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ABSTRACT

A normal fuzzy neural network(NFNN) with five layers is proposed. Focusing on the structure optimization of network, a new node selection method and corresponding back propagation learning algorithm rules are presented In the case with fewer input nodes, the training is more fast in this kind of neural network. Water-flooded zone identification in measure-well explanation is an important problem in the oil field development; especially in its later period. Complex geology conditions lead to many fuzzy characters in measure-well curves. In the combination of all kinds of fuzzy conditions, oil water-flooded behaves as strong water-flooded, middle water-flooded, weak water-flooded and no water-flooded, etc. NFNN is applied to water-flooded identification in oil well measure-well to find its mapping relation between well measure-well and water-flooded level,accordingly realize the water-flooded zone identification in measure-well explanation of fuzzy oil. Test results illustrate its practicability.

PREFACE[1][2]

Fuzzy neural network (FNN) is the combination of fuzzy logic and neural network, the combination of the two makes up for the shortcoming that neural network in fuzzy data process and the disadvantage that pure fuzzy network in learning. At the same time, FNN makes the “black box” question of neural network vitrification, that is, it can realize many cause and effect relations described in rule by neural network’ s input and output. Fuzzy logic’ s obvious advantage is that it can express human’ s logic meanings that often used more natural and more direct, and it is fitter to direct and high knowledge expression. But it is very difficult to express knowledge and procedure changed with time; neural network can realize self-adaptive by learning function, get knowledge automatically expressed by (exact or fuzzy) data. But the knowledge is expressed impliedly in neural network, and it is difficult to know it’ s meanings directly, so we can’ t make semantic explanation directly. We can get the conclusion that both have advantage and disadvantage. It isn’ t difficult to find that their advantage and disadvantage is supplementary each other. That is, fuzzy logic is fit to analysis and design procedure from top to bottom when planning intelligent system, while neural network is fit to improve and perfect system from bottom to top after designed a intelligent system initially. Thus, we can realize advantage mutual benefit by combining them skillfully, that is, one field’ s inherent disadvantage can be equalized by the other field’ s advantage.

Normalized fuzzy neural network (NFNN) is a representative model of FNN, it’ s basic structure can be divided five layers: that is input layer, fuzzy layer, normalized layer, rule layer and anti-fuzzy output layer. The network’ s character is that fuzzy layer, normalized layer and rule layer’ s node number is assured by computing while input and output mode and fuzzy layer’ s subject function is definite. Network ‘ s train modify fuzzy center, square subtract and link weigh value from rule layer to anti-fuzzy output layer.

Water-flooded zone identification of oil field measure-well explanation is a prominent question during petroleum development, particularly during development’ s middle-late period. Complicated geographic condition has many fuzzy character expressed in measure-well curves, oil field water-flooded zone is divided strong water-flooded zone, middle water-flooded zone, weak water-flooded zone and no water-flooded zone under the condition of all fuzzy condition’ s combination. We can extract mapping relation between measure-well curve and water-flood grade by using NFNN to water-flooded zone identification of oil field measure-well explanation, so we can realize water-flooded zone identification’ s automatization and avoid misjudging result from personal factor.

FUZZY RULE’ S DESCRIPTION[2]

Fuzzy logic’ s general rule can be described as:
Rule k: if x_1 is A_{k1}, .., x_n is A_{kn}, then

y_1 is B_{k1} ,…, y_m is B_{km} (or $y_1=b_{k1}$,…, $y_m=b_{km}$)

thereinto, A_{ki} and B_{kj} is U_i and V_j' s fuzzy set respectively, and that $X=(x_1,x_2,\dots,x_n)^T \in U_1 \times U_2 \times \dots \times U_n$ and $Y=(y_1,y_2,\dots,y_m)^T \in V_1 \times V_2 \times \dots \times V_n$ is fuzzy logic system' s input and output. Assuming we have K fuzzy if-then rules. Fuzzy logic system' s numerical value output made up of center average anti-fuzzy generator, product reasoning rules and fuzzy generator has the mode as follows:

$$y_j=\frac{\sum_{k=1}^{K} b_{kj}\left(\prod_{i=1}^{n} m_{A_{ki}}(x_i)\right)}{\sum_{k=1}^{K}\prod_{i=1}^{n} m_{A_{ki}}(x_i)} \tag{1}$$

thereinto, $m_{A_{ki}}$ is fuzzy set A_{ki}' s subject function, we can use Gauss or Sigmiod function.

