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THE RESEARCH OF FACTORS NEURAL NETWORK EXPERT SYSTEM OF MINING OPTIMAL DESIGN

Hauling SONG
Fuxin Mining Institute of China

Baozheng SUN
Fuxin Mining Institute of China

ABSTRACT ; This article analyses the properties of the mining design parameters, and indicates that it is not suitable for using the conventional nerve network to decide and optimize mining design parameters, because the mining system works in the stochastic and fuzzy environments and the complexity and particularity of a colliery production. It constructs the factor—space, state—space, and model of knowledge expression of a mining system, puts forward a new method of factor neuron network, suitable for dealing with the random and fuzzy parameters of mining system,in mining design and optimization.

1 INTRODUCTION

1.1 the research outline of the artificial neuron network

Accoding to the neuron structure of the human brain, McCullon and Pitts put forward a neuron model in 1940's. Before long it was used to realize intelligent functions by parallel co-operation between neurons, and formed a network. With the development of the neuron network theory, a kind of fuzzy neuron network was originated in 198O's. After that this research field acquired the tendency to combine neuron networks with fuzzy logic projects, and the factor neuron network theory was born. So the factor neuron network is a new theory and a way for a artificial neuron network.

1. 2 the application of an artificial neuron network in a mining system

Owing to the particularity and complexity of mining production, the diversities of mining geological conditions, and the fuzzy language descriptions of most regulations of assessments and optimizations, the effect of fuzzy and random factors, the construction for knowledge storage becomes more difficult, and is of only typical signification in a limited range. So the applications of neuron network in mining optimal design are in a stage of development, a lot of research has to be done still.

2. FACTOR NEURON AND NETWORK

2. 1 factor neuron (FN)

An information processing unit is called a FN, it needs the fnllowingcondition :

J). unit input

$$X_{ijk}(t) \in \{X_z\} \qquad Z = \{n, s, f\} \tag{1}$$

Xjjk represents number k input of i unit j factor at t time. Xn, Xs, Xf represent the factor — space of one value, fuzzy value and ste value respectively.

2). the regulation of unit dissemination

$$E. = \{Ei_{jk}(t)\} \tag{2}$$

e.-UCEijk) (31

$E_{ijk}(t) = X_{ijk}(t) * W_{ijk}(t)$ (4)

E, is the input strength of i unit, el is the total input strength *IX* is the operator symbol, Eijk(t) and Wijk (t) repersents the correspondent strength and value of „unmber K input of i unit j factor at t time.

* is general operator, $W_{ijk}(t) \in \{X_Z\}, Z=\{n,s,f\}$.

3). unit activation state

$a_i \in \{X_z\}, Z=\{n,s,f\}$ (5)

4). unit threshold function

$T_i \in \{X_z\}, Z=\{n,s,f\}$ (6)

5). unit activation regulation

Acceding to the situation of present unit's state, input strength, threshold, a new state is generated, its form

Js, $a_i(t+1)=m_1(e_i(t),T_i(t),a_i(t))$ (7)

6). unit output

$y_i=m_2(a_i(t),T_i(t)) \in \{X_z\}, Z=\{n,s,f\}$ (8)

7). study regulation

$\triangle T_i = m_3(a_i(t),T_i(t),e_i(t))$ (9)

$\triangle W_{ijk} = m_4(a_i(t),d_i(t),e_i(t))\ m_5(y_i(t),W_{ijk}(t))$ (10)

$\triangle T_i, \triangle W_{ik}$ represent the changing rate of thershold and value respectively. m(.) is matching function, di (t) is a teacher—input of unit Ui.

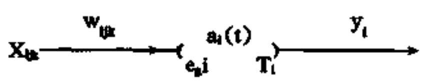

fig 1. principle structure of factor neuron

2. 2 factor neuron network (FNN)

Based on the knowiege factor expression theory, FNN theory divids a whole knowledge system into some stratifing knowledge elements or model—factor neurons, they are made up of the basic concepts and relations, and concect them organically to form FNN. The input of each neuron is the input factor and state, so is the ouput. The independent structure of differentneurons can express the different means. When describing the big conceptwe can construct a set big—factor expression system. When describing the small-concept we can construct a set small—factor expression system. The combinationsof the big and small factor system include the whole factor —space e. g. the mining system. The different factors deal with different ways, suitable for solving the problems of optimization and design in a mining system.

