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Modelling the Artificial Neural Network for Heating System Choice for City Electrical Transport

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Abstract

The provided results prove that the use of Artificial Neural Networks with application of the proposed algorithm can be a very useful for solving choosing problem of HVAC system for public electric transport. Usage of created model and algorithm will raise possibility to increase efficiency of choosing task, so choosing time will be minimized with high result validity. When use artificial intellect, opportunity rises to do system self tuning and to export and change findings with some similar choosing systems. The elaborated system model can be used for different system choosing tasks, too.

Introduction

This article describes usage of Artificial Neural Network (ANN) for choice of Heating, Ventilation and Air Conditioning (HVAC) system for city electro transport passengers' interior. Neural Network is trained to analyze the parameters of the system and detect the possibility of its usage in the specific task.

There are system criteria formalized in the article. Defining of consumer's priorities and temperature control system parameters provides an optimal choice of HVAC system, taking in account effective energy consumption problem. HVAC system choosing criteria and procedure for air condition system choice are formalized in the article. Deep and detailed investigation of the behaviour of such a system, its operation and running processes requires its generalized mathematic modelling, taking into account all possible regimes of the operation of compressor and fan motors and setting an algorithm of their control in all possible regimes under any condition. When use artificial intellect, opportunity rises to do system self tuning and to export and change findings with some similar, distant choice systems.

This paper provides mathematical model of heating system choosing method for passengers' interior climate parameters control. There are main conclusions at the end of the article.

Table 1

Groups of system parameters

No	Parameter		Constructive	Environmental	Service	Costs
1.	Dimensions / mm /	d	X			
2.	Weight / kg /	m	X			
3.	Power voltage / V /	u	X			
4.	Power current / A /	i	X			
5.	Cold productivity / kW /	q_1		X		
6.	Heat productivity / kW /	q_2		X		
7.	Outside air consumption / m^3/h /	v		X		
8.	Minimal interior temperature / $^\circ$C /	t_1		X		
9.	Maximal interior temperature / $^\circ$C /	t_2		X		
10.	Automatic temp. regulation Y/N	s_1			X	
11.	Digital control panel Y/N	s_2			X	
12.	Outside air filtration Y/N	s_3			X	
13.	Inside air anti-virus protection Y/N	s_4			X	
14.	AI based control system Y/N	s_5			X	
15.	Energy saving control regime	s_6			X	
16.	Price EUR	c_1				X
17.	Monthly exploitation cost EUR	c_2				X
18.	Monthly service cost EUR	c_3				X

1. HVAC System Parameters

HVAC system is characterized by several parameters. They can be divided to several groups:

1. Constructive parameters;
2. Environment control parameters;

3. Service functions;
4. Costs.

Weight is adjusted to each group of parameters, which defines a degree of importance of each parameter. Each group consists of individual parameters which also are classified by their degree of importance inside each group with the respective weight.

When choosing HVAC system, individual parameters are analyzed at first and then weight category of the whole group is evaluated.

2. Problem Formulation

The purpose is to choose the optimal HVAC system for public electro transport passengers' interior, taking into account the admissible constructive parameters, the necessary interior environment parameters, as well as the necessary service functions. Costs for obtaining of system and exploitation costs are important, too. As all these parameters are defined for each product already at a factory then intellectual method for comparison of parameters of many similar devices can be used. That would give a possibility to do the choice of the most appropriate HVAC system quickly and with a high reliability.

In order to make quick and based on weights system choice, artificial intellect systems are the most appropriate, that is, usage of artificial neural network as a basis of choice system. Usage of neural networks has several advantages in comparison to other methods. Possibility to perform system training using expert's knowledge or by transferring knowledge base from similar choice systems is one of the main advantages. That is absolutely flexible and can be adjusted to any choice criteria of HVAC system. Number of parameters to be analyzed is limited only by number of neurons in input layer.

