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Intelligent Control of Cooling-Heating Systems by Using Emotional Learning

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Introduction

The neuro fuzzy model has turned out to be a popular model in recent years, due to its high flexibility and remarkable ability in learning different algorithms. Because of its outstanding reaction in dealing with uncertainties, complicated control systems and decision-making problems, its popularity has been increased. High efficiency and proper flexibility of emotional learning are two noticable advantages of this learning pattern in comparison with other learning patterns.

In this paper, emotional learning based on neuro fuzzy system by Takagi Sugeno is used. The purpose is to present a method to control a cooling-heating system in such a way that the accuracy of this system increases, the cost of the control decreases and consequently industrial efficiency improves.

Cooling-heating systems have complicated dynamic structures and are very sensitive to enviromental changes. Due to these properties and other characteristics, classic methods mostly can not properly control these systems. The application of classic methods has other disadvantages like partial stability, the necessity to perform sophisticated mathematical operations and complicated implementation.

The implementation of cooling-heating systems by using emotional learning, based on the fuzzy inference system, may be considered as a suitable solution. Use of this learning algorithm not only decreases the cost of control and makes control of that system easier, but it can also readily be applied to cases where the control systems are very large and have a highly complex structure. this method works properly when a system encounter uncertainties.

Flexiblity is one of the important factors of patterns or algorithms which control different systems. Emotional learning patterns, in comparison with other learning patterns such as adaptive network, based on the fuzzy inference system, enjoys more efficiency and more flexibility.

Review of approaches

Because emotional learning is one of the most effective learning patterns in dealing with cooling-heating control systems, this paper uses this algorithm of learning. Emotional learning is based on the neuro fuzzy model by Takagi Sugeno. Neuro fuzzy models create corrective patterns, which present a perceivable learning structure [1, 2]. Takagi Sugeno is one of the pioneers in this field who performed adaptive patterns for the fuzzy inference systems [3]. One of the advantages of Takagi Sugeno's method is that it can be generalized, which is a crucial element in decision making and predictions.

Classic methods of decision making in real situations are often unsuccessful and do not act in an optimum way because of their natural uncertainty. These methods mainly focus on fully rational decision making and optimizing, which in real utilization are not adequate to deal with control systems.

Fuzzy-logic is very effective in applying emotional learning for two reasons:

- Its logical structure against uncertainty existing naturally in systems;
- Reflection of a human's way of thinking in its rules.

Physiological modelling of emotional learning in human's brain according to its nervous system have been helpful to design a more realistic emotional learning pattern. The early calculating models of nervous systems were designed only with the purpose of describing the emotional learning process in human's mind, but they rapidly evolved to be used in the engineering functions of control systems. Applying emotional learning has advantages such as less performing mathematical operation, high speed in calculation and easily meeting different requirements, which makes it into one of the effective methods in controlling and decision making. Also this method is effective at dealing with uncertainties and noise.

The popularity of behavioural approach systems has been increasing in recent years, because of their efficiency in different scientific applications [4, 5]. In complicated physical, economic and social issues which require rational reaction and decision making, other factors like sense and emotion are considered frequently. Therefore, it is obvious that not only feelings and emotions are not necessarily negative but also it is possible to use them in dealing with decision making problems and uncertainties. A multitude of living creatures have used elements like feeling and emotion in their evolution. Some psychologists believe that in some areas like decision making emotions are as important as IQ [6]. These examples indicate the importance of considering the elements such as emotion.

Neuro fuzzy model

Generally there are two main types of fuzzy learnable models:

- Takagi Segno's fuzzy inference system base on neural network;
- Neural fuzzy local linear model.