FNN is an information processing system, $FNN = \{F,U,W,T,Q,\sum,P,\delta,\sigma,\alpha,\beta\}$ it must be satisfactory,

1). $U=\{u_i \mid u_i=FN_i\}, |U| \geqslant 2$ (11)

$W=\{W_{ij} \mid W_{ij}$ is the value of u_i to $u_j\}$ (12)

$W: U \times U \rightarrow W$

$(u_i,u_j) \rightarrow W_{ij} \in W$

2). giving the initial state set

$\sum = \{X \mid X$ is any vector satisfying the FNN input$\}$

$\in Q$ (13)

it makes *b*, $\sum \times Q \times W \rightarrow Q$

$(X,q,W) \rightarrow q \in Q$

3) giving the initial state set P, Q and making

$\sigma, Q \times W \times T \rightarrow P$ (14)

$(q,W,T) \rightarrow \sigma(q,W,T) = y \in p$

4) if $\langle X_0, y_0 \rangle$ is a pair of specimen input and output, making

$\alpha, \Sigma \times W \times T \times P \rightarrow W$ (15)

$(X_0,W,T,y_0) \rightarrow \alpha(W) = W \in W$

$\beta, \Sigma \times W \times T \times P \rightarrow T$ (16)

$(X_0,W,T,y_0) \rightarrow \beta(T) = T \in T$

5) the system assessment function n(•), FNN's process state

$qp, qp+1 \in Q$ and $y \in P$ (17)

It satisfies $\max\{n(qp,y)\} \leqslant \max\{n(qp+1,y)\}$, FNi is any neuron structured FNN.

$F=\{f_i \mid f_i$ is FNN's a factor including the recognizable state$\}$

$Q=\{q_i \mid q_i$ is FNN's group$\}$

T= {Ti |Tı is the threshold vector set of corresponding each FNi of FNN).

n is assessment function of a system , it may be Lyapounov function,andnear function too.

So FNN is a serial and parallel, multi — unit, memorial, self—studying information processing system, and reflects the basic properties of the human brain. It is reasonable for us to use FNN as an intelligent system based on the theory of knowledge—factor expression.

3. THE KNOWLEDGE — FACTOR EXPRESSION OF A MINING SYSTEM

3.1 the model of knowledge factor expression

In the space U, the factor expression of knowledge bi M (0) = < 0 , V , X > or M (0 , V , X) , 0 is the object set on the U, V is the factor set in field U, X is the factor—space based V in the field U (Xu(f)mf ÇF, F s U } . the model of knowledge factor expression is a foundation, an object or a fact in field U , it can express a trinal group M(o,V ,X) ,0 is object set, V is a factor set corresponding O in field U, X is the factor—space based on V in field U, {XU(f) f G F , F € V}.

When describing fact, O represents the main object narrated by a proposition, V is its property or relation described, the factor—space X is the concrete state.

When describing a concept, O and V represent its extension and intensionrespectively.X can give it an explanation of volume. The intension of a concrete concept can be projected on some concrete values of each factor state—space,i. e. number value, set value and fuzzy value.

Based on the above analyses, constructing the expression model of a mining system knowledge as follows.

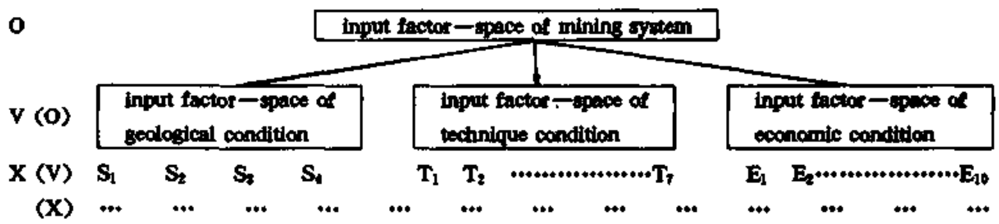

fig. 2 tree structure of mining factor—space

1). factor—space of geological knowledge

G.= {Si,Sj,S,,SoSs,S,}

= {reserves, size of worked area, coal seam condition, geological structure, hydrogeological condition, natural disaster}

2). factor—space of technique condition knowledge

T. = {Tj ,Tj ,Tj ,*Tt* »Ts ,T« ,*Tj}*

= {working system, transport system, ventilation system, hoist system, power system, pumping system, packing system}

3). factor—space of economic condition knowledge

Et= {Ei ,Et ,E> ,E| ,Eg , £ | ,Er ,£> ,E» ,Em}

= {investment, productivity, cost each ton,profits, percentage of recorvery, project volume, constructing period, efficiency, safety, reliability}

We can divide until the basic fact space in detail, where neglected.

3. 2 analyses of knowledge factor expression

The factor network of knowledge expression is a radiating structure. It can express the layer of fact structure clearly and properly. The objects and facts of different properties and strata can be shown by the corresponding factor—space, and reach the destination of determinate classification. At the same time, it is a overlaping and embedded structure, MCO.V (O), X (V), "O* Trimming each branch, we can make a subbranch. That shows the transmitting and inheriting and the least redundancy of knowledge.

