BUILDING ENERGETIC EFFICIENCY ESTIMATION USING THE NEURAL NETWORK TECHNOLOGY

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Abstract: The building energy consumption represents an important domain of study because of these implications to social, economic and environmental issues. Many complex tasks can be solved using the artificial intelligence methods. The paper describes the building energy consumption evaluation with aid of neural network solutions. Based on the known building behavior data the neural network is trained for evaluation of different solutions for the new building. This new method reduces the building design duration and saving spends founds.

Keywords: energy saving, energy efficient buildings, artificial intelligence, neural network.

1. INTRODUCTION

Economic strategies of the durable development impose the efficiency promotion and the rational utilization of the building energy consumption. The buildings represent a significant energy consumer in a society and their energy consumption has important implications to social, economic and environmental issues.

Many researches with regard to the energy building saving try to solve the complicated problems. A challenging task today is to design and promote energy efficient buildings in a cost effective and environmentally responsive way.

In the most of industrialized and developing countries nearly half of the national energy consumption is in buildings Heating, ventilating and air-conditioning (HVAC) systems are major energy users in buildings. When considering the costs of a new building, some 30% up to 50% is related to HVAC systems in case of commercial buildings, and 5% up to 10% in case of domestic buildings. With respect to environmental impact and economics, the ability to make sensible and well-based decisions regarding the choice of the building energy saving methods.

The potential for energy savings in the building sector is large: the primary potential is in the reduction in the use of HVAC systems since more than 60% of the building energy consumption is used to condition the indoor environment (Gandrile and Hammond, 1998). Accurate methodology for energy calculations is most crucial for the design and analysis of the performance of building systems. It is generally accepted that buildings can be designed to be energy effective if their thermal insulation is increased, window size and lighting level decreased, shading devices properly installed and heating and cooling systems adequately designed, installed and maintained.

These energy savings features must be considered with reference to numerous constrains, such as added costs for materials, construction and maintenance, conformance to local building codes, occupancy life styles, aesthetics,

construction practices and availability of equipment. These many constraints make very difficult the precise calculations.
A new method of the energy savings estimation in the building, based on the neural networks is proposed. This method uses the NeuroSolutions software facilities.

The use of computers simulations makes it possible to evaluate the sensitivity of various design alternatives on the net energy usage, and they are the most popular and flexible nowadays for building energy analysis.
Building energy simulation is analysis of energy performance of building using computer modeling and simulation techniques. Calculation of building loads and energy consumption are involved to determine the energy characteristic of the building and its building systems. Building energy simulation employed to design the building to the requirements of local building regulations, codes and standards. Subsequently, it can supplement energy auditing to check the energy performance of the as built building.

With building energy simulation complicated design problems can be investigated and their performance can be quantified and evaluated. It is also useful tool for developing a better understanding of the building performance. With appropriate computerized engineering tools, professionals would be able to evaluate various energy saving options before deciding on implementation. Energy analysis can help designers to develop an effective building form and design strategies.

NeuroSolutions software provides an object-oriented simulation environment for neural network design and application. It has quickly evolved into the software tool of choice for both the neural network beginner and expert alike. This leading edge software combines a modular, icon-based network design interface with an implementation of advanced learning procedures, such as recurrent backpropagation and backpropagation through time. The result is a virtually unconstrained environment for designing neural networks to solve real-world problems such as financial forecasting, pattern recognition, process control, targeting marketing, and many more.

NeuroSolutions for Excel is a product that benefits both the beginner and advanced neural network developer. For the beginner, NeuroSolutions for Excel offers visual data selection, one-step training and testing, and automated report generation. For the advanced user, NeuroSolutions for Excel offers the ability to perform parameter optimization, run batch experiments, and create custom batch experiments programmatically. The best part is that all of these tasks can be performed without ever leaving Microsoft Excel.

We can build a database with known data of the energy saving building characteristics in Excel. Based on the acquired information a neural network is build and trained. The obtained neural network is used for simulations and study of the new building with the object of find the optimal solutions of the energy saving.

2. DOMAIN AREAS FOR BUILDING ENERGY SIMULATION

The different energy saving techniques is used for the old buildings and new buildings. Simulating the energy performance of building requires relevant parameters of the design and operating conditions of a building. The amount of data required and the accuracy of results vary depending on the assumptions and the nature of analysis techniques used.

