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NEURO-FUZZY METHODS IN THE MANAGEMENT OF TECHNICAL SYSTEMS AND OBJECTS

Abstract: *The history of neuro-fuzzy networks begins in the 1990s, 20 century, two approaches to solving creative problems from a separate field were united. These approaches are neural networks and fuzzy logic. There are a huge number of researchers studying the construction and application of neuro-fuzzy methods to solve problems, including managment. This article provides an overview of one of the neuro-fuzzy networks, ANFIS (Adaptive-Network-based Fuzzy Inference System). Its structure, principles of its work, comparison with other neuro-fuzzy networks are considered.*

Keywords: *Neuro-fuzzy networks, ANFIS, Adaptive-Network-based Fuzzy Inference System, intellectual systems, membership function.*

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НЕЙРО-НЕЧЕТКИЕ МЕТОДЫ В УПРАВЛЕНИИ ТЕХНИЧЕСКИМИ СИСТЕМАМИ И ОБЪЕКТАМИ

Аннотация: *История нейро - нечетких сетей начинается в 90-е годы 20 века, когда были объединены два подхода к решению творческих задач из какой – либо отдельной области. Эти подходы - нейросети и нечеткая логика.*

Существует огромное количество исследователей, изучающих построение и применение нейро – нечетких методов для решения задач, в том числе и управления. В данной статье представлен обзор на одну из нейро - нечетких сетей – ANFIS (Adaptive-Network-based Fuzzy Inference System). Рассмотрена ее структура, принципы ее работы, сравнение ее с другими нейро – нечеткими сетями.

Ключевые слова: *Нейро-нечеткие сети, ANFIS, адаптивно-сетевая система нечеткого вывода, интеллектуальные системы, функция принадлежности.*

INTRODUCTION

Many studies in the late 20 century focused on intellectual systems. Such systems include neuro-networks, fuzzy logic, evolutionary algorithms. Many of them in the 21 century were subject to hybridization, which allowed to strengthen advantages and offset disadvantages of individual systems. The purpose of this work is to investigate one such combination – Neuro-fuzzy networks.

The basis for the concept of artificial neural networks appeared when trying to study processes that occur in the brain during activity. The artificial neural network training algorithm was first proposed in 1949 by D. Hebb.

There is a separate variety – neuro-fuzzy networks in the theory of neural networks. They are based on the application of fuzzy logic and artificial neural networks in tandem. This machine is recognized as the most promising for many tasks of intelligent management.

Fuzzy logic is one of the most powerful inventions of the 20century. Fuzzy logic uses state degrees in its set. Unlike classical logic, in which there are only two states of 1 and 0, in fuzzy logic the state falls into the interval [0; 1], that is, there can be both 0.15 and 0.73.

There are neuro-fuzzy models such as:

• Mamdani Model;

• Model Takagi - Sugeno – Kanga.

Based on the TSK model, a popular adaptive neuro-fuzzy output system (ANFIS) is built. The ANFIS architecture consisting of five layers. In detail these layers of neurons will be considered in the main part.

The relevance of the topic is due to the fact that many fields of science and technology have creative tasks with which the person alone cannot solve, which is where neuro-fuzzy methods can help him. They have already been used by researchers in such tasks as drone control and even Bitcoin forecasting etc.

The work addressed such as issue:

• Study the structure of typical neuro-fuzzy network;

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The combination of two methods: neural networks and fuzzy logic allows to collect all advantages of both methods and compensate for disadvantages. These methods included good processing power as well as learning ability. Hybridization also allowed various tasks to be solved using a powerful apparatus of fuzzy logic, the principle of reasoning in which is as close as possible to human reasoning.

In neuro-fuzzy networks, the output is carried out according to the rules of fuzzy logic, and the functions of belonging to which the network operates are adjusted by neural networks. As the topic is booming, researchers apply a variety of methods to teach neuro-unclean networks. These are methods such as ANFIS, genetic algorithms, bee roe algorithm, etc. This article will discuss the ANFIS learning algorithm. The principle of his work is based on the principle of the construction of Takagi-Sugeno reasoning.

Structure of ANFIS:

The ANFIS structure is shown in the figure below:

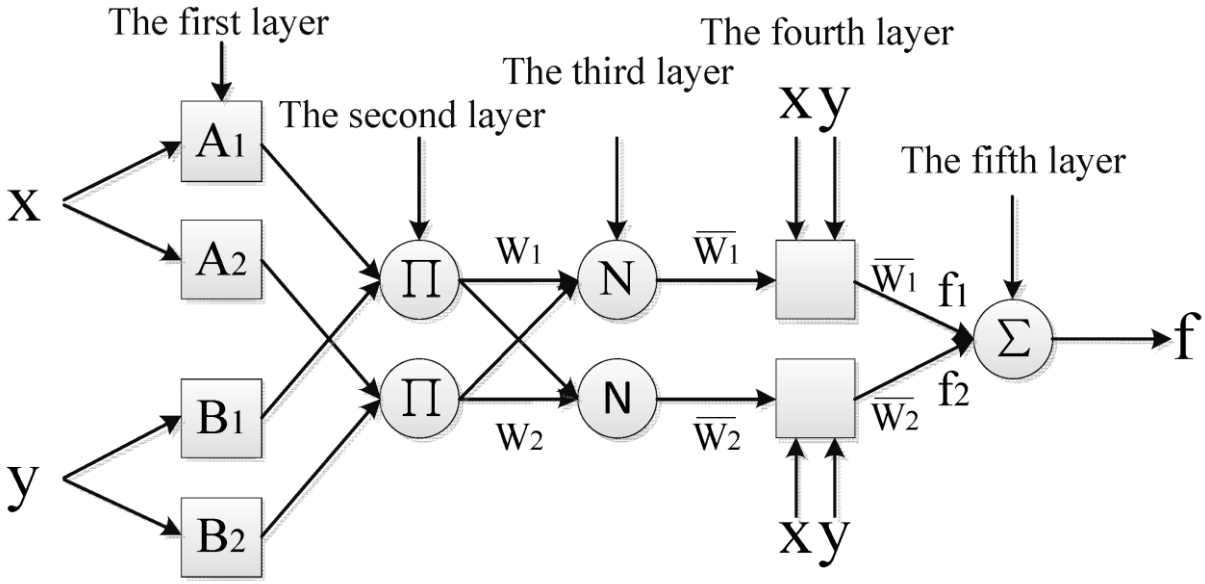

Figure 1. Structure of ANFIS

Briefly, the ANFIS principle of operation can be described as follows: we have a membership function that has basic parameters. The network adapts these basic membership function parameters using learning algorithms that include learning (sample) data.

ANFIS is built on Takagi - Sugeno rules, which look like this:

- If x is A1 and y is B1, then $f1 = c_{11}x + c_{12}y + c_{10}$,

- If x is A2 and y is B2, then $f2 = c_{21}x + c_{22}y + c_{20}$.

The notion we will need to understand the principles of learning and build the structure of neuro-fuzzy networks is a membership function.

Membership function $\mu_A(x) \in [0, 1]$ puts in compliance to each number $x \in X$ from an interval [0.1] characterizing decision belonging degree to a subset A. At creation of function of accessory $\mu_A(x)$ some property, sign or attribute which characterizes some set of objects X is associated with each indistinct set of A. Than more concrete object $x \in X$ has this property, especially is close to 1 corresponding value $\mu_A(x)$. If element $x \in X$ definitely has this property, $\mu_A(x) = 1$ if $x \in X$ definitely has no this property, $\mu_A(x) = 0$.

Describe ANFIS neuro-fuzzy network layers:

1. Each neuron in layer number 1 is adaptable with a parametric activation function, the role of which is performed by the corresponding membership function μ(x) or μ(y). The output of this neuron is the degree to which this input satisfies the membership function, i.e. $\mu_{A1}(x)$, $\mu_{A2}(x)$, $\mu_{B1}(y)$ or $\mu_{B2}(y)$. A typical example of the membership function is a bell-shaped function:

$\mu(x) = \frac{1}{1+|(x-c)/a|^{2b}}$, где {a, b, c} - set of parameters

Changing the values of these parmeters changes the appearance of the bell function. Layer 1 parameters are called condition parameters. This layer is adaptive.

2. Each node in layer 2 is a fixed node whose output is calculated by multiplying all signals arriving at it. The output of each node is the degree of truth of the i-th rule:

$w_i = \mu_{Ai}(x) * \mu_{Bi}(y)$, i = 1,2.

3. Each node in layer 3 is a fixed node that calculates the relationship of the ith rule i-th truth degree and the sum of the truth degrees of all rules.

$\hat{w}_i = \frac{\propto_i}{\propto_1 + \propto_2}$, i = 1,2.

This is how the degree of truth is normalized.

4. Each node in layer 4 is an adaptive layer with an output signal:

$\hat{w}_i f_i = \hat{w}_i (c_{1i}x + c_{i2}y + c_{i0})$, i = 1,2,

Where $\hat{w}_i$ there is a normalized degree of truth obtained from the output of layer 3 and $\{c_{1i}, c_{i2}, c_{i0}\}$ there are a plurality of parameters of this node. The parameters of this layer are called conclusion parameters. The layer is adaptive.

5. Layer 5 is represented by a single node that calculates the sum of its arguments:

$f = \sum_i \hat{w}_i f_i$.

The result of the fuzzy output is calculated. The layer is fixed.

We looked at the structure of the neuro-fuzzy ANFIS network.

The network requires prior training. The first phase of training is self-organization, in it the initial adjustment of parameters of membership functions and

construction of rules base takes place. In the second phase the teacher is trained, in this phase the specified parameters are optimized.

The neuro-fuzzy network ANFIS was created quite a long time ago, but it still has not lost its relevance. ANFIS is used for many optimization tasks and identification of technical systems. For example, it was used to create a microclimate control system in the room, as it was used to control the orientation of the spacecraft.

CONCLUSION

The neuro-fuzzy networks themselves and their applications in various fields are being actively studied. They have great potential in the tasks of technical processes and objects management, in particular in the tasks of identification and diagnostics.

Of course, the article did not address much information about the application of ANFIS, but the study of neuro-fuzzy networks is not in place, so in the future my study of this topic will continue. In future research, I want to understand what other areas of science and technology can be used by neuro-fuzzy networks.

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