# NEURAL NETWORKS IN THE PREDICTION OF ENERGY CONSUMPTION

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**Abstract**: The energy consumption is as important in all the domains as difficult the prediction of the consumption is. The models of global energy consumption are most often nonlinear. Therefore the neural networks offer an invaluable assistance for this field. This paper presents a model for predicting the energy consumption in a building with the neural network. The application is designed in Matlab.

**Keywords**: energy consumption, neural networks, prediction

## 1. INTRODUCTION

The problem of the source of energy necessary for the all the human activities was and is still a major problem for the scientists. In automatic control, the importance of this field has tree main reasons:

- the fossil fuel is limited so that the fossil combustibles crisis is imminent
- the cost of the energy is high for any system and it's paid continuously during the life cycle of the system
- the sustainability of systems, especially the wireless systems

The prediction of the energy consumption is a meaningful task for the management department because knowing the future consumption of energy, the managers can take decisions easier about the estimation of the budget, the development, the new investments etc. The main hindrance for the energy prediction is the complexity of the model.

In this paper the prediction is performed for the energy necessary for heating the interior of a building. The source of energy is natural gas. The chosen method is the technique of artificial neural networks because it is invaluable for applications where formal analysis would be difficult or impossible. Traditionally, regression analysis has been the most popular modeling technique in predicting of the energy consumption [1]. But, step by step, the neural networks have begun more employable because of their capacity of processing nonlinear systems. The prediction of the consumption for the collected data was also performed with the polynomial regression [2]. At the end of the paper a comparison between the models will be done.

## 2. NEURAL NETWORKS

An artificial neural network (ANN), often just called a neural network (NN), is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation [3]. The main advantage of this technique is the ability of learning, skill that the traditional systems don't have it. In most cases, an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase.

The architecture of the neural networks can be of manner supervised or unsupervised. Supervised neural networks are trained to produce desired outputs in response to sample inputs, making them particularly suited for prediction. They are few types of supervised networks as feedforward, radial basis, dynamic networks and LVQ. The feedforward neural network was the first and arguably simplest type of artificial neural network.

There are numerous algorithms available for training neural network models; most of them can be viewed as a straightforward application of optimization theory and statistical estimation. Most of the algorithms used in training artificial neural networks are employing some form of gradient descent. This is done by simply taking the derivative of the cost function with respect to the network parameters and then changing those parameters in a gradient-related direction. The most used algorithms for supervised architectures are Widrow-Hoff (LMS or Delta rule) and backpropagation (BP). BP learning algorithm is currently the most popular learning rule for performing supervised learning (used in 80% of commercial neural network applications). It is regarded as being biologically unrealistic. For applying this algorithm, at least one hidden layer is imperative. The inputs propagate forward through the network produce an output signal. The output is compared with the target pattern and the difference between the output and target is calculated for each output neuron. These errors are then propagated backwards for adjusting first the weights leading to the output layer, and second the weights leading to the hidden layer [5].

### 2.1. Neural network propose for the application

In our application we use feedforward architecture that has one-way connections from input to output layers. The neural network has one input, followed by a layer of five neurons with the transfer function a hyperbolic tangent (equation 1), and followed by a layer with a linear transfer function. Hyperbolic tangent function is a good choice because it's completely symmetric, as shown in the figure 1. Another reason why hyperbolic tangent is a good choice is that it's easy to obtain its derivative and also the value of derivative can be expressed in terms of the output value. Other transfer functions that we tested are sigmoid and logarithmic sigmoid. The algorithm used for training the networks is Levenberg-Marquardt backpropagation algorithm. This algorithm appears to be the fastest method for training moderate-sized feedforward neural networks (up to several hundred weights).

$$\varphi(x) = \frac{1 - e^{-2x}}{1 + e^{-2x}} \tag{1}$$

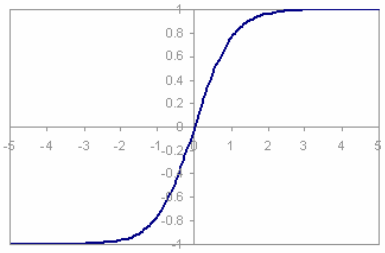


Fig. 1 Hyperbolic tangent function

## 3. ENERGY CONSUMPTION PARAMETERS

In buildings, the energy is consumed for different purposes as heating, cooling, ventilation, electronic devices, lighting. The energy used for heating depends of the thermal comfort [6]. Human thermal comfort is defined by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) as the state of mind that expresses satisfaction with the surrounding environment (ASHRAE Standard 55).