3. Artificial Neural Network

The back propagation artificial neural network (ANN) is used (Fig.1) in the decision system described in the paper.

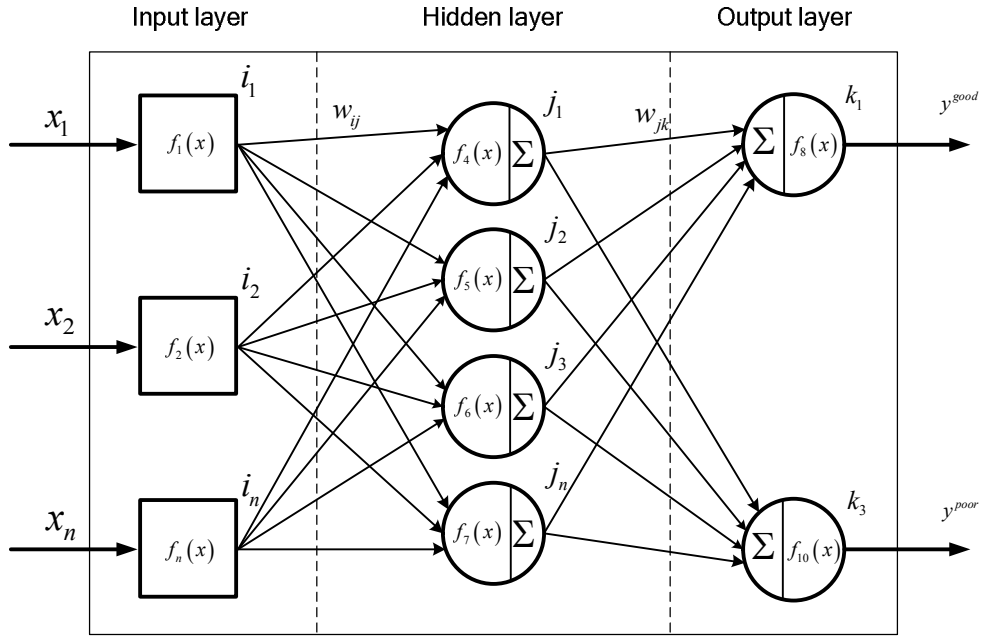

Fig. 1 Back propagation artificial neural network. Input layer elements: $\{i_1, i_2, ..., i_n\}$, hidden layer elements: $\{j_1, j_2, ..., i_n\}$, output layer elements: $\{k_1, k_2, ..., k_n\}$, input patterns: $\{x_1, x_2, ..., x_n\}$, weights: $\{w_1, w_2, ..., w_n\}$, neuron activation function: $f(x)$, outputs: $\{y^{good}, y^{poor}\}$

An ANN works as a solid massive parallel processor, which is constituted by several simple units and has a natural propensity to store experimental knowledge and use it to create non-linear relationships between inputs and outputs. In other words, an ANN is a highly interconnected network made of many simple processors. Each processor in the network maintains only one piece of dynamic information and is capable of only a few simple computations. An ANN performs computations by propagating changes in activation between the processors [2].

ANN consists of three or more layers- Input, hidden (one or more) and Output layers. The output of a neuron in a layer goes to all neurons in the following layer. Each neuron has its own input weight *w*. The weights for the input layer are assumed to be 1 for each input. The output of the ANN is reached by applying input values to the input layer, passing the output of each neuron to the following layer as input. The number of neurons in the input layer depends on

the number of possible inputs, while the number of neurons in the output layer depends on the number of desired outputs. The number of hidden layers and how many neurons in each hidden layer cannot be well defined in advance, and can be changed. The addition of hidden layer could allow the network to learn more complex patterns, but at the same time decreases its performance.

The ANN could be divided into seven basic parts, as described in [3]:

- The set of individual processing units or neurons.
- The state of activation of processing unit.
- The function used to compute the output of a processing unit.
- The pattern of connectivity among the processing units.
- The rule of propagation employed.
- The activation functions for each individual processing unit.
- The rules of learning that allow the determination of the pattern of connectivity between processing units.

