The Proposal of Cadastral Value Determination Based on Artificial Intelligence*

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Key words: neural network, artificial intelligence, cadastral value, mass appraisal.

SUMMARY

Political and economical transformation, that has taken place in Poland during the last fifteen years caused necessity of carrying deep financial reforms. The modernization of cadastral and land register systems creates new possibilities of defining taxes based on real estate ownership. The system of real estate tax is going to be modified. The tax based on estate area is suggested to be changed into the tax based on estate's value, that is defined in the polish law system as cadastral value.

Cadastral value calculation as the basis for due estate tax is going to take place in the whole country. It will be realized by carrying out the mass appraisal. The mass appraisal is going to be not only a great organization task, but a technological one. The valuation methods used by real estate experts are not always proper for mass appraisal. Cadastral value definition does not need such a detailed data, that are necessary for single estate value estimation. So the authors suggest using neural networks for mass appraisal.

The neural network analysis concerning internal neuron functions, type and structure layers, that are made in this paper, allowed to establish criteria for employing neural networks. Experiments made in this work show high usefulness of such methods for mass appraisal. That is also possible to use proposed methods for cadastral value verification in countries different from Poland.

* This work is financed from funds for science, allocated for years 2005-2008, research project no 4 T12E 016 29

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1. INTRODUCTION

Political and economical changes that have been taking place in Poland during last fifteen years and accession of Poland to EC in 2004 caused necessity of carrying out deep financial reforms. The modernization of Ground Cadastre and Land Register systems enables changes in tax calculating methods, thus from based on size into one based on real estate value. The tax, based on the real estate value is due to replace several other taxes and is supposed to simplify the polish taxation system. In order to achieve that not only large financial means are necessary, but willingness of political elites must follow as well.
The variety of real estates market and its immaturity does not always allow us to use the advanced valuation methods. The implementation of methods used in countries of highly developed economy is often not possible, either. The valuation based on comparative approach is one of the most popular market value estimation method. When using this method, we presume that estates market value is found by comparison with similar estates with known transaction prices. We also have to know differences between these estates, that have influence on their value. The prices of estates that are representative for the market are supposed to be references during the mass appraisal. The real estates value determination purpose is to assign cadastral values to all estates in elaborated market. The main difficulty here is lack of information on real estates similar to those being subject of trade. The number of these estates depends on presumed valuation method. In case of using neural networks, it is determined by network learning algorithm and its size. The proper real estates data base should guarantee complete identification and comparison possibilities, on the basis of chosen attributes that influence estates value. Establishing such a data base from the beginning is a long-time and expensive operation.
During computer technologies implementation, that have been taking place in Polish State Centre of Surveying and Cartographic Documentation for ten years, a lot of different data bases were created. Data concerning ground cadastre, utility infrastructure, topographical objects (including digital terrain model) and environmental information is stored there. Land Register System in Poland is also being converted into computer data base. We suppose that these data bases can be used as the sources of real estates attributes.

2. NEURAL NETWORK SELECTION AND LEARNING

The necessary condition for neural network appropriate work is obtaining proper values of its parameters – weights. The weight finding process is defined as neural network learning. The

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learning is an iterative process. Its implementation depends on network type and purpose. The neural network learning algorithms may be divided into two main groups:

- Learning with a teacher. The network is provided with information on input data and corresponding output data. The target of learning with a teacher is finding weights, so the network after being provided with input data gives back output data or values close to them.
- Learning without a teacher. During the process of the network learning, the network is provided only with input data. The target for network learning is to reach its stability. That means that during subsequent input data presentation, weights do not change any more, so the output data do not alter either.

The chief network features are approximation and generalization abilities. The approximation ability is a skill of proper output values calculating, for data that take part in learning process. The generalization ability is a skill of proper output values calculating, for data that did not take part in learning process. The overlearning, that may happened during learning process occurs when the network has got an approximation ability, but does not have generalization ability.

One of main difficulties in application of comparative valuation method is lack of information on real estates, that were the subject of trade, similar to valuated one. Number of these estates with necessary information depends on established valuation method. In neural networks this number is determined by its size and network learning algorithm. The collecting of sufficient data is possible in large and well developed real estate markets.

Unfortunately, prior attribute reduction is necessary in poorly developed markets, that have restricted estates number. During data dimension reduction, it is necessary to replace original variable set by the new lesser one. Input attributes reduction enables network size reduction, that means learning data set diminishing, learning time shortening, and improvement in network generalization abilities. Data dimension reduction methods may be divided into two groups:

- The feature representatives choice. That means method based on choosing the independent variable subgroup from the original group. This subgroup consist of variables with the strongest correlation with dependent variables (input variables optimal set).
- Main components analysis. It is the method enabling replacement of original variables set with the new variables, that were absent in original set, but they show dependent variable formation.

Genetic algorithm reduction, that resulted in the choice of the variables with the strongest correlation with dependent variable. The outcome of that reduction is the input data (real estates attributes) diminution from 21 to 18. Main components analysis was conducted by linear network that have 28 entries and 28 exits. Results that were obtained enabled us to choose five main components describing the original data set with precision of 1/10000.

