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House selling price assessment using two different adaptive neuro-fuzzy techniques

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ABSTRACT

It is of high importance to estimate the house selling prices because sellers and buyers need this information in an accurate way at time of sale. As a result of the fact that the estimation of the house prices is extorsive considerable research has been published in the literature on estimating house prices. This study covers the application of two different adaptive neuro-fuzzy (ANFIS) approaches for the estimation of house selling price.

In this study, two different ANFIS models, namely ANFIS with grid partition (ANFIS-GP) and ANFIS with sub clustering (ANFIS-SC), were used in forecasting house prices, and the results were evaluated. Comparison of results from the two techniques indicated that the ANFIS-GP models performed better than the ANFIS-SC models. The study suggests that the ANFIS-GP technique can be successfully used in the estimation of house prices in the construction sector.

1. Introduction

Mathematical models are used to estimate future trends in many areas [1,2]. A substantial body of information can be found in the literature on modeling and estimating house prices spanning a period of more than three decades [3]. It is vital to estimate the explicit housing sales price in the operation of the housing market. Home sellers and buyers desire to have the information of a fair value for their house in particular at the time of the sales arrangements. An explicit estimated price of a house has a major significance to investors coming across with alternatives among housing securities and other investment opportunities. [4,5] Nonetheless, residential housing can be considered as a composite good that is sold as a package of various factors, such as location, environment, and structural attributes, etc. Hence, reaching the explicit estimation of a house price is a complicated matter. The method of selecting relevant factors and investigating the effect of the factors in predicting the selling price of a house lays an important role in determining prices. Artificial intelligence tools such as artificial neural network (ANN) and fuzzy logic approaches can be efficiently applied to a variety of problems [6,7]. Nowadays, combining both approaches is favored by most, leading to the development of neuro-fuzzy computing techniques. At the same time, modeling, forecasting, and explaining the long-term equilibrium of house prices have drawn considerable interest in the literature [3,8]. In house price assessment, many features of a house are often used to determine its fair value, and many methods have been used for determining house selling prices. Pagourtzi et al. [9] have separated these methods in two different groups as traditional and advanced. Some examples of traditional methods are comparable method, investment/income method, profit method, development/residual method, contractor method, multiple regression method and stepwise regression method. The other methods, especially those simulating the thought processes of the market players in which the estimation of the exchange point is attempted have been called "advanced". Some of the advanced methods are artificial neural networks (ANN), hedonic pricing method, spatial analysis method, fuzzy logic (FL), and autoregressive moving average (ARMA) method.

Recently many data mining techniques have been applied to model construction management processes including the prediction of house prices. One of the most commonly employed data mining methods was neural network method, [10–13] In addition, other methods like semi-parametric regression [5], hedonic method [14], and fuzzy logic have also been used [15–18].

This paper illustrates the design and implementation of an adaptive neuro-fuzzy inference system (ANFIS) to predict selling prices for houses. In many different areas, ANFIS-based systems have been studied. Guldal and Tongal [19] explained the use of ANFIS in predicting lake-level changes and the resulting ANFIS produced better results when compared with methods based on recurrent neural network (RNN), auto-regressive (AR) and auto-regressive moving average (ARMA)

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models. Cobaner [20] used two different ANFIS-based techniques for the estimation of evapotranspiration and found that ANFIS-SC model worked much better than the ANFIS-GP and neural network models. If there is a preexisting data set of property features and sale prices, house selling price assessment is more likely to present an ideal setting for applying an ANFIS-based approach. In residential real estate, such historic data are not difficult to obtain. An ANFIS-based system has an advantage over traditional statistical estimation because it does not need any mathematical modeling of the data. Given the consensus that fuzzy logic-based systems offer promise to the field of property value assessment [15,16] and its success outside of the field of property assessment, the use of ANFIS in property assessment is essentially investigated in depth.

The advantages of using the ANFIS model in house price estimation are explained using a case study. An ANFIS and fuzzy logic gain learning ability to artificial neural networks. The ANFIS model is highly adaptive and efficient when nonlinear relationships among different variables are investigated. The model shows the stored knowledge in terms of fuzzy linguistic rules, which allows the model decision-making process to be examined and understood in detail. In this paper, two different methods for constructing fuzzy rule-based models of the Takagi–Sugeno type relating to house value assessment are illustrated. They correspond to the grid partition and subtractive clustering identification methods. Although the models perform similarly, ANFIS-GP method gives the best results. The results propose that the ANFIS-GP method can be used as an assessment tool for determining house value.

