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Artificial neural networks and adaptive neuro-fuzzy inference systems approaches to forecast the meteorological data for HVAC: The case of cities for Turkey

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ABSTRACT

Limited energy resources and increasing need for energy due to population growth seem to lead researchers to focus on these issues. Forecast of meteorological data has significant importance in design of thermal systems. In this study, forecasting of meteorological data used in thermal system design was performed for fifty cities to represent the entire Turkey. Data obtained from General Directorate of Meteorology (MGM) were modelled by artificial neural networks and adaptive-network based fuzzy inference systems. Matlab software was used for modeling and forecasting of prospective data with high sensitivity in thermal systems. Surfer and ArcGIS software were used to create humidity, temperature, solar radiation maps for Turkey. Root mean square error (RMSE), mean absolute error and (MAE), coefficient of variation (COV) and the coefficient of determination (R^2) were used to validate the result of the proposed approaches. The results were satisfactory with respect to RMSE, MAE, COV and R^2 to forecast the meteorological data. Annual solar power potential maps for Turkey were also proposed and compared with MGM results. The results of the proposed approaches are compatible with the result of the MGM. The Turkey policy maker(s) from MGM can easily use these approaches if a software is constructed.

1. Introduction

Among renewable energy resources, solar energy technology is the fastest improving and growing. Due to continuously advancing technology and decreasing costs, solar energy is deemed as one of the most important energy resources of the future [1]. Quantitative information regarding global radiation is necessary in calculation of evaporation and soil moisture, hydrological studies, agricultural studies, climatology, building energy analysis and many more fields. Today, solar radiation values have a significant importance for many engineering designs such as design and optimization of solar powered systems and architecture. Therefore, information about change in solar radiation is necessary [2] in many research fields such as agriculture, hydrology, and meteorology [3]. It is not possible to infer directly the radiation over large areas because of measuring at only a small number of stations [4].

One of the fields which require solar radiation values and other meteorological data is climate control and planning of comfort elements in modern buildings. HVAC (Heating, Ventilating and Air Conditioning) systems regulate and control the climate, temperature and air flow in buildings and help ensure a comfortable environment. HVAC systems are important for health of those who live in that environment as well. Because, systems with well-regulated climatic conditions and appropriate fixed values keep hazardous organisms such as mold away from the environment. Besides, the most significant benefit of automated HVAC systems is low energy consumption and therefore energy saving. Any improvements in energy efficiency of HVAC systems could be instrumental for avoiding further dependency on fossil fuels [5].

Input/output implementation, input devices, controlled devices, and all human factor subcategories have significant effects on energy use with respect to control experts [6]. Different inputs are used for evaluating the HVAC systems in literature [7]. The software input/output implementation, input devices, controlled devices, and all human factor subcategories to have significant impacts on energy use [6]. In this study, the considered input variables are

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months, number of sky clear days, cloudiness, average air pressure, ground surface minimum temperature, mean solar time, and evaporation. In this paper, Sugeno-type ANFIS also used for forecasting values for temperature, solar radiation, relative humidity. ANFIS is a kind of adaptive neuro-fuzzy inference system [8] which connects fuzzy logic system with neural network [9]. The flowchart of the study is presented in detail in Fig. 1.

This study presents a forecast of solar radiation, temperature and relative humidity based on other meteorological parameters using ANN and ANFIS for fifty cities in different regions of Turkey in a way that it will represent the entire country. Values obtained because of this forecast are compared with meteorological data and TS-825. Results are presented in charts and tables. The rest of paper is organized as follows: The proposed approaches are presented in Section 3 and Section 4. The application is detailed in Section 4. Finally, the conclusion is presented in last section.