NORMALIZEDNEURAL NETWORK' S ANALYSISSITUS STRUCTURE

$m_{A_{ki}}$ is subject function of the k-th node of input variable x_i, and assuming x_i has n_i item nodes that used to fuzzy partition, that is input variable x_i' s fuzzy subject function' s number is n_i. So general NFNN structure be described as picture 1:

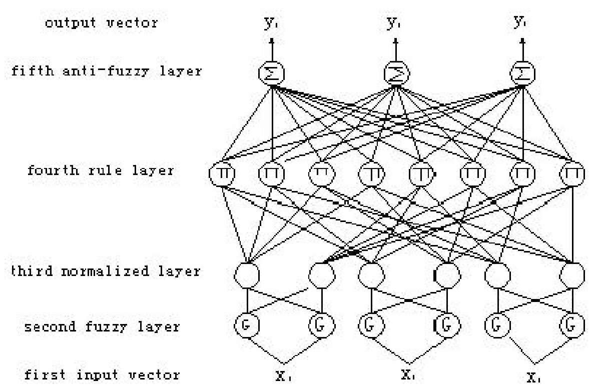

Fig.1 normalized neural network analysissitus structure

First layer: input layer

This layer' s input vector can be exact numerical value vector, also can be fuzzy vector.

Second layer: fuzzy layer

This layer uses Gauss function as subject function, first layer' s the j-th node' s output responding to x_i is:

$$m_{A_{ij}}(x_i)=\exp\left(-\left(\frac{x_i-m_{ij}}{s_{ij}}\right)^2\right) \tag{2}$$

thereinto, m_{ij} and σ_{ij} is A_{ij}' s average value and square subtract, assuming $N=\sum_{i=1}^{n} n_i$, whereas $j=1,2,\dots,n_i$. This layer has N nodes.

Third layer: normalized layer

This layer normalized the first layer' s output. That is:

$$m'_{A_{ij}}(x_i)=\frac{m_{A_{ij}}(x_i)}{\sum_{j=1}^{n_i} m_{A_{ij}}(x_i)} \tag{3}$$

thereinto, $m'_{A_{ij}}(x_i)$ is $m_{A_{ij}}(x_i)$ ' s normalized output. The layer' s node number equals to the second layer' s node number, that is N nodes.

Fourth layer: rule layer

The layer connects premise (normalized node) with conclusion node (output node). The connection' s rule is: every normalized node only connect with a normalized node belongs to the same input node. Thus NFNN network' s initial structure has $K=\prod_i n_i$ normalized nodes.The k-th node' s output is:

$$z_k=\prod_{i=1}^{n} m'_{A_{is}}(x_i) \tag{4}$$

thereinto, $s=s(k,i)$, and $1 \le s \le n_i$. Assuming $n_i=3, n=5$, then $N=3n=15$, $K=3^n=3^5$. If array the second node as follows:

0	0	1	0	0	1	0	0	1	0	0	1	0	0	1

Thereinto,0 shows no connection with fourth layer, 1 shows have connection. Then, from k=1 to $k=3^5$,connection state as follows:

k=1: 001 001 001 001 001 001

k=2: 010 001 001 001 001 001

…

$k=3^5$: 100 100 100 100 100 100

So, we can get the conclusion as follows:

$$k=\sum_{i=1}^{5} s(k,i)3^{i-1}-\sum_{i=1}^{4}3^i \tag{5}$$

thereinto, s(k,i) is decided as follows rule:

1) $$s(k,i)=\left(k+\sum_{j=1}^{4}3^j-\sum_{j=1}^{i-1}s(k,j)3^{j-1}\right)/3^{i-1} \mod 3 \tag{6}$$

2) if s(k,i)=0, then s(k,i)=3

Fifth layer: anti-fuzzy layer

All the fourth layer' s rule node connect with the layer' s output node. The layer finishes center average anti-fuzzy. Assuming the layer has p nodes, output heft j is:

$$y_j=\sum_{k=1}^{K} b_{kj} z_k=\sum_{k=1}^{K} b_{kj}\prod_{i=1}^{n} m'_{A_{isi}}(x_i) \tag{7}$$

NORMALIZED FUZZY NEURAL NETWORK ' S LEARNING ALGORITHM

Using grads decline method to adjust NFNN' s parameters.