In this paper due to the generality of its formula, the mathematical model Takagi Sugeno's fuzzy inference system has been adopted

$$Rule_i: \quad If\ u_1 = A_{i1}\ and\ ...\ and\ u_p = A_{ip}, \quad then\ \hat{y} = f_i(u_1, u_2, .., u_p), \tag{1}$$

where i=1, 2,…, M, and M is rule and [$u_1, u_2, .., u_p$] are inputs of the network, (Aij) is input set, (u_j) is rule number j and also $f_i(.)$ is non – fuzzy function which is usually considered as linear form of inputs

$$\hat{y} = w_{i0} + w_{i1}u_1 + ... + w_{ip}u_p. \tag{2}$$

The other form of (2) is

$$\hat{y} = a^T(\underline{u}).W. \tag{3}$$

Therefore, the output of medal is calculated based on following equation

$$\begin{cases} \hat{y} = \dfrac{\sum_{i=1}^{M} f_i(\underline{u})\mu_i(\underline{u})}{\sum_{i=1}^{M} \mu_i(\underline{u})}, \\ \mu_i(\underline{u}) = \prod_{j=1}^{P} \mu_{ij}(u_j), \end{cases} \tag{4}$$

where $\mu_{ij}(u_j)$ is [j_{th}] member function in [i_{th}] rule, and μ_i (u) is correctness degree of $[i_{th}]$ rule.

In optimizing method base on gradient, cost function is used for optimization of parameters

$$J = \frac{1}{N}\sum_{i=1}^{N}\left(y(i) - \hat{y}(i)\right)^2, \tag{5}$$

where N is number of learning data.

One of the main issues which should be considered while learning is extra training which leads to loss of the ability to generalize.

Fuzzy inference system with emotional learning

This method is base on an emotional signal, which represents emotional reaction of individuals towards their environment. A feature of emotional signal is that it can be produced as any combination of elements and limitations leading to improving system control [7].

The cost function is only defined based an emotional signal, furthermore learning algorithms should be designed in such way to decrease the cost function. Then the system would learn to fulfill desire operations in general. If the user emphasizes on some elements or characteristic, it would appear on their emotional signals. The definition of emotional signal profoundly depends on current situation. This signal could be the follower of error, rate of error changes or the other varieties.

The cost function is defined based on emotional signal and one simple form of it could be indicated as following [8, 9]

$$J = \frac{1}{2}k\sum_{i=1}^{N} es(i)^2, \tag{6}$$

where "*es*" is emotional signal.

Learning model weights are adjusted based on non-linear optimization methods such as gradient. By means of gradient method the changing weights equation is obtained as following

$$\Delta w = -\eta\frac{\partial J}{\partial w}, \tag{7}$$

where η is learning rate and it is corresponding with neuro fuzzy controller. The right side of this equation is obtained with the use of chain rule

$$\frac{\partial J}{\partial w} = \frac{\partial J}{\partial es}.\frac{\partial es}{\partial y}.\frac{\partial y}{\partial w}. \tag{8}$$

Referring to (6), the following could be concluded

$$\frac{\partial J}{\partial es} = K.es. \tag{9}$$

Because $f_i(.)$ is linear function of weights, the equation (10) is true

$$\frac{\partial y}{\partial w} = \frac{\sum_{i=1}^{M} u_i\mu_i(\underline{u})}{\sum_{i=1}^{M} \mu_i(\underline{u})}. \tag{10}$$

In most cases it is not easy to calculate $\frac{\partial es}{\partial y}$ remainder. It is the cost to release an emotional signal and also for defining a system with no default. Considering some defaults, however it is possible to calculate this remainder approximately. For example if emotional signal is considered as an error signal, the error might be defined as following

$$e = y_r - y, \qquad (11)$$

where y_r in the equation above is approximate output. Thus the (12) equation would be true.

$$\frac{\partial es}{\partial y} = -\frac{\partial es}{\partial e}. \qquad (12)$$

This equation can fit into equation (8) whit (-1), thus the algorithm just decreases the cost function and does not necessarily optimize it. In the last step weights are updates by the following equation

$$\Delta w = -k.\eta.es.\frac{\sum_{i=1}^{M} u_i \mu_i(\underline{u})}{\sum_{i=1}^{M} \mu_i(\underline{u})}. \qquad (13)$$

Intelligent control of cooling-heating systems

Cooling-heating systems are one of the most significant parts of control system, especially in factories and stores. These places have complicated and dynamic environment and their control system are often uncertain. Therefore, the classic methods of controlling system cannot tolerate high complexity and variability of these sorts of environment; and if they can be implemented, it would contain lots of costs [10].