Thermal comfort is affected by heat conduction, convection, radiation, and evaporative heat loss. Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. Any heat gain or loss beyond this generates a sensation of discomfort. It has been long recognized that the sensation of feeling hot or cold is not just dependent on air

temperature alone. Factors determining thermal comfort include air temperature, mean radiant temperature, air movement / velocity, relative humidity, isolative clothing and activity levels. To forecast very exactly the energy consumption in a building all these factors must be taken into account. But if the building is well isolated and all the other conditions for a healthy environment are reached, the most important parameter is the temperature. Some of the conditions for a healthy environment are the air quality and the lighting.

The data are collected in Belgium between 1st October 2005 and 28th February 2006. The graphic for the daily average temperature of that period is presented in the figure 2 and the gas consumption in the figure 3.

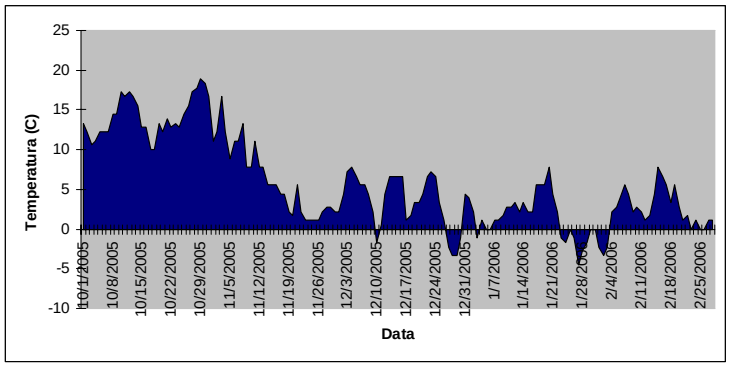


Fig. 2 The daily average temperature

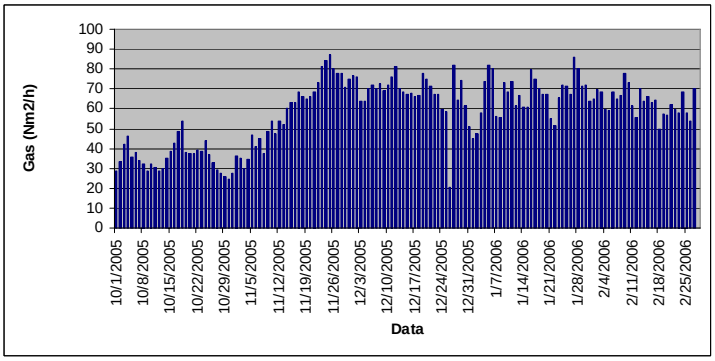


Fig. 3 The daily average gas consumption

## 4. THE SIMULATION

The simulation is performed in Matlab 7.5 [7] for October month and then the results are compared with the real data for determining the best model. The best result (figure 4) is obtained for the particular architecture presented in the section *2.1. Neural network propose for the application*. For having a good comparison, we had modified one by one the following parameters: the architecture of the network, the number of layers, the number of neurons and the steps necessary of training. The minimum number of epochs good for our solution is 1000 and the maximum number of neurons in the first layer is 5. Other learning algorithms that have been used are quisi – Newton backpropagation and resilient backpropagation.

Comparing with the results obtained with polynomial regression [2], the estimation of neural network is better then the one obtained through polynomial regression.

To evaluate the results between neural networks and regression we used the sum of squared errors, but for evaluation of the results between polynomial regression and multiple regression we used the coefficient of determination (equation 2).

$$R^2 = \frac{\sum\left(\overline{Y} - avg(Y)\right)^2}{\sum\left(Y - avg(Y)\right)^2} \tag{2}$$

In our case the polynomial regression is better that the multiple regression, where the parameter external humidity is taken into account, but as it was mentioned above, if the building is well isolated, this parameter doesn't have influence on the system.

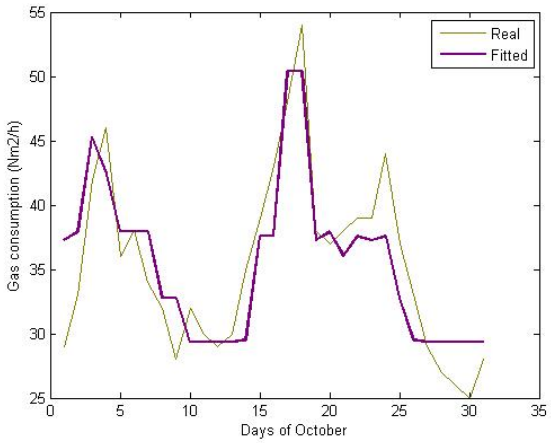


Fig. 4 Comparison between real data and simulated data

## 5. CONCLUSION

Neural networks are powerful technique for prediction of the nonlinear systems. The above investigation shows promising results, but they have to be studied more to find the best network architecture and parameters. They also have to be taken into account the new advanced network types and training algorithms.

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