The factor—space tree can give some explanations of functions about models of different relations, to realize analysis (classification), synthesis (judgement), project and analogy. When describing analysis, it can be explained as a downward-alternating calculation. When describing synthesis, it can be explained as an upward alternating calculation. When describing analogy, it can be explained as a general alternating caldilation, e. g. same stratum, same group, vice versa.

3. 3. the state value of factor—space in mining system

3. 3.1 the definition for the state of factor—space in mining system

The state sets of factor—space in mining system are compound sets, we quantify every factor, then get their state sets.

Definition 1: design state ste is quantified by the design value of a mining factor—space

Definition 21 working state ste is quantified by the production value of a mining factor—space

The production state set describes a real state of a mining system, e. g. productivity factor, design state ste is its design productivity, working state ste is its output per year.

3. 3. 2 property analyses of the factor state value

Because the variables and factors of a mining system are complex, its factor —space has different values and types.

The basic types are

a. double value state i {a,b}

e. g. C(cutting—machine working state) = {working, shut off } = {0,1}.

b. state of value limited seqenceof number, {X| X,-i,X,eR,i=1,2,-,n}

e. g. X (the number of simultaneously operating working faces)= {1,2,3,4}.

c. continuous value state,[a,b] a,bÇR

e.g. X(output) = {Qmin, — ,Qmax}.

d. interval value state, {["ai.bi] a,,bi£Ri=I, 2,-,n}

e. g. roof classification target j

e. visible function state; the exchange «-Hit.-." of factor variables have relatif «*> :.- T - J ~ii- -', distribution functions.

f. language value state, a description of fuzzy 'v: tor variables.

e. g. coal existence condition = {most stable, more stable, stable, less stable,more unstable, most unstable},

The same factor exists for some corresponding relations among different factor values, they can be exchanged with erch other.

The factor—space value states are unmerical value (a,b,c), set value(d,e) and fuzzy value types.

4. THE REALIZATION AND CHARACTERISTICS OF DIFFERENT FACTOR — SPACE VALUESTATES IN MINING SYSTEM

The FNN of a mining system is mainly made up of above three kinds of factor — space value states. It needs to synthsize their FNN's characteristics to realize.

4.1 construction of numerical value factor neuron

If it satisfies the definition of FN •

$$a(t-(-l)=m(E(t),T_1(t),a(t)) = f(X^W_{1i})6[0,1] \quad (18)$$

Output is y=m(a(t),Tı)=g(a,tı) 6 [0,1],then FN is noe—value neuron, g is a function for classification judgement, and Ti is a classificatory threshold value. This kind neuron has three kinds of forms.

1). (V •. A) form* *. e. (max,min) form

$$f(\bullet) = (Xu,Xtt,-,X,.) \bullet (W_{,,},W,2,-,W_{to})' = (X_t,AW_{(l})V(X_EAW_{12})\ldots V(X_{ta}AW_{ta}) \quad (19)$$

g(•)=near(a,,Ti)

When X is one dimension , and T=a, (V , A) form is min neuron.

2). (A s V) forir>, ı. e. (nun,max) form

$$f(\bullet) = (X_{,,},X_{,2},-,X_{ta}) \,.\, (W_{,1(}W_{12},-,W_{ta})' = (X,,VWII)A(XBVW_{0}).\text{»} A(X\text{»},VW_{to}) \quad (20)$$

g(•)=near(a,,Ti)

Whr; \ r- j.v i'* ;«••• >n, and T=a, (A , V) form _» ;.ux ' ''r .

$$f(\cdot)=(X_{i1},X_{i2},\cdots,X_{in})\cdot(W_{i1},W_{i2},\cdots,W_{in})'$$
$$=(X_{i1}\cdot W_{i1})+(X_{i2}\cdot W_{i2})+\cdots$$
$$+(X_{in}\cdot W_{in}) \quad (21)$$
$$g(\cdot)=near(a_i,T_i)$$
near('","') is a function of nearness degree.

4. 2 construction of set—value factor neuron and network

The input and output state of set—value factor neuron network upgrad form poult to ste, which has a signification to gain knowledge, collect information and recognize modle. Specially in mining system, many classification variables and coefficients are represented by the set value, it is *mare* conformable *to* object practices.

•i 2. ! detonation of set neuron.

$$a(t+1)-m(£(t),T_i(t),a(t))$$
$$\approx 1(X*W)=[a,b]\in P[0,1] \quad (22)$$
cumut i. y —m'(a(t),T_i)=g(a,t_i)∈p[0, i]

adj> — 'ivc state of a neuron at l urnej
Eu"; — toc input strength of a neuron at t timet
T= neuron threshold value,Ti is i kind *nf* threshold*
m(•) — 'Hatching function;
f=state transferring function.
X = {Xi}, W = {Wi}, they are n—dimension input vectors and values respectively.
X1,WiÇP([0,1]), * is the compound operator, y and g are the input and output functions of neuron.