In this paper a cooling–heating controller system is designed based on emotional learning algorithm. This system contains a temperature isolated chamber which is controlled by two heaters and one cooler [11].

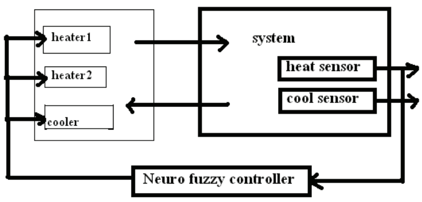


Fig. 1. Heat isolated chamber

The emotional signal is produced by fuzzy inference and including two variants. One variant is error and the other one is derivation of error. Each of these two inputs variants have three member functions. The emotional signal as the critical part contains nine member functions. Emotional fuzzy critical rules are defined based on the method human learn something [12]. Emotional signal defuzzification is based on mean of center method. Figure (2) shows the output based on inputs.

At first matrix parameters are replaced with zero. But after short time, by means of emotional leaning they will reach the appropriate amount. Since the learning steps are on line, learning never stops work as an adaptive controller. Therefore, figure of weight matrix surface after a short time changes as following figures.

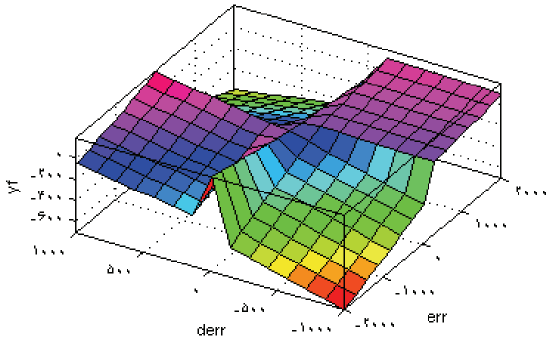


Fig. 2. Fuzzy rule emotional parameter in 3D input

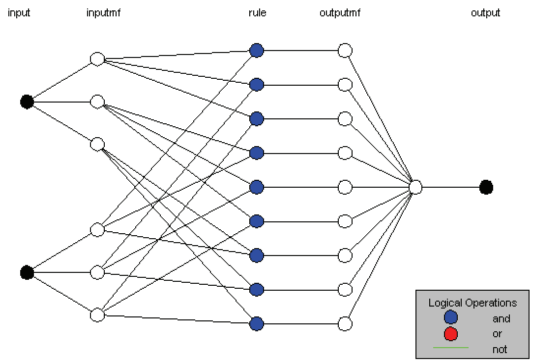
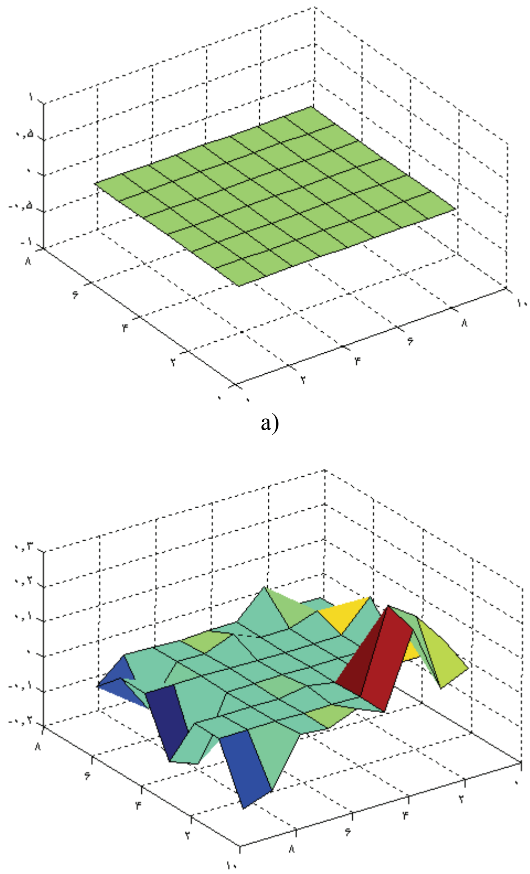


