The Sync Tracing Based on Improved Genetic Algorithm Neural Network

Yuanbin Hou, Chunfeng Song, Ning Li
School of Electricity and Control
Xi’an University of Science and Technology
Xi’an 710054, China
houybin@sohu.com, song0729@sina.com, huanglingln@yahoo.com.cn

Abstract—The elevator system is important in nine safety manufacture. Aiming the character of frequent startup and stop with nonlinearity, the sync tracing method based on improved genetic algorithm neural network is presented. Because the condition of the normal adaptation function is too free, the adaptation function is improved, which is the new function altering with input space, then, improved genetic algorithm neural network (IGANN) is established, the IGANN not only avoids getting into local extremum point, but also realizes sync tracing. It is proved by simulation of 400kW assistant elevator in nine, that the sync tracing IGANN is effective for the character of frequent startup and stop with nonlinearity.

Keywords- sync tracing; improved genetic algorithm neural network; safety manufacture; nine elevator

I. INTRODUCTION

The identifying and controlling of the mine key equipment is an important step in safety manufacture. General mine elevator system with nonlinearity consists of a master elevator and an assistant elevator, which starts and stops frequently. In particular the assistant elevator with responsibility for elevating people and equipment will influence directly the safety manufacture in mine. Especially for the problem of the elevator system, the sync tracing method based on improved genetic algorithm neural network (IGANN) is presented in this paper.

Study work of expert mostly include of the genetic algorithm neural network, Improved intelligent genetic algorithm, such as: algorithm neural network model based on coke oven gas collector pressure system[1]; Optimization of thermal stress and deformation of the casting during solidification by neural network and genetic algorithm[2]; Improved intelligent genetic algorithm is applied to the engineering field and the economic field[3][4][5].

Not the search space knowledge or other assistant information, but only the adaptation function is used to evaluate individual and acts heredity in the normal genetic algorithm. But the condition of the adaptation function is too free and difficult to set in genetic algorithm. In sync tracing IGANN, it changes from the adaptation function to the function altering with the system input. On the base the sync tracing method based on improved genetic algorithm neural network is formed, which avoids getting into local extremum and realizes sync tracing.

II.  IGA BASED THE ADAPTATION FUNCTION

A. Presented problem

In traditional genetic algorithm, the adaptation function is given by

\[ f(x) = \begin{cases} C_{max} - g(x) & \text{when } g(x) < C_{max} \\ 0 & \text{others} \end{cases} \]

(1)

In the formula (1), the condition \( C_{max} \) more than objective function \( g(x) \) is more free and difficult to define. The selection result of \( C_{max} \) is different extremely from others’ design, so it is difficult for us to judge which result is the best, even it will introduce random roam and influence directly the action of heredity. Therefor, experts spent lots on the research, and drew the conclusion that the individual competition can be improved by magnifying the value of the corresponding adaptation function. The adjustment of the adaptation function is called scaling. Since the scaling of adaptation function was introduced by De Jong, scaling has been a symbol of competition in the evolution process. The scaling forms are shown as

\[ f_s(x) = af(x) + b \]

(2)

Where \( f_s(x) \) is the adaptation function after scaling, \( a \) and \( b \) can be defined by many ways but it must be satisfied that the original adaptation function \( f(x) \) is the average of the adaptation function \( f_s(x) \) after scaling, or that the max of the adaptation function after scaling is appointed multiple of the original adaptation function. Besides, there are many scaling way of adaptation function, such as truncation scaling and power scaling. The definition and scaling form of all these adaptation functions have some uncertain parameters, such as \( C_{max}, a, b \) and \( \sigma \) to try and confirm many times in practical action of heredity. In particular, \( C_{max} \) is random in genetic algorithm, which brings a lot of trouble for genetic algorithm in engineering application.
B. Improved design of the adaptation function

In order to solve the uncertainty of the adaptation function in traditional genetic algorithm, and make adaptation function \( f(x) \) change with the varying of the input individual, accordingly the adaptation function can be used to estimate individual in reason and more finish selecting, crossing and variance, the improved adaptation function is given by

\[
f(x) = \begin{cases} 
C^* - g(x), & g(x) < C^* \\
0, & \text{otherwise}
\end{cases}
\]

