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A neuro-fuzzy algorithm for improved gas consumption forecasting with economic, environmental and IT/IS indicators

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ABSTRACT

In energy sector, accurate prediction of long term gas consumption is very important for decision-making and policy process. In addition, conventional approaches may not provide precise results. In this paper, an integrated forecasting algorithm based on Adaptive Neuro Fuzzy Inference System and Computer Simulation (ANFIS-CS) for long term gas consumption has been proposed. Standard input variables include different economic, environmental and IT/IS (number of internet users divided by population in each year) indicators, and the output variable is gas consumption. The concepts of post-processing and pre-processing are considered in the proposed method. At first the best distribution function is identified for each year and then CS is used to create random variables for each year to predict the effects of probabilistic distribution on annual gas consumption. Finally, data is fed into ANFIS model to find the network with the lowest mean absolute percentage error (MAPE). To show the quantitative benefits of the ANFIS-CS, 12 different structures of a well-known class of adaptive neural networks (ANNs), namely Multi-Layer Perceptron (MLP) as well as 10 different types of regression models are developed and the MAPE values of ANN-MLP models and regression models are compared with the MAPE of proposed model. The results of this comparison show the applicability and superiority of the proposed method. This is the first study that presents an integrated intelligent forecasting approach for accurate gas consumption considering the economic, environmental and IT/IS indicators.

1. Introduction

Growing worldwide demand for energy causes shortage of energy sources. Therefore, development of intelligent predicting algorithms and methods is inevitable. In this way, governments will be able to manage their future programs. In the all nations, one of the most important factors in economic and social developments is energy. Natural gas is one of the most important energy resource around the world. In most nations' energy equations, natural gas is a significant component. Also, around the world, a large number of households use natural gas for heating their home. According to this growing importance, the need for providing a quantitative demand model of this type of energy resource becomes an interesting topic. The growth in its consumption is inherently related to the growing of the economy and society. There are many different models and methods for describing and forecasting the evolution of natural gas consumption. Among those approaches two distinct approaches are known to be more useful and applicable called soft-computing approach and econometric approach.

A suitable technique can be selected according to desired nature, the nature of available data and level of details in the approximation. One typical approach is to employ more than one method and then, comparing the approximations to achieve a more precise evaluation (Azadeh et al., 2010, 2011). Therefore, in this paper, Adaptive Neuro Fuzzy Inference System (ANFIS) and Computer Simulation (CS) methods are used in four main steps. The results of the proposed model is compared with those of 12 MLP-ANN models and different types of regression models. The conceptual relationship between the steps of proposed approach is shown in Fig. 1.

Fig. 1 shows the superiority and applicability of the proposed algorithm; input variables which effect gas consumption are also identified. Then, the best distribution function is identified and computer simulation is used for generating the required data. In the next step, data is fed into ANFIS model to find the network with the lowest mean absolute percentage error (MAPE). We show the quantitative benefits of ANFIS-CS model by developing the ANN and regression models and then comparing the MAPE values of them. Finally, the ANFIS network which is the preferred model,

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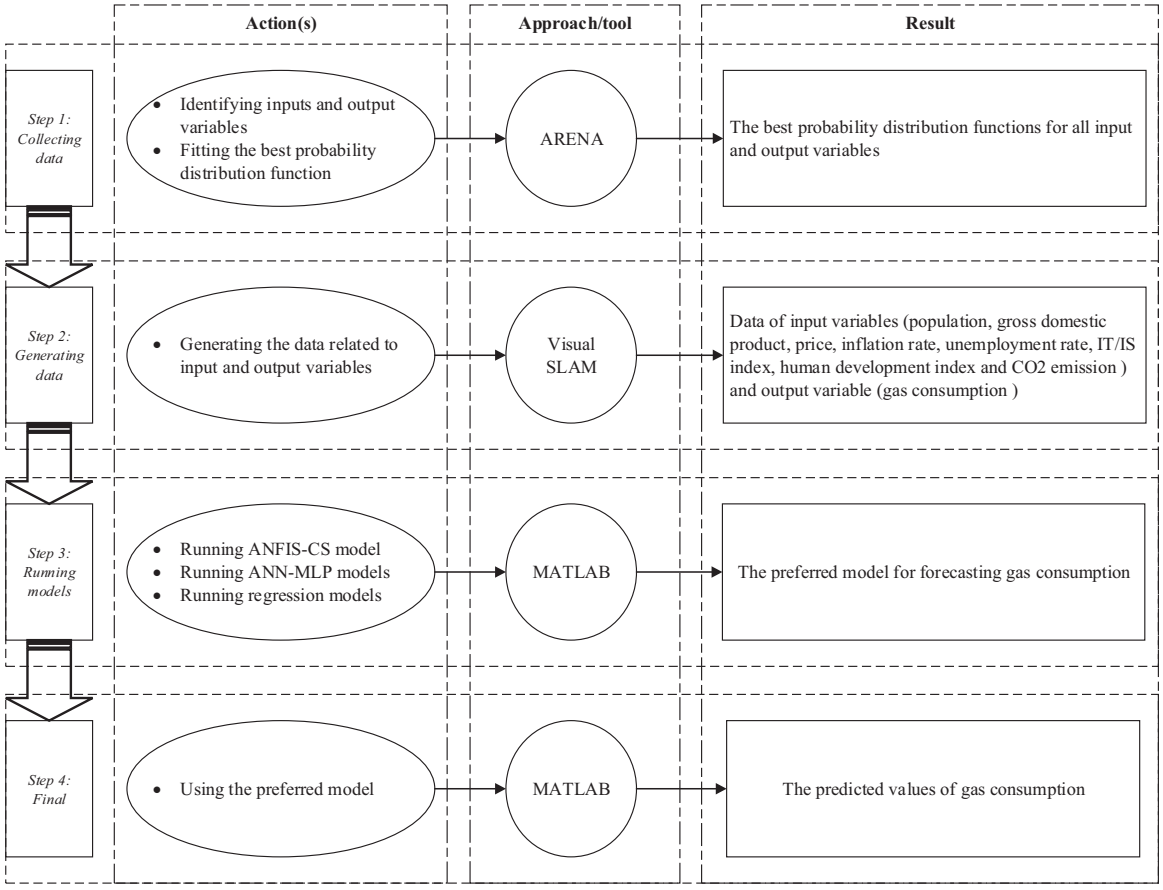

