Innovative Systems Design and Engineering
ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
Vol.5, No.1, 2014

Application of an Artificial Intelligence and Neural networks for Modeling the Thermal Dynamics of a Water tank and Its Heating system using Home Central Air conditioners

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Abstract:
Artificial Intelligence and Neural networks (AI&NN) have been used for modeling the thermal dynamics of a water tank, its heating system with the help of central air conditioners. A temperature sensor, multilayer feed forward neural network, using a error back propagation training algorithm, has been applied to predict the water tank temperature and hot air temperature. Real weather data for a number of winter months, together with a validated central air conditioners model (based on the building central air conditioners), were used to train the network in order to generate a mapping between the easily measurable inputs (hot air temperature, water tank temperature, heating valve position) and the desired output. I.e. the predicted hot water temperature. The objective of this work was to investigate the potential of using an artificial intelligence and neural networks with singular value decomposition method (SVD) to predict the Hot water tank temperature to shut down the central air conditioners hot air temperature sensor. Early for checking the heat of water inside the manufactured water tank.

Key Words Artificial Intelligence and neural networks, singular value decomposition, Hot air temperature sensor, water tank temperature sensor, prediction.

1. Introduction:
The hot air energy use due to central air conditioners of buildings or multistory apartments in developed countries in developed countries such as cold countries represents about 60% of the total national energy use. For an average flat, about 20% of the net income is related to hot temperatures in rooms and multistory buildings in cold countries. Hot air and Hot water represents one of the major issues in the sustainable use of multistory buildings in cold countries today. The hot air energy and hot water energy analysis model can either be based on steady state and dynamic conditions. For example, be based on a complex physical description in order to simulate the hot water tank or may be based on experimental data. Models that are based on measured central air conditioners performance data represent another alternative. Steady state methods are commonly degree night based, using the basic assumption of constant hot air gain over the period in question. Accuracy can be improved by correcting the temperature using a variable base [1]. There are a large number of approaches for dynamic analysis [2]. Thermal network models, for example, use a description of the building components in terms of a network of capacitors and resistors. These form a simple approach and same approach can be used for good understanding of the water tank temperature and hot air temperature with the help of sensors, training algorithms to control resistors and capacitors [3, 4]. More recently, artificial intelligence and neural networks have drawn some attention as a modeling and predicting technique. Neural networks have a certain capacity to map linear and non linear dependencies in the data without using any preconceptions. They have been used to predict building energy use for both short and long term periods and particularly for 60min energy use [5, 6]. The power of neural networks in modeling complex interactions and in system identification has been demonstrated [7, 8]. In this work, particular problems arise because if the very slowly varying deterministic part of solar radiation (a time scale of days), a building with a two time scale of around 12h (structure) and 1h (air mass) and a heating plant with a time scale of minutes. In this study, an NN has been adopted for modeling the thermal behavior of a building, heating system and deterministic part of the solar radiation in order to control. In this paper using same technique to different approach from central air conditioners where it is pumping the hot air outside we are utilizing for heating water in water tanks with the help of AI and NN.

2. Artificial Intelligence:
AI as a science that investigates knowledge and intelligence, possibly the intelligent application of knowledge. Originally to investigate how much the system learn about human occupancy patterns by using mainly simple

movement sensors as input. The main function of the system was to try to establish hot air temperature and hot water temperature with sensors. This was done by reference to a short term memory of sensor data and heuristics to detect and correct sensors in reasoning when they occurred. Inside the water tank, outside the water tank temperatures are measured by the system. All two sensors are implemented using low-cost LM35ICs with very simple amplifier to correct voltage range and lower line impedance to reduce the effects of noise. Temperature is available to the system in ^{0}C. Water heating controller system has direct and unique control of the hot air temperature it is released by central air conditioners. It is able to get feedback from this loop through the water temperature sensor from the water tank. Using the feedback the system is able to maintain temperature at levels that are more appropriate than the hot or cold provided by a simple thermostat. Automatic microprocessor controller (AMC) carries out functions in a reactive way i.e. it responds to conditions. The behavior of the AMC is controlled by a set of rules, but the way that rules are applied can be modified by high level commands.