Fig. 3. Neural network structure of fuzzy rule

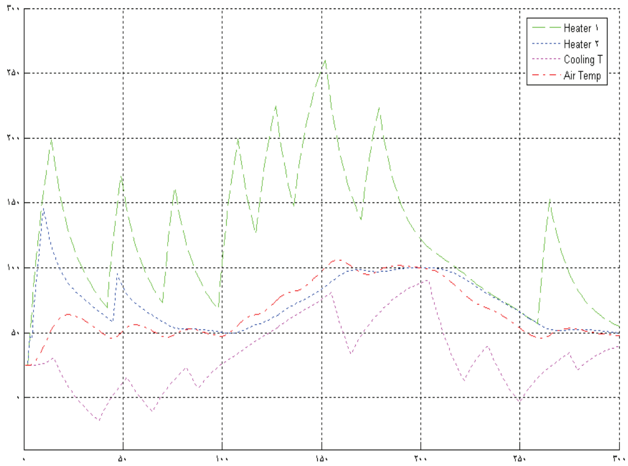


a)

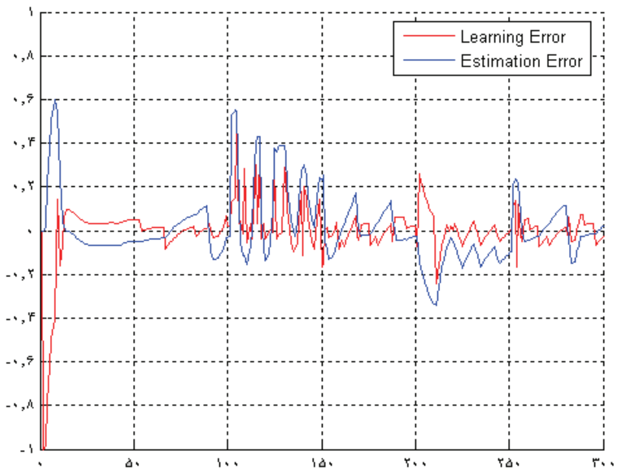
b)

Fig. 4. Weight matrix before learning (a) and weight matrix after learning (b)

The conclusion is that after short period of time the amount of error of approximation and error of learning decrease. Due to high flexibility and variability of emotional learning, the error index would never stay at zero. However, in some cases it remains reasonably close to zero. It would be the cost of eliminating noises, system control adaptability, calculation simplicity and appropriate time response.

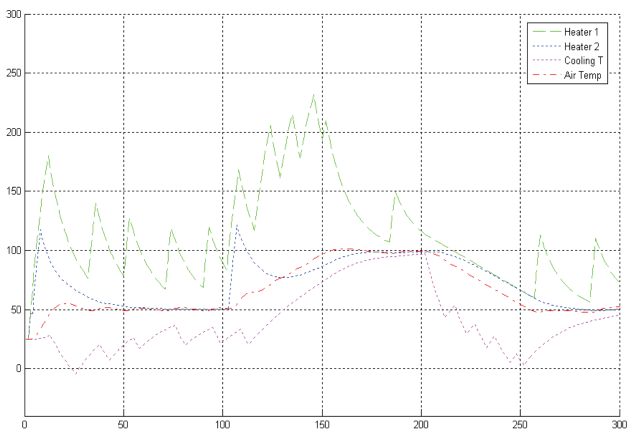


a)