The calculated main components and genetic algorithm describe all changeability of analysed knowledge base. Its virtue is network learning data diminution. So the main components analysis for neural network building, may be successfully performed for small estates markets. In the case of large knowledge base, when there is no danger of network underlearning, data dimension reduction with application of genetic algorithm is easier for users. It causes removing some attributes from data set and reducing information necessary

for real estate valuation. We should underline that these results were obtained for the well developed estates market and it is not possible to implement them directly in another.

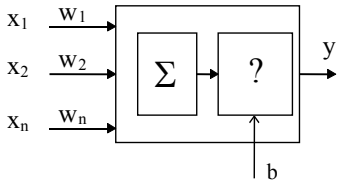

Fig. 1. Mathematical model of neural cell.

3. TAXATION

The proper network selection for real estates valuation depends on several parameters. Two of them (connected with estates data base) are the number of collected attributes describing single estate and estates size.

We assume that the majority of data, that are used for estates valuation originates from different data bases. Information like location, shape, soil – based land classification, building function and technical parameters are stored in ground cadastre. Terrain assignment is defined in local spatial plan and utilities accessibilities are included in utilities cadastre system.

Data accessibility itself does not always give possibility of its use, for example they may not make proper estates attributes. The map or reconnaissance may be of some help here. The thorough map examination let us to get some knowledge about estates type, localization accessibility and neighbourhood. Some additional information can be obtained from digital map, stored with computer technology. Such an interactive work reveals information that are not visible on the map printed on the paper. For instance, when working with digital map we can visualise all known object attributes, list objects situated on the way between two points or carry out travel time simulation.

The method of finding object features based on digital map is common and easy, but operator assistance is necessary here. During mass appraisal, it would probably cause large amount of additional work to carry and produce a lot of extra costs. So it should be simplified and automatized.

The number of independent variables (attributes) corresponds to neuron number in the output layer. It is possible to lessen that using methods described earlier. Input layer neuron number reduction simplifies network construction. That enables using the smaller data bases in the process of network learning. So the size of estates data base and its influence on learning process extorts possible data base reduction. In all designed network structures, one neuron responsible for estates value is going to occur. It is responsible for particular independent value present in input layer – real estates value.

The next important problem is the selection of proper neural network construction. Such factors like proper learning process, learning method and its time consumption, layers structure and neuron internal functions should be taken under consideration here.

Multilayer perceptrons, that have one or more hidden layers have been examined during real estates valuation in Cracow. Different learning algorithms were tested. Radial Base Function (RBF) networks, Generalized Regression Neural Networks (GNRR) and Linear Regression Networks were verified there.

After comparing results obtained for these networks of different types and taking into account input data base size and network learning parameters (including time consumption factor), the three layer perceptron was chosen for our purpose. Radial Base Function networks were also found possible for application and others were rejected as not suitable for this task.
Output values for chosen network structure (obtained estates values) for all analyzed real estates set and all used attributes were calculated. Obtained values have been found satisfactory. Such a procedure corresponds to mass appraisal requirements. Real estate valuation outcome may be obtained for any analyzed estate.

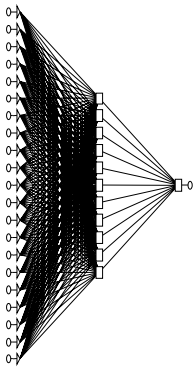

Fig. 2. Three-layer perceptron.

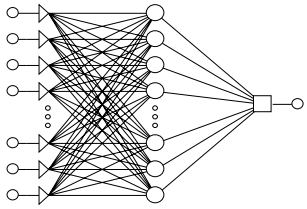

Fig. 3. RBF network schema.

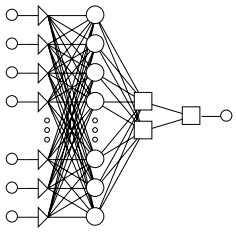

Fig. 4. GRNN network schema.

4. RECAPITULATION

It is possible to elaborate the real estates valuation method based on artificial intelligence, that includes data verification process. Neural network analysis for different neuron internal functions, network structure and layer types, that has been made in this paper enabled finding proper neural network criteria.
Possibility of data dimension (number of attributes) reduction shows that the genetic algorithm, that has been used here, enables finding attributes, that have insignificant influence on real estates price. It results in their removal. It is very helpful, because lesser data number may be collected. Unfortunately, slight drop in attributes number does not result in data necessary for network learning reduction. Such a reduction is proposed for large estates markets, for it may simplify data base construction. The other attribute reduction method is the network main components analysis. It is carried out by employing set of original values and enables to find a new variable set, which has lesser attributes number. This method is proposed to use for small bases, that may not be enable to carry out the network learning process without significant attribute reduction. If conditions necessary for network learning are met with original base, the base dimension reduction is not recommended, for it always causes the limitation of market information and may result in the altering the estate market characteristic. Network constructions analysis shows that three-layer perceptron may be the appropriate tool for mass appraisal. The neuron number in input layer is equal to attribute number. Radial Base Function networks may also be used for real estates valuation, but its much more difficult to find learning parameters for them. It is not recommended to extrapolate descriptive parameters, because it is not possible to find function generated by this network structure. The proposed network structure enables carrying out not only detailed estate valuation for a single estate, but mass appraisal as well. Properly chosen knowledge base, based on representative estates, with necessary restrictions made during attributes defining, enables us to build the neural network, that can carry out the mass appraisal.

The realized explorations shows that such methods are highly suitable for mass appraisal. Moreover these methods may be used for cadastral values estimation and verification in other countries.

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