2.1 Neural Networks:

A neural network is a massively parallel distributed processor that has a natural propensity for storing experimental knowledge and making it available for use [9]. It resembles the human brain in two respects, the network through learning process acquires the knowledge, and interneuron connection strengths, known as weight, are used to store knowledge. In neural networks the simple model of machine learning the environment supplies some information to a learning element. The learning element then uses the information to make improvements in a knowledge base and finally the performance element uses the knowledge base to perform its task. The kind of information supplied to the machine by the environment is usually, imperfect with the result that the learning element does not know in advance how to fill in missing details or to ignore details that are un-important. The machine therefore operates by guessing, and then receiving feedback from the performance element. The feedback mechanism enables the machine to evaluate its hypothesis and revise them if necessary. The network usually consists of an input layer, some hidden layers and an output layer. In its simple form, each single neuron is connected to all other neurons of a previous layer through adaptable weights. Knowledge is usually stored as a set of connection weights. Training is the process of modifying the connection weights in some orderly fashion, using a suitable learning method. The network uses a learning mode, in which the input is presented to the network along with the desired output and the weights are adjusted so that the network attempts to produce the desired output. The back propagation algorithm is one of the most commonly used algorithms for the training of neural networks [10]. Back propagation training is a gradient descent algorithm. It tries to improve the performance of the neural network by reducing the total error by changing the weights along the gradient. We now summarize the relations that we have derived for the back propagation algorithm. First the correction

$$W_{ij}(n) = Ns_j(n).Y_i(n)-\partial\sum(n) \tag{1}$$

Where N is the learning rate parameter, $\partial_j(n)$ is the local gradient, $\partial\sum(n)$ instaneous error energy. The performance in terms of speed of convergence and the likelihood of being trapped in local minima for both the gradient descent and error energy ($\sum(n)$) technique are sensitive to the number of neurons in each layer. The performance in terms of speed of convergence and the likelihood of being trapped in local minima for both the gradient descent and error energy ($\sum(n)$) technique are sensitive to the number of neurons in each layer and also the number of hidden layers in the network.

3. Singular Value Decomposition (SVD):

Singular value decomposition (SVD) represents an efficient numerical technique for the analysis of multivariate data [11]. SVD can be used as a preliminary stage in most types of multivariate analysis, and can greatly increase the computational efficiency of linear techniques such as key vector analysis and non linear techniques such as cluster analysis and neural network analysis. The SVD method of solving for the output weights also has the advantage of giving the user control to remove unimportant information that may be related to noise. Singular value decomposition (SVD) has previously been applied to the problem of data extraction from marine data [1, 12], texture analysis of remotely sensed data. This application is problematic in as much as there are three time scales involved: of the order of 30min to 2h for the heating the water in the tank and hot air is produced from central air conditioners, of the order of every 3h for the water tank and when the solar radiation heating system is off (or) cold weather such as minus temperature in cold countries. Then we can take the help of central air conditioners functioning of hot air outside as an output. This output will work as input for heating water in tank. Because already they are wasting the power energy for central air conditioners (hot air) in rooms of multistory buildings. This is an idea why we cannot use wastage of hot air from central A/C to heating water in cold countries with the help of control AI&NN. For this application, three variables are observed: Hot air temperature, water tank temperature, valve position. These are presented as an observation matrix O (of size mxn, which contains both the current values and the past history over 3h, with a 30min sampling time) for each of the three parameters in each row. Thus there are 9 values associated with each parameter, hence n=27. The SVD method decomposes this O matrix into three matrices W,L, and V. The SVD method decomposes this O matrix into three matrices W,L and V. The SVD of O is defined as:

$$O = WLV \tag{2}$$

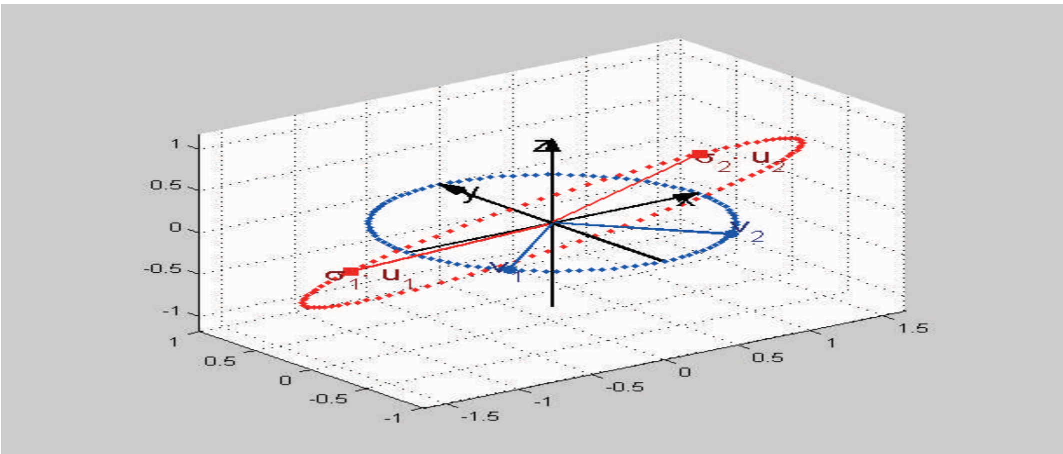
Where W and V are pseudo-unitary containing the first 'n' column Eigen vectors of O^TO and row Eigen vectors OO^T respectively. The L matrix contains the corresponding Eigen values, in decreasing order of significance, on the leading diagonal. In many it is useful to partition the matrices are:

$$O=(W_1 W_2)\begin{Bmatrix} L_1 & 0 \\ 0 & L_2 \end{Bmatrix}\begin{Bmatrix} V_1 \\ V_2 \end{Bmatrix} \tag{3}$$

Where W_1 contains the first 'k' columns of W, L_1, the first 'k' rows and columns of 'L' and 'V_1' the first 'k' rows of 'V'. The 'O' matrix can then be decomposed into two terms:

$$'O' = O_s + O_N = W_1 \begin{Bmatrix} L_1 \\ 0 \end{Bmatrix} V_1 + W_2 \begin{Bmatrix} 0 \\ L_2 \end{Bmatrix} V_2 \tag{4}$$

Where the subscript 'S' denotes signal space and 'N' noise space. As the value of 'K' increases, O_s becomes a closer and close approximation to 'O' and the values in 'O_N'.



become smaller and smaller. The closeness of the approximation is given by I(k) defined by the following equation:

$$I(k) = \frac{\sum_{i=1}^{I=1} L_{i,i}}{\sum_{I=1}^{i=n} L_{i,i}} \tag{5}$$

The value of I(k) will increase monotonically to 1. If significant correlation is present in the data (the rows and or columns of the O matrix) the series will rapidly approach the value 1. It is the property that is used for dimensional reduction. It is found in this application with k=8, I(k)>0.70. as illustrated fig.1. This indicates that more than 70% of the observation signal is contained within the first 8 dimensions. To simply the neural network structure, information contained in the dimensions higher than 8, has justifiably been ignored.

4. Proposed Objective:

The network developed in this research was required to generalize a method for shutting down the hot air system in anticipation of adventitious heat gains by water tank (water temperature is increased to certain level) with the help of temperature sensors by an Artificial intelligence. The network would therefore provide a forward prediction intelligence of water heating system need. In this scheme, the available training data are partitioned into a training set, S1 and a validation set S2. The neural network is trained on S1 until the performance of the network on S2 starts to disapprove. The specific heat of water is 1 calorie/gram ^{0}c = 4.186 joule/gram ^{o}c. which is higher than any other common substance. As a result water plays a very important role in temperature regulation. The specific heat per gram for water is much higher than that for a metal and as far as consider it is more meaningful to compare the molar specific heats of substances.

$$Q = CM\Delta T$$

Heat added = specific heat x mass x ($t_{final} - t_{intial}$)

Such as air heaters (electrical generators of hot air) of 15kw or cannons of heat powered by diesel with a calorific value of 68.5kw. But while it come to central air conditioners machines or air source heat pumps units rated for more than 65,000 BTU (British thermal unit)/hr of cooling and producing hot air. Water tanker is manufactured by aluminum 0.215. To calculate the wattage requirement to heat water in a tank, use the following equation
Watts = 3.1 x 1500 x 100/0.5 = 930000

1500liters of water

In central air conditioners we are using Draft induced fan motor up to 240 VAC the air allows into the burner to generate heat air which is exhausted air out of the home. This air contains the stock of fuel combustion such as carbon monoxide.