Infinitesimal error function is:

$$E = \frac{1}{2}\left\| D - Y \right\|^2 \tag{8}$$

thereinto,Y is NFNN's real output heft, D is expectation output vector.

If w_{ij} is the parameter to be adjusted, study rule is:

$$w_{ij}(t+1) = w_{ij}(t) - \eta \frac{\partial E}{\partial w_{ij}} + \alpha \Delta w_{ij}(t) \tag{9}$$

$$\Delta w_{ij}(t) = w_{ij}(t) - w_{ij}(t-1)$$

thereinto, η is study speed; α is inertia coefficient. Assuming $w_{ij}=b_{ij}$, m_{ij}, and σ_{ij}, we can get:

$$\frac{\partial E}{\partial b_{kj}} = (y_j - d_j) z_k \tag{10}$$

$$\frac{\partial E}{\partial m_{ij}} = \sum_{j'=1}^{p} (y_{j'} - d_{j'}) \sum_{k=1}^{K} b_{kj'} \left(\frac{\delta(j, s(k,i))}{X} - \frac{Y}{X^2} \right) \frac{\partial m_{A_{ij}}(x_i)}{\partial m_{ij}} \tag{11}$$

$$\frac{\partial E}{\partial \sigma_{ij}} = \sum_{j'=1}^{p} (y_{j'} - d_{j'}) \sum_{k=1}^{K} b_{kj'} \left(\frac{\delta(j, s(k,i))}{X} - \frac{Y}{X^2} \right) \frac{\partial m_{A_{ij}}(x_i)}{\partial \sigma_{ij}} \tag{12}$$

thereinto,

$$X = \sum_{j=1}^{n_i} m_{A_{ij}}(x_i) \tag{13}$$

$$Y = m_{A_{i,s(k,i)}}(x_i) \tag{14}$$

$$\frac{\partial m_{A_{ij}}(x_i)}{\partial m_{ij}} = \frac{2(x_i - m_{ij})}{\sigma_{ij}^2} m_{A_{ij}}(x_i) \tag{15}$$

$$\frac{\partial m_{A_{ij}}(x_i)}{\partial \sigma_{ij}} = \frac{2(x_i - m_{ij})^2}{\sigma_{ij}^3} m_{A_{ij}}(x_i) \tag{16}$$

thereinto, $\delta(j, s(k,i)) = \begin{cases} 1, & j = s(k,i) \\ 0, & j \neq s(k,i) \end{cases}$ .We can get NFNN network's update rules if we use equation (10-12) to(9).

WATER FLOODED ZONE IDENTIFICATION[3]

During oil field measure-well explanation, we choose representative five parameters (thick, deep-lateral resistivity,spontaneousness potentio,interval transit time,puny potentio,water-flooded grade) as input by expert experience and test analysis due to measure-well explanation's too many parameters, while output is water-flooded grade. Stylebook gives an example as follows:

thick	Deep lateral Resistivity	spontaneous potentio	interval transit time	Micro electrode	Water flooded grade
0.60	20.000	5.000	150.00	2.500	2.000
0.90	11.000	1.000	280.00	2.000	4.000
0.20	17.000	6.500	148.00	1.400	3.000

Thereinto, water-flooded grade 2, 3, 4 express weak, middle, strong water-flooded zone respectively.

NFNN's analysissitus structure is the model of 5-15-15-243-1, that is 5 input nodes, 15 fuzzy nodes (each input has three subject functions), 15 normalized nodes, 243 rule nodes and 1 output node.

The study procedure of network use the mode of single sample loop to modify the error, that is we can extract one sample to carry out network study random until satisfy the precision of error, then extract another sample…. We can choose 210 samples to train network. Study parameters choose as follows: max study times 30000, study speed 0.7, inertia coefficient 0.5, study precision 0.1(the max warp that each sample's real output and anticipant output). Network train times is 6605 or so actually (each time modify 210 samples until satisfy precision). Study result as follows partly:

Anticipant output	real output	Absolute warp	sort
3	2.9224964	0.0775036	3
2	1.9018251	0.0981749	2
3	2.9108875	0.0891125	3
1	1.0514562	0.0514562	1
4	3.9901506	0.0098494	4
…	…	…	…

We can use the network after studying to other measure-well explanation's water-flooded zone sort identification, identification rate can exceed 84 percent during the same zone block's measure-well explanation identification, we have arrived at some level in water-flooded identification.

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