(3)

\[
C^* = \|g_m(x) - E[g(x)]\|_2 + E[g(x)] \\
g_m(x) = \max_{w \in X} g(x)
\]

(4)

Here \( g_m \) is the max of the individual in present input dimension, \( E[g(x)] \) is the average of the \( n \) objective functions. Here \( C^* \) given in formula (4) replaces the current appropriate input \( C_{\text{max}} \) in formula (1). Thus, not only the adaptation function \( f(x) \) is guaranteed for nonnegative value, but also the \( f(x) \) changes with individual’s variety in input space. In genetic algorithm, for an objective function the same result will appear if it is set by different personnel. Consequently, the adaptation function \( f(x) \) may tie down the genetic operation to make it more reasonable.

III. DESIGN OF SYNC TRACING BASED ON IGANN

In the neural learning of back propagation BP, the work should start from the first hidden layer, then second and so on when modifying the weight of each hidden layer and output layer, until the weight of the output layer has been modified. Finally the output of the network is calculated. Consequently BP network is a nonlinear system with lag. If the weight of each layer is put into a matrix in sequence and coded by binary, an individual of genetic colony will be finished. Then the genetic operation, such as crossing, replication, variance will go along according to the improved genetic adaptation function in formula (3) and (4). Thus, the sync tracing based on improved genetic algorithm neural network is realized.

The error from the identification and control with this algorithm is taken as the input of the neural network. To prevent the long individual and complicated computation, single neural cell is adopted to identify and control. The input \( x_j(i) \) is a column vector with three dimensions, namely, \( e(i) \), \( e(i-1) \) and \( e(i-2) \). The weight matrix \( w(i) \), shown as formula (5), is modified by genetic algorithm.

\[
w(i) = \begin{bmatrix} w_1 \ w_2 \ w_3 \ \theta \end{bmatrix}^T
\]

(5)

Here, \( w_1 \ w_2 \ w_3 \) is respectively the weight of the neural network input, \( \theta \) is the threshold.

If the weight is between \([-32, 32]\), each of three weight and threshold may be expressed in five-bit binary. A genetic individual will come into being by connection of them in sequence, which is a serial of binary in twenty bit. The relationship between each character string value of connective weight and practical weight is shown as formula (6), the same as threshold.

\[
w_j(i,j) = w_{\min}(i,j) + \frac{\text{binreplace}(i)}{2^j - 1}] \\
\times[w_{\max}(i,j) - w_{\min}(i,j) + 1]
\]

\[
= -32 + \lfloor a_i / 31 \rfloor \times 65 \quad \text{(6)}
\]

where \( \text{binreplace}(i) \) is decimal according to the five-bit binary standing for the weight or threshold after the genetic operation and is replaced by \( o_i \). The mean square deviation is taken as objective function, namely,

\[
g(x) = g(e) = \frac{1}{2} \times [e(i) - e(i-1)]^2 \quad \text{(5)}
\]

The adaptation function is calculated by the subprogram for the improved adaptation function.

When performing the genetic operation, such as selection, crossing and variance, the probability of inheriting for evaluating each of the weight and threshold is given by

\[
P_i = f(x_i) \sum_{j=1}^{N} f(x_j)
\]

(7)

Where \( N \) is the number of individual in colony, taken \( N \) as 60, then the individual coded in a serial of 20-bit binary is crossed a little. In practical training 60% bigger probability is selected, namely, the front 12 individuals are inherited directly by next generation. The individual, whose probability is less than 0.001, need random variance at arbitrary position in 20 bit. Only a few of individuals are selected to cross, whose probability is more than 0.001 and after 13. After genetic operation, the individuals, 20-bit binary serials, are translated into corresponding weight and threshold according to the formula (6). Then it is prompted by sigmoid function, given by

\[
y_m(i) = \frac{1}{1 + e^{-\text{net}(i)}}
\]

\[
\text{net}(i) = \sum_{j=1}^{3} w_j(i) \times x_j(i) + \theta_j
\]

(8)

where \( y_m(i) \) is the output of the single neural cell, \( \theta_j \) is the threshold of the single neural cell in the \( i \) time genetic operation.