5. An AI & NN for Modeling and Prediction of Hot Air Temperature and Water Tank Temperature in a Multistory Building:

In the present study, an artificial intelligence and neural networks has been used to model the central air conditioners hot air pumping out from the multistory buildings and this hot air is used for heating the water tank to produce the hot water into the building. It is important to include all significant variables but not to include irrelevant or redundant information. At the very least, too much information will increase the network training and prevent the network from learning adequately. Both the input and output data were sampled at 30min intervals because the water tank dynamic depends on past as well as the current values of the inputs. Three variables were used, hot air temperature (T_0), water tank temperature (T_i) and heat valve position (V_p). Because of the need to supply historic data, not only the current values inputs (Q)
Were used but also, inputs (Q-1), inputs (Q-2) ……………….. Inputs (Q-i). The value of I was increased by trial and error and it was found that a minimum value of i=3 was needed to capture the heat water tank and hot air temperature dynamics carefully. This effectively provides 12h of historic data to the network, but led the unwelcome effect of increasing the number of effective inputs to 27. The SVD technique as described before was used to decrease these inputs to 8, as this value was sufficient to keep nearly all the important information in the data. Various network architectures were investigated and a number of different network sizes and learning parameters have been tested. In fig.2 it is a conventional feed forward type and consists of three layers: an input layer with 8 neurons, 5neurons in hidden layer, and 1 neuron for the output layer.

The proposed NN is trained by Error-Back propagation based on the Error gradient descent algorithm. The activation function used with the input and output neurons are linear, whereas in the hidden neurons is of the sigmoid form given by:

$$Y = \frac{1}{1+e^{-x}} \tag{6}$$

In this algorithm the number of hidden neurons was estimated by running the network with different number of hidden neurons and calculating the mean square error using the training, validation and testing data set. Based on this, the number of hidden neurons arrived at was five. (fig.3) . The network was trained every two weeks, using a data set consisting of the two previous weeks of observation data. The networks was trained using 100 different random starting values for the weights and bias and one with the lowest mean square error is chosen. The early stopping method was used to overcome the problem of overfilling and mat lab neural networks toolbox package was used for training, validation and testing [14]. Once a satisfactory degree of input-output mapping was reached, the network training was frozen and a set of test data was applied for verification. Finally, the trained network was used to predict the hot air temperature of the water tank temperature up to 3h ahead.