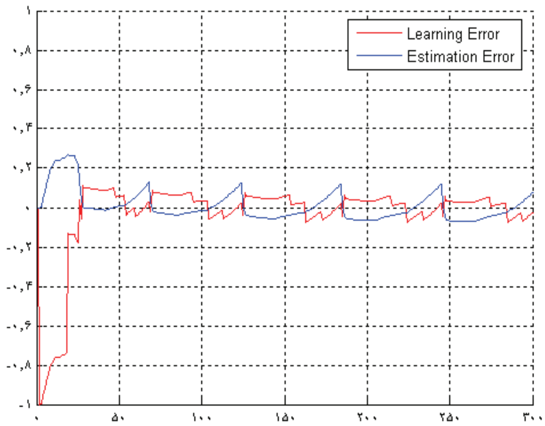


b)

Fig. 5. Learning with no prediction of system situation



a)



b)

Fig. 6. Learning with prediction of system situation

Fig. 6 illustrates that by use prediction, learning error decrease.

Another point which influences error index and system applicability is forecasting future conditions of system, which can lead to remarkable improvements in learning and operation system.

Conclusions

Temperature control is one of the main problems in cooling-heating control systems because of high complexity of these systems and vast variability of parameters. In some papers some method such as PI + FF (Proportional Integral plus Feed Forward) or models like RBF (Radial Basic Function neural network) are suggested.

In this paper emotional learning algorithm is considered as one of the neuro fuzzy learning methods, which is based on Takagi Sugeno's fuzzy inference system.

In control of temperature emotional learning can act better than lots of other methods. In addition forecasting is considered as an efficient factor to improve learning of network.

Comparing this method with other learning patterns such as Adaptive network based an fuzzy inference system, shows more efficiency of this method.

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A. Rezaee, M. Khalil Golpayegani. Intelligent Control of Cooling-Heating Systems by Using Emotional Learning // Electronics and Electrical Engineering. – Kaunas: Technologija, 2012. – No. 4(120). – P. 26–30.

In this paper emotional learning based on neuro fuzzy system by Takagi sugeno is used. High efficiency and proper flexibility of emotional learning are advantages of this learning pattern compare with other learning patterns. Use of this learning algorithm not only decreases the cost of control and makes control of cooling-heating system easier, but it can also readily be applied to cases where the control systems are very large and have a highly complex structure. This paper is about the control of cooling – heating and greenhouse system; which they could be used in agriculture and industry. To use emotional learning causes the quality of products improves. Cooling – heating and greenhouse system because of complicated dynamic structure, high time sensitivity and their natural uncertainty mostly con not be controlled and optimized by classic method. Some disadvantages about classic system are conditional stability**,** the need to performing sophisticated mathematical operations and complication in implementation. Implementation of cooling heating systems by using emotional learning (based on fuzzy inference system) can be considered as a suitable solution. Ill. 6, bibl. 12 (in English; abstracts in English and Lithuanian).

A. Rezaee, M. Khalil Golpayegani. Intelektualus aušinimo-šildymo sistemos valdymas, naudojant emocinį mokymąsi // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 4(120). – P. 26–30.

Šiame darbe panaudotas emocinis mokymasis pagrįstas Takagi Sugeno neuroneraiškiosios logikos sistema. Dėl didelio efektyvumo ir tinkamo lankstumo emocinis mokymasis yra pranašesnis, palyginti su kitais mokymosi modeliais. Naudojant šį mokymosi algoritmą sumažėja valdymo išlaidos ir palengvėja aušinimo-šildymo sistemos valdymas, be to, šis algoritmas lengvai gali būti panaudotas tais atvejais, kai valdymo sistema yra labai didelė ir sudėtinga. Aušinimo-šildymo ir ekologiško namo sistema dėl savo sudėtingos dinaminės struktūros ir natūralaus neapibrėžtumo, negali būti valdoma ir optimizuojama klasikiniu metodu. Aušinimo ir šildymo sistemų, naudojančių emocinį mokymąsi, įdiegimas gali būti laikomas tinkamu sprendimu. Il. 6, bibl. 12 (anglų kalba; santraukos anglų ir lietuvių k.).