2. Adaptive neuro-fuzzy inference system (ANFIS)

ANFIS includes a number of nodes connected through directional links. Each node is defined by a node function including fixed or adjustable parameters. The training phase of a neural network is a process to determine parameter values to sufficiently fit the training data.

The basic learning rule is the well-known back-propagation method which seeks to minimize some measure of error between the network's outputs and desired outputs [21]. Jang [22] presented a learning procedure for the fuzzy inference system (FIS) that uses a neural network learning algorithm for constructing a set of fuzzy if-then rules with appropriate membership functions (MFs) from specified input–output pairs. ANFIS provides two main perspectives: the first one is to transform human knowledge or experience into the rule base and database of a fuzzy inference system and the second one is to tune the membership functions to minimize the output error measure or maximize performance index. ANFIS can also act as a basis for building a set of fuzzy if-then rules with appropriate membership functions to generate the stipulated input–output pairs. The research of Jang [22] is the reference of the detailed algorithm and mathematical background of the ANFIS The general structure of ANFIS is presented in Fig. 1.

Depending on the types of inference operations upon the 'if-then rules', most FISs can be classified into three types: Mamdani's system, [23] Sugeno's system [24] and Tsukamoto's system [25]. Mamdani's system is the most commonly used; however, when it comes to Sugeno's system, it is more compact, and more effective, while being applicable with mathematical analysis. Additionally, it is well adapted with linear techniques and optimization. Thus, to eliminate time consuming and complicated techniques, the most popular candidates have been sample-data based fuzzy modeling which takes advantage of adaptive techniques. Because it lends itself to the use of adaptive techniques Takagi–Sugeno type was adopted in the ANFIS models [26,27].

To build up a fuzzy system, first, the linguistic variables should be provided in addition to the numerical variables. Then, the system requires If/then fuzzy rules to qualify simple relationships between the fuzzy variables. A typical rule set with two fuzzy If/then rules in a first-order Sugeno system, can be shown as

$$\text{Rule 1: If } x \text{ is A1 and } y \text{ is B1, then } f_1 = p_1x + q_1y + r_1 \quad (1)$$

$$\text{Rule 2: If } x \text{ is A2 and } y \text{ is B2, then } f_2 = p_2x + q_2y + r_2. \quad (2)$$

x and y refer to input and output variables, respectively. The A and B terms denote the linguistic terms (such as small, large) of the precondition part with membership function. The 'If' part of the rule, which is "x is A", is called the premise, while the then part of the rule, "y is B", is called the consequent. The p, q, and r indicate the consequent parameters [26].

The result of each node in the layer 1 is:

$$O_{1,i} = \mu_{A_i}(x) \quad \text{for } i = 1,2 \quad (3)$$

$$O_{1,i} = \mu_{B_{i-2}}(y) \quad \text{for } i = 3,4. \quad (4)$$

Therefore, the $O_{1,i}(x)$ is fundamentally indicated as the membership grade for 'x' and 'y'. The membership functions vary, but for this purpose, the Gaussian function was used.

Gaussian MF as given in the following equation:

$$\text{Gaussian MF} = f(x;\sigma,c)e^{\frac{-(x-c)^2}{2\sigma^2}} \quad (5)$$

where c is the curve mean and σ is the variance. These are the premise parameters.

In layer 2 every node is settled multiplying the incoming signals and transmits the product out. This is where the t-norm is used to 'AND' the membership grades.

$$O_{2,i} = w_i = \mu_{A_i}(x)\mu_{B_i}(y), \quad i = 1,2 \quad (6)$$

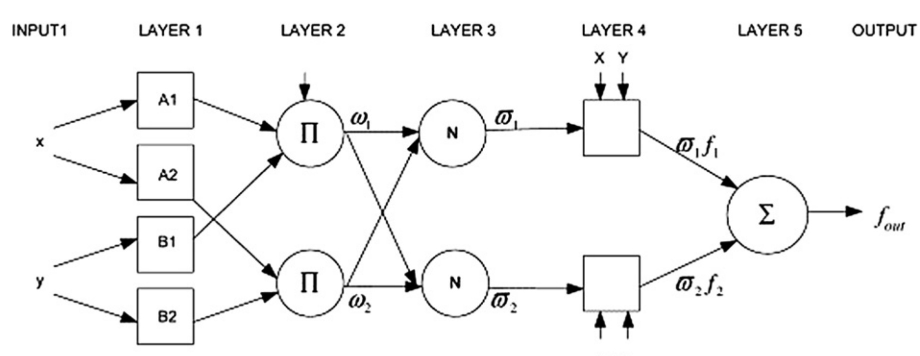

Fig. 1. The structure of ANFIS model.