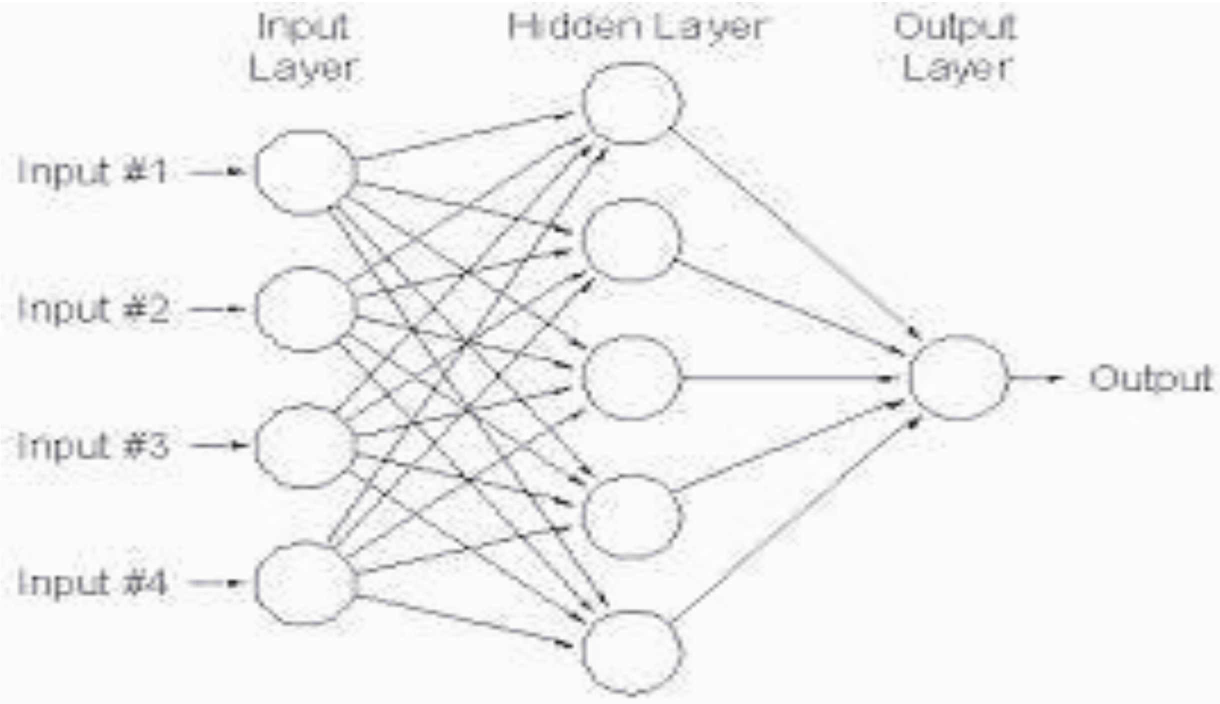


Fig 2. Multi layer feed forward neural network

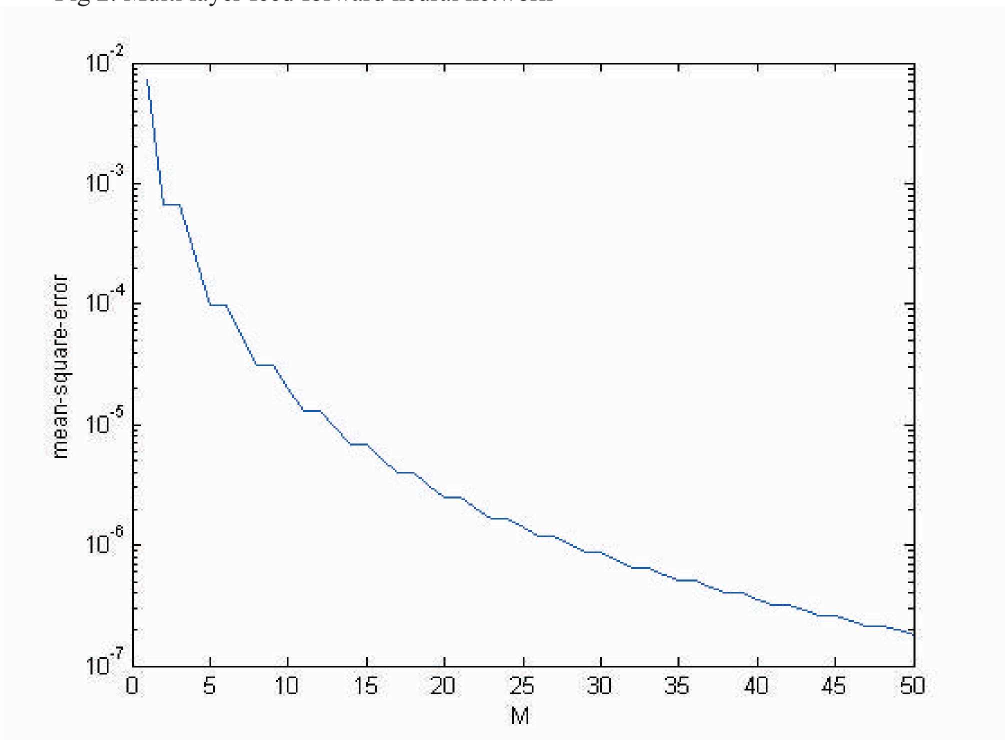


Fig 3. Network Mean square error

6. Conclusion:

In this study, an artificial intelligence and neural network has been used to model the thermal dynamics of central air conditioners to produce and make its heating system to produce hot water in order to predict the water tank temperature. The network has the potential application as a predictor in intelligent heating controller design to overcome the problem and usage of wastage energy (hot air) to make up hot water (water tank).

A network with good accuracy for a time horizon of up to 3h has been demonstrated, thus can be used for control intelligence to shut down by sensors when it a crossing certain level temperature either hot air vice versa. Non availability of research information on thermodynamics of air conditioners using AI & NN, lot of related work has been taken from thermal dynamics of a building heating system, testing and results (simulation) couldn't completed. I will try to complete in future paper.

In this paper, the output of the proposed has been compared with NN & AI. According this provided information about an area. We can use AI & NN on Air conditioners and water tanks with the help of sensors, algorithms and heating water equations.

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