Step 1. Initialize system;

Step 2. Insert current (n^{th}) system parameters in ANN input layer;

Step 3. Process data with ANN. Output Good/Poor data; If Poor then delete entry (with current n);

Step 4. Save current system data in new table n_1;

Step 5. Next n;

.

Step 7. Check last entry of table;

Step 8. Repeat steps 2-7 with new table data.

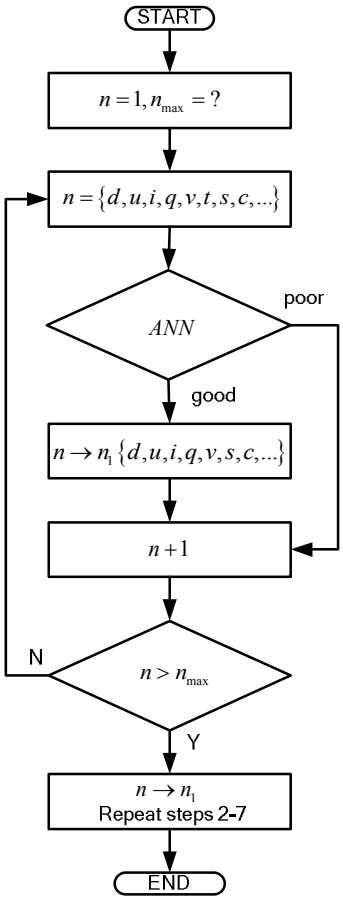

Fig. 2 Problem decision algorithm

3.1. ANN Back Propagation Algorithm

It is necessary to train a multi layer feed forward network by gradient descent to approximate an unknown function, based on some training data consisting of pairs (x, t). The vector x represents a pattern of input to the network, and the vector t- the corresponding desired output. The overall gradient with respect to the entire training set is just the sum of the gradients for each pattern.

In the paper there is used fully connected layered feed forward network- that is, each node in a given layer connects to every node in the next layer, then it is often more convenient to write the back propagation algorithm in matrix notation rather than using more general graph form. In this notation, the biases, weights, net inputs, activations and error signals for all units in a layer are combined into vectors, while all the non-bias weights from one layer to next form a matrix W which is described in [1].

4. Problem Decision Algorithm

In order to perform optimal choice of HVAC system for electro transport passengers' interior, it is necessary to define precisely an idea about admissible constructive parameters as well as about necessary interior environmental parameters and necessary service functions which has to be provided by the system. All these parameters have to be

classified in groups (table 1) and weight to each of them inside the group has to be adjusted. Preparing of choice system and data is performed in the following order:

Step 1. Critical parameters groups table of systems is prepared;

Step 2. Suitable weight is assigned to each group of parameters $a_g \leq 0.5$;

Step 3. Group significance weight is assigned to each parameter in group $a_p \leq 0.5$;

Step 4. Total weight is calculated $a_g + a_p = a \leq 1$;

Step 5. ANN training is performed using expert knowledge or knowledge transferred from other choice system.

After Artificial Neural Network system training is finished, comparison procedure of aggregated system data is performed according algorithm in Fig. 2.

Data about each parameter of current system is entered in ANN input layer neurons. Value of each parameter is evaluated using the weight of neuron. If the proportion is within acceptable limits neuron becomes activated. Hidden layer neurons compare input signal values and become active according to functions assigned during training process. Hidden layer outputs are delivered to output layer neurons. Only two neurons, which indicate ANN work result, are in the output layer.

When number of system $n > n_{max}$, that means all data of HVAC systems being in the list are processed, data of not useful systems are deleted from the data base and comparison using useful systems data is performed again (Step 2-7). As well as new and stricter choice criteria are entered in ANN. Process of choice is finished when one, the most appropriate HVAC system is found.

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