The following seven major domain areas were identified as relevant for building energy simulation:

1. Location
2. Building description
3. Climatic data
4. Envelope (Building construction)
5. Lighting
6. HVAC System
7. Additional systems

Building description includes schemes of building, dimensions and composition, orientation, buildings function, etc. The base characteristics of the building are: total volume of the building, total surfaces area, total external doors and windows area, designed number of occupants and buildings operation period.
Other new domains are developed for building energy saving and the simulation can take this into account. A few new researches are: optical elements for high efficiency illumination, solar control and photovoltaic power in buildings, integrated system for day-lighting, natural ventilation and solar heating, polymer network liquid crystal with reflective, scattered and clear states, intelligent and energy-optimized lighting systems based on the combination of daylight and the artificial light of sulphur lamps, high performance variable solar control glazing, and so on.

The large variety of conditions for building energy saving require a complex work of the simulation process. Using the neural network technique allow a first estimation of the design building solution. After this estimation other modeling and simulation techniques can be used.

3. NEURAL NETWORK IMPLEMENT

An Artificial Neural Network is a computer program that can recognize patterns in a given collection of data and produce a model for that data. Typical artificial neural network applications are: classification, function approximation, time series prediction and data mining.

Utilization of artificial neural network supposes initial training. The training of artificial neural network if performed in following steps:

1. Present data to the network
2. Network computes an output
3. Network output compared to desired output
4. Network weights are modified to reduce error

For network training a Microsoft Excel workbook is used. The workbook file is made of input data columns and output data columns. The structure and the data of the workbook are presented later in this paper.

After training the artificial neural network act in two steps:

1. Present new data to the network
2. Network computes an output based on its training

NeuroSolution for Excel allow the same workbook for training and the simulation results. In this manner we can solve the following problem: given a characteristics of a building (e.g., location, building data, climatic data) create a system that will estimate its energy economy.

Using different building characteristics for selected technologies in the design phase the system allows finding the adequate solution. The artificial neural network system is time and resource saving.

Collection of information's is the beginning of artificial neural network implementation. The collected data is stored in an ASCII text file with column label: "Chmbrs" (the number of the building chambers), "Windw" (the number of the building windows), "Heat" (a coefficient of heating system), "Envel" (the envelope of the building), "Tehnol" (a coefficient of technologies used), "Year" (the oldness of the building), "Location" (the location of building), "Energy" (a coefficient of dispersed building energy).

The Neural Expert Wizard self-acting the structure of the artificial neural network based on the data text file. The selections are:

1. Problem type selection: Function Approximation
2. Input file selection
3. Tag input columns: "Chmbrs", "Windw", "Heat", "Envel", "Tehnol", "Year" and "Location"
4. Tag symbolic inputs: "Location"
5. Data model file selection

6. Select the desired outputs: “Energy”
7. The artificial neural network complexity: low (enough for this simplest example)

In figure 1 the structure of the artificial neural network is shown.

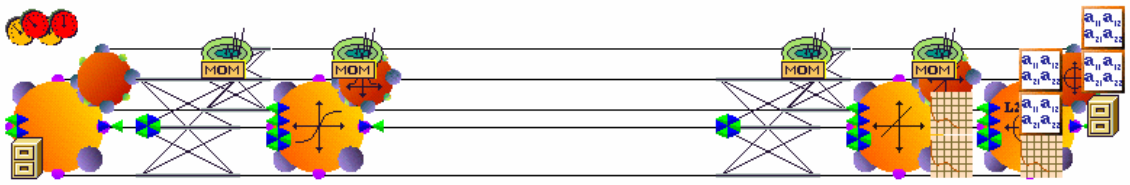


Fig 1. The Synthesized Artificial Neural Network

The training of the artificial neural network begins with action of Start button. Based on the supplied input data from the text file the NeuroSolutions software training the model of artificial neural network with respect to desired output (Energy). The results are shown in figures 2, 3 and 4.

