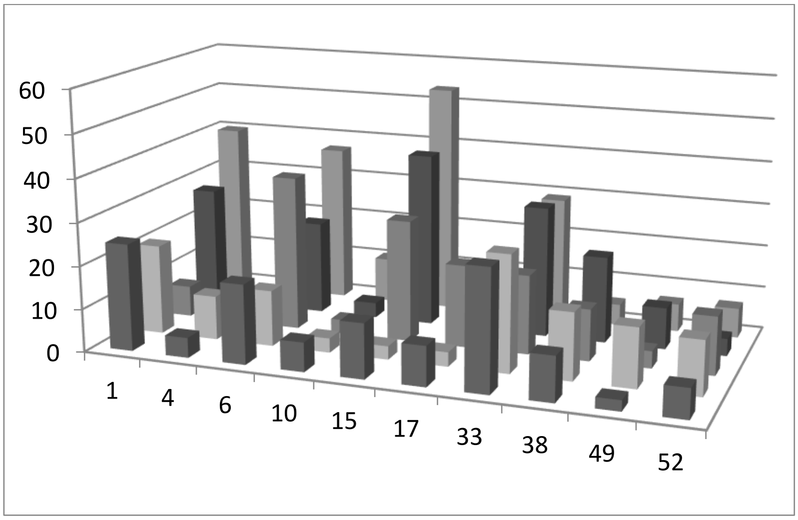

Figure 2. The percentage errors for all iterations - predict the amount of rainforcement

5. RESULTS

Prediction in the diagrams are not homogeneous, not according to the samples (buildings) or either in successive iterations. *Figure 1* shows that the maximum error is on the buildings under the ordinal numbers 1, 33 and 52 in the primary database for predict the amount of concrete while the *Figure 2* detects that the maximum error is in the location code 15 for prediction of the amount of reinforcement. Looking at the two *Figures* together the most accurate predictions appear on buildings No. 38 and 49. Maximum error for prediction of amount of concrete occurred for buildings which have the complexity of the base 2 (base medium complicated) and 3 (complex base) and type of floor structure AB monolithic slab which is supported directly on the piers.

Maximum error for prediction of amount of reinforcement occurred for buildings which has simple base, prefabricated celling type "FERT" leaning on-line beams and a small number of stiffening walls. Buildings that have the most accurate prediction of both types of materials are based on the complexity 2 (medium complicated basis), a large number of stiffening walls and have a large total gross area of the building. These samples provide the most accurate prediction even though they have different ceiling systems that rely both on-line beams. Within each iteration of the mean absolute percentage error did not exceed 20%.

However, most convenient and most even (looking at both parameters together) solution is obtained based on the first-ranked network in the first iteration. Obtained optimal network model for prediction of the MLP 9-3-2 with three hidden neurons which has made a prediction of the quantity of concrete with a mean absolute percentage error of 11.62%, while the prediction of quantity of reinforcement with a mean absolute percentage error of 12.46%.

6. CONCLUSIONS

The aim of this study was researching the possibilities of applying methods of neural networks in prediction of the amount of materials. Obtained models can be used for various purposes from the calculation of the necessary amount of material for the construction of a building to estimation of recycling capacity during demolition. Estimation of the amount of materials is based on data on existing buildings constituting the primary database, which is also an input to the model of artificial neural networks. The analysis of the basic database is carried out by software package Statistica 8 and estimation of amount of concrete and reinforcement using artificial neural networks was performed. The methodology is based on the definition of the input parameters, the creation of this model within the software on the basis of which are obtained the output data in the way of prediction of concrete and reinforcement for the buildings defined parameters. Obtained optimal network model for prediction of the MLP 9-3-2 with three hidden neurons which has made a prediction of the quantity of concrete with a mean absolute percentage error of 11.62%, while the prediction of quantity of reinforcement with a mean absolute percentage error of 12.46%.

ACKNOWLEDGMENTS

The work reported in this paper is a part of the investigation within the research project TR 36017 ''Utilization of by-products and recycled waste materials in concrete composites in the scope of sustainable construction development in Serbia: investigation and environmental assessment of possible applications'', supported by the ministry for Science and Technology, Republic of Serbia. This support is gratefully acknowledged.

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PROCENA KOLIČINA RECIKLAŽNIH KAPACITETA VIŠESPRATNIH ZGRADA PRIMENOM VEŠTAČKIH NEURONSKIH MREŽA

Rezime: *Veštačka inteligencija u građevinarstvu se koristi u svim fazama projektovanja i izvođenja radova, od inicijalne faze do krajnje faze rušenja objekta i procene reciklažnih kapaciteta. U radu je prikazan model za procenu količina materijala (betona i armature). Model je baziran na veštačkoj inteligenciji odnosno procena količina materijala se vrši pomoću veštačkih neuronskih mreža. Za potrebe istraživanja rađeno je više modela. Modeli koji daju prihvatljiva rešenja testirani su na realnom uzorku i dobijena tačnost predikcija je do 13% .*

Ključne reči: *veštačka inteligencija, neuronske mreže, konstrukcija, armatura, beton*