2. Background

Behrang et al. [10] estimated daily global solar radiation on a horizontal surface due to using ANN. The solar irradiance values of Dezful, Iran were estimated using the daily mean air temperature, relative humidity, sunshine duration, evaporation and wind speed Between 2002 and 2006. Tymvios et al. [11] applied the Angström linear approach and ANN for forecasting of the solar radiation on a horizontal surface. Mellit et al. [12] developed a hybrid model based on ANN to estimate daily global solar radiation using monthly data of six meteorological stations in Algeria between 1991 and 2000. The results of the proposed hybrid approach were compared with AR (autoregressive), ARMA (autoregressive moving averages), Markov chain, MTM (Markov transition matrices) and measurable values. Mellit et al. [13] used ANFIS-based system to estimate total solar radiation data in isolated areas with respect to monthly average sharpness index and geographical coordinates. Mellit and Pavan [14] modelled solar radiation prediction using ANN. They used a multi-layered sensor model to estimate the solar radiation based on 24 h using air temperature and average daily solar radiation values. For many years, ANN were applied to energy researches as beam solar radiation [15], monthly mean daily diffuse solar radiation [16], monthly mean daily global solar radiation [17], estimation of solar radiation over Turkey [18], global solar radiation using air temperature and relative humidity [19], predicting global radiation [20], estimating global solar radiation and air temperature data in a semi-arid environment [21], monthly-mean daily global solar radiation [22]. Alsina et al. [23] have been widely applied for this purpose. In addition, the potential of energy for countries are analyzed using ANN [24].

Biswas et al. [25] implemented ANN for the prediction of residential building energy consumption. Sholahudin and Han [26] forecasted heating load of a building proposing Simplified dynamic neural network model using Taguchi method. Beccali et al. [27] also applied ANN for a fast prediction of the energy performance of buildings. Ascione et al. [28] presented ANN to predict energy performance and retrofit scenarios for any member of a building category. Afroz et al. [29] presented a reference for the building research community and guideline for the energy management personnel to select the best-suited modeling technique. A comprehensive review papers on solar radiation estimation has been presented by Yadav and Chandel [30]; and recently Bou-Rabee et al. [31]. Interested readers are directed to read this useful review papers.

ANNs are multidimensional information spaces which can learn information patterns. In this way, ANN imitates the human brain and its learning process. For this reason, there is no need for characteristic information about the system. Instead, ANN examines the relationship between input and output parameters, which are previously fed data. Thus, ANN is used to calculate possibly non-linear relationship between two or more inputs and outputs [32].

ANNs show structural and mathematical differences [33]. They usually consist of three layers as the input, the output and the hidden layer [28]. The number of cells in the input layer is equal to the number of data entered ANN. The number of cells in the output layer is equal to the number of information to be received from ANN. The number of nodes in the hidden layer, on the other hand, is found experimentally. The number of cells and the number of connections between the cells affect the learning capacity of ANN. Although a single cell has multiple inputs, it has only one output. The cell processes this input information and transfer the information to the next layer. Input information are multiplied by their respective weights and summed and then processed by being subjected to activation function. Thus, the information to be transferred to the next layer is obtained. Mathematical differences between ANNs are algorithms used to train them and the type of activation function used at cell output. Non-linear modeling may be obtained due to activation function's containing exponential functions.

3. Artificial neural networks

The general structure of ANN (Fig. 2) consists of at least 3 layers.

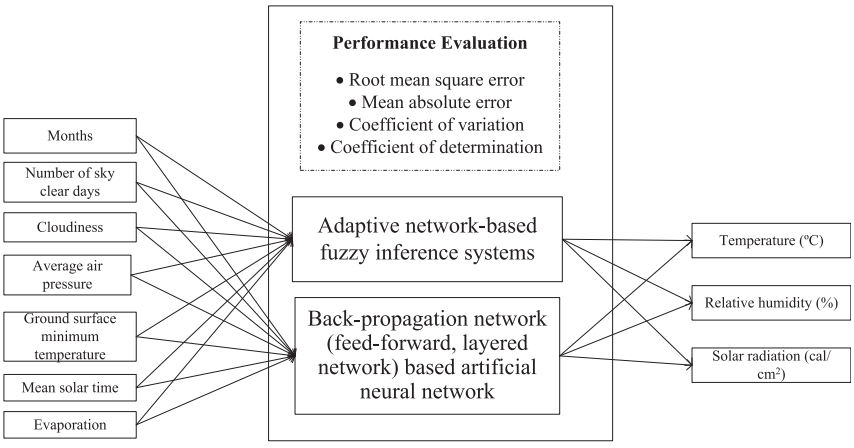

Fig. 1. The flowchart of the study.