Fig. 1. Conceptual relationship among steps of the proposed integrated algorithm.

is used to forecast gas consumption up to 2013. To validate the results of proposed model the predicted values calculated by ANFIS-CS, are compared with actual data.

The rest of this paper is organized as follows. In Section 2, we review the related literature. Methodology (main concepts related to this study and proposed algorithm) is described in Section 3. In Section 4, the case study and obtained results are presented to illustrate the applicability of the proposed algorithm. Finally, this study is concluded in Section 5.

2. Literature review

The discussion regarding relationship between energy consumption and economic growth has attracted great attention in the literature. Also, the effects of none-economic indicators such as social or environmental conditions are in view of additional concerns about the effects of energy consumption. In the previous related papers, forecasting of consumption of natural gas has been investigated by different forecasting techniques and tools. One of the first tools established for predicting of gas consumption is the Hubbert curve model (Al-Fattah and Startzman, 2000; Al-Jarri and Startzman, 1997; Cavallo, 2004; Cherif et al., 2013; Imam et al., 2004; Li and Zhang, 2014; Maggio and Cacciola, 2009; Reynolds and Kolodziej, 2009; Saraiva et al., 2014; Siemek et al., 2003; Valero and Valero, 2010)

Since 1960s, different statistical models have been used and developed for forecasting natural gas consumption. Balestra and Nerlove (1966) used time series data and statistical techniques to estimate demand of natural gas. In this regard, Beierlein et al. (1981) used seemingly unrelated regression estimation to estimate the natural gas consumption in northeastern United States. Herbert et al. (1987) employed regression analysis, whereas Herbert (1987) used linear regression model and residual analysis. Liu and Lin (1991) and Erdogdu (2010) used auto-regressive integrated moving average (ARIMA) models. Liu and Lin (1991) used cross correlation function method (CCF method) and linear transfer function method (LTF method). Brabec et al. (2008) used nonlinear mixed effects (NLME) model which is compared with auto-regressive with exogenous (ARX) inputs and auto-regressive integrated moving average with eXtra/eXternal (ARIMAX) process. Lee and Singh (1994) employed generalized Tobit model, modified multiple regression technique, White test, Hausman test, Chow test and assessment by the nearest neighbor rule. Reddy and Balachandra (2003) proposed an integrated mathematical model in which various elements influenced the India's energy demand such as GDP and population growth were considered. Also, they developed the environmental and energy outlook in their study.

Forecasting energy consumption can be attained by certain mathematical models and simulation tools. Azadeh et al. (2008) integrated three approaches including design of experiments, computer simulation and artificial neural network (ANN), and proposed a new method to forecast monthly energy consumption. Gutiérrez et al. (2005) surveyed the use of a Gompertz type innovation diffusion process for capturing the growth process of natural gas consumption and stochastic modeling in Spain. Based on a decomposition method, Sánchez-Úbeda and Berzosa (2007) predicted natural gas consumption of industrial end-use during a medium-term horizon (1–3 years) with a very high resolution (days). In order to estimate demand of natural gas and petroleum products in India, Parikh et al. (2007) proposed a NG estimation model considered population and GDP as inputs of their model.

Different statistical methods such as regression models and Box Jenkins model (Abraham and Nath, 2001; Boran, 2014; Goia et al.,