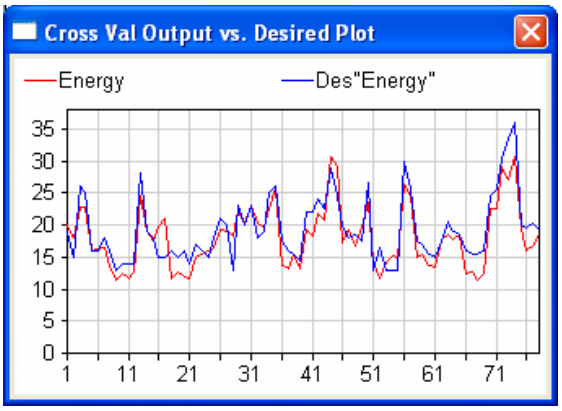


Fig 2.

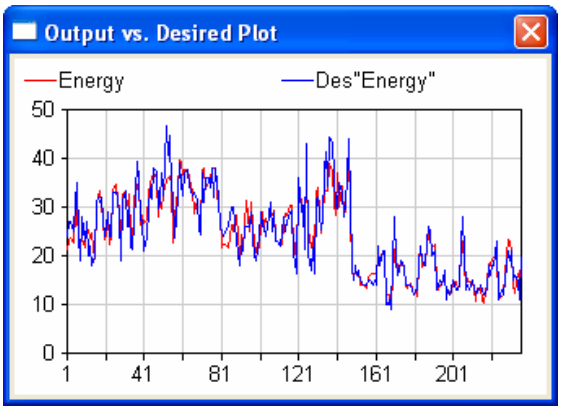


Fig 3.

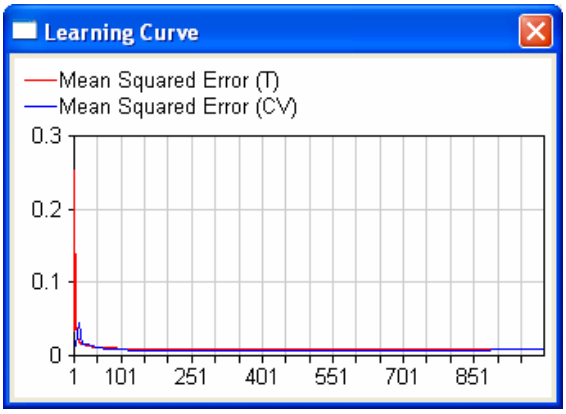


Fig 4.

The obtained average cost of criterion is 0.00867.

To assess the model prediction performances, two quantitative prediction accuracy measurements were calculated and examined, the mean absolute percentage error (MAPE), and the coefficient of variation (CV). The MAPE measure the average percentage of the model prediction error and is calculated by:

$$MAPE = \frac{\sum_{i=1}^{n}(AE_i)}{N}$$

$$AE_i = \sqrt{(Y-y)^2} \;/\; N$$

Where N is the number of sample of projects. AE represent the absolute error. The Y and y denote the actual and the network predicted total cost of variations respectively. Finally, the coefficient of variations (CV) is calculated by:

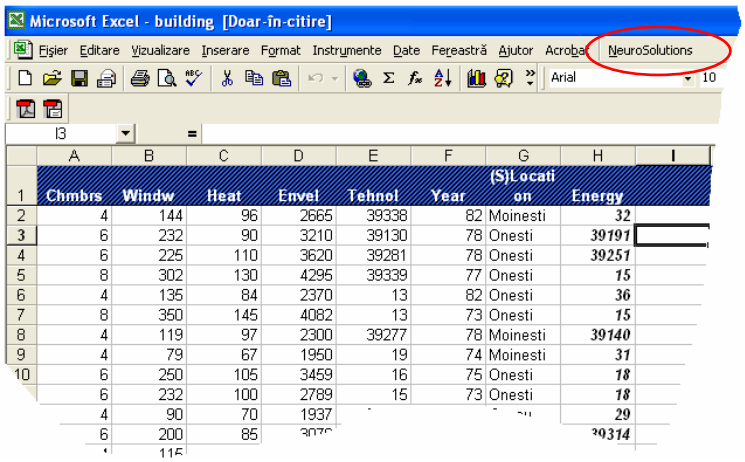
$$CV = \frac{SD_r}{MTCV} * 100$$

where SD_r is the standard deviation of the error and the MTCV is the mean of the actual total cost of variations.

The second test used independent (i.e. unseen by the model) data set. This test is a simulation of the use of the model in practice and assesses how the model will perform if presented with unknown data set.