4. 2. 2 forms of set neurons

This kind neuron has three kınıis of forms.

1) (V 、Λ) form:

$$f(X*W)=\bigvee_{i=1}^{n}(X_i\wedge W_i),$$
$$g(\cdot)=near(a_i,T_i) \quad (23)$$

2) (Λ 、V) form:

$$f(X*W)=\bigwedge_{i=1}^{n}(X_i\vee W_i),$$
$$g(\cdot)=near(a_i,T_i) \quad (24)$$

3)(+、•) form:

$$f(X*W)=\sum_{i=1}^{n}X_i\cdot W_i$$
$$=[\sum_{i=1}^{n}X_i'\cdot W_i',\ \sum_{i=1}^{n}X_i''\cdot W_i''] \quad (25)$$
$$g(\cdot)=(a,T_i)=\max_{1\leqslant i\leqslant m}(near(a,T_i))$$

g (•) is m kind function classified by maximum attaching function| near is a function of nearness degree.

4. 2. 3 the realization of FNN

Suppose the front proposition area is X= {Xi ,X2, •••, Xo>, the back proposition field is Y = {yi, y_2, •••, y_m}- If it has the blind degree of front proposition A $A'\in P[0,1]$,e blind degree of back proposition $B\in P([0,1]$ and relation R= {ry},,, ,*B>* =*A'* • $R\in P[0,1], R=\{r_{ij}\}_{nm}=S(X_i\rightarrow Y_i)=[n_{ij},P_{ij}]$.

X_i is used as an input—layer node of FNN, yi is a output—layer node of FNN,Wij=rij, using two layers (V , Λ) form to realize.

This neuron can be used a synthesis of system assessment. When inspecting this complex system, we see it is a cross system, and give its satisfactory degree [$m_£$,ki] (i=1,2,*",n) respectively, mi is the basic

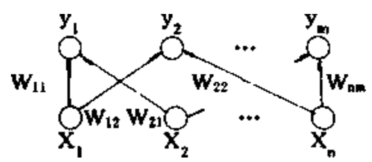

fig. 3 set form FNN

satisfactory degree of expert on i factor , Ki is the most satisfactory degree of expert on ı factor, mi —Ki is the unsatisfactory degree of expert on i tactor. According to the different importance ..: ı.„* ,ı< • system, the different value Wi was g^ivei • .- 0>i ferent operator relations of a factor's real value jud weight construct the i-.'feron 'iropertio s. »•: judge model.

4. 3 construction of fur/ - -'v. factor neuron and

FNN

4. 3.1 definition of fuzzy—value factor neuron

if a neuron satisfies $_t$

$a(t+1)=m(E(t),T(t),$

$a(t))=f(X*Y)=A_i\in F(U)$ (26)

$y=m(a,T_i)=B_i\in F(V).$

X= (Xi ,Xj, ••• ,X„) is an input vector of neuron, Xi is number i input factor variable its value is fuzzy language. Y=(Wi,W$_2$,—,Wn) is value vector of neuron, Wi is number i input value, it may be a fuzzy language value.

* =the compound operator j

F(U)=the fuzzy power set of input variables in basic field U,

$A_i\in F(U)$=fuzzy language value j

F(V) =the fuzzy power set of output variables in basic field V>

$B_i\in F(V)$=fuzzy language value.

This is a general model of n—dimension synthetic judgement of complex systems. We can use this method to inspect a complex system of n factors. First experts assess single factor, and gain the single assessment results XiiXa, •••,X$_{to}$ of N factors, based on these, according to the different values, the value synthetic decision can be worked out.

1) the value — average synthetic decision models;

(+, •) form neuron, $(X*Y)=\sum_{i=1}^{n}(X_i,W_i)$

y=max(near(a,T,)) $1\leqslant i\leqslant m$ (27)

near is naerness degree function.

2). the conservative synthetic decision models in n—dismension complex systems:

$(\vee,\wedge)$ form neuron, $f(X*Y)=\bigvee_{i=1}^{n}(X_i\wedge W_i)$

y=max(near(a,T,)) $1\leqslant i\leqslant m$ (28)

3). the optimistic synthetic decision models in n—dimension complex system $_t$

$(\wedge,\vee)$ form neuron, $f(X*Y)=\bigwedge_{i=1}^{n}(X_i\vee W_i)$

$y=max(near(a,T_i))$ $1\leqslant i\leqslant m$ (29)

5. CONCLUSION

Synthesising the above different forms of FNs, they cover all kinds of ways deciding schemes, and the dealing methods of different properties design parameters, e. g. classification, synthetic judgement eck putting FNs together to make a FNN, some are subFNN, we can solve the whole mining optimal design problems.

FNN is a very new way, this article is its first application to a mining system. The reference [4] gives a detailed application model. I am sure that FNN will become a complete theory and method in mining optimal design.

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