Same project can be achieved in Excel. The advantage of this implementation consists in facility of simulation of new situations.

First the NeuroSolution software is opened from main program. An Excel workbook appears with NeuroSolution option button in main menu. The earlier created text file with the input data is imported in Excel worksheet (figure 5).



	A	B	C	D	E	F	G	H
1	Chmbrs	Windw	Heat	Envel	Tehnol	Year	(S)Location	Energy
2	4	144	96	2665	39338	82	Moinesti	32
3	6	232	90	3210	39130	78	Onesti	39191
4	6	225	110	3620	39281	78	Onesti	39251
5	8	302	130	4295	39339	77	Onesti	15
6	4	135	84	2370	13	82	Onesti	36
7	8	350	145	4082	13	73	Onesti	15
8	4	119	97	2300	39277	78	Moinesti	39140
9	4	79	67	1950	19	74	Moinesti	31
10	6	250	105	3459	16	75	Onesti	18
	6	232	100	2789	15	73	Onesti	18
	4	90	70	1937				29
	6	200	85					30314

Fig 5.

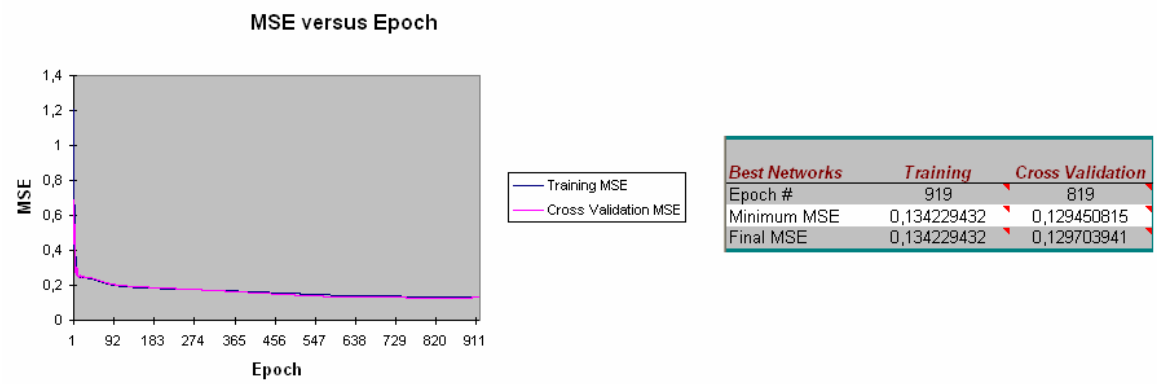
The worksheet columns are identified as input, output and symbolic. The symbolic columns are automatic codified in numbers.

The rows of worksheet must randomize for proper artificial neural network training.

Then a lot of input data rows are assigned for training, cross validation and testing. The designer establishes the destination of the input rows percent for each action.

Creation of artificial neural network model supposes the selection of one of network type of network: classification network, function approximation network or custom network. The function approximation artificial neural network type is selected.

The results of artificial neural network training are shown in figure 6.



Best Networks	Training	Cross Validation
Epoch #	919	819
Minimum MSE	0,134229432	0,129450815
Final MSE	0,134229432	0,129703941

Fig 6.

The NeuroSolution for Excel software offer the possibilities of testing and using of the trained artificial neural network. First the option Test network can be activated in the Excel NeuroSolution Menu. Second the designer can use the "Apply Production Datasheet" by selecting a new "Row(s) As Production" for new entry data.

4. CONCLUSIONS

The potential for energy savings in the building sector is large. Energy efficiency of buildings is important for both economic reasons and environmental concern. New technologies in planning, design and operation for energy efficiency often require the use of computers, and with the advent of desktop computing, building energy simulation is expected to grow in importance. To evaluate building performance and achieve energy efficiency goals, engineers should take full advantage of computer simulation tools that are readily available.

The large variety of conditions for building energy saving require a complex work of the simulation process. Using the neural network technique allow a first estimation of the design building solution. After this estimation other modeling and simulation techniques can be used.

The obtained results indicate the possibilities of artificial neural network using in the study and design of the energy saving for the building.

The paper can be used to help designers and engineers to bring right decision about selection of adequate building energy simulation software.

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