The improved adaptation function given by formula (3) and (4) is used in genetic operation, then the genetic algorithm is integrated with BP neural network. Therefor, the sync tracing method based on IGANN comes into being. This controller not only inherits the merit of good global search from genetic algorithm, but also takes the virtue of
good approach to nonlinearity from neural network. So the controller can be applied in complicated nonlinear multivariate system. The control algorithm may be described as follows\(^3\): 1. Initializing the weight, threshold, back propagated error \(e\), cycle time \(M\). 2. Calculating the output of the neural network according to the formula (8). 3. Transfer the genetic algorithm subprogram of improved adaptation function and modify the weight of neural network according to the formula (6), (7) and genetic operation. 4. Judge whether the back propagated error no more than \(e\), if true, turn to \(5\), if false, turn to \(2\). 5. Judge whether the cycle time is equal to \(M\). If true, turn to \(6\), if false, turn to \(2\). \(6\) finished.

IV. VERIFYING BY EXPERIMENT

A. Normal control and analysis of the elevator

Now there is an assistant elevator system, 400kW/6000 V/66A in a mine. Its time constant of electro-magnetism is \(T_1 = 3s\), and lag time constant of high voltage transducer is \(T_2 = 0.5s\). Filter time constant in back propagated way is \(T_f = 0.08s\), rating rotate speed \(n_r = 1470(r/m).\) After twenty times drive attenuation, practical speed is \(n_{se} = 73(r/m)\). The diameter of roller in elevator system is 2.06m. The open loop transfer function and feedback transfer function can be expressed as

\[
G(s) = \frac{5}{(3s+1)(0.5s+1)}, \quad H(s) = \frac{1}{0.08s+1} \tag{9}
\]

If proportion adjuster is introduced, namely, \(G_c = Kp\) and \(Kp = 0.8, 1.1, 1.4, \ldots, 2.9\), the response curve of steps is obtained, shown as figure 1, where vertical axis stands for rating rotate speed of the elevator.

![Figure 1. The response of steps when \(Kp\) becoming bigger](image)

Shown as figure 1, the overshoot of the system response of steps increases, but the steady error decreases with the proportion coefficient \(Kp\) increasing. The rotate speed is less than \(n_g\) all the time, and the steady error approaches 20% when \(Kp = 0.8\). When \(Kp = 2.9\), the steady error is about 8%, and the overshoot is about 38%. The steady error and overshoot of assistant elevator should both less than 5%, so the safety manufacture is not satisfied with the control system of assistant elevator.

B. The identification and analyse of the assistant elevator based on sync tracing IGANN

Because the time constant of feedback transfer function is less than 1/6 of the other two time constant in the formula (9), it is ignored. The closed loop z transfer function is expressed by

If the system is identified by the algorithm of the sync tracing IGANN, the disperse normalized difference function is given by

\[
c(z) = \left[w(z) - Z^{-1}[w(z)(z^{-1})]\right]
\]

where \(Kp = 2\), \(a_1 = 0.5859\), \(a_2 = -0.1194\), \(v(k)\) is the noise added to the system for simulating the practical disturbance, \(k = 0.3, 0.5, 1, \ldots\) is the amplitude of variable with input \(u\) for simulating the speed of elevator. The noise signal is produced by the instruction of \(randn\) in Matlab. To ensure that the mine elevator run safely, the input voltage \(u\) should be set in seven order for 460 meter deep mine when the elevator works, namely, start and accelerate, crawl, accelerate again, run steady, decelerate, crawl, decelerate again and stop. Now the input voltage is provided according to the front four orders, also the max \(u_{max}\) corresponds to the line speed \(n_{se} = 8(m/s)\) when running steadily. If the formula (10) is regarded as the teacher signal learned by the algorithm of STIGANN, the simulation result is gotten and shown as figure 2.

![Figure 2. The identification result with noise](image)
In the figure, $v_p$ is the teacher signal, the "1" on the vertical axis stands for the speed $n_{se} = 8\, (m/s)$, namely, the steps response $c = v_p$ when running steadily, who acts as start and accelerate, crawl, accelerate again, run steady, until the speed is $n_{se} = 8\, (m/s)$. In the process, $y_m$ is the output of the STIGANN algorithm learning. Show as Figure 2 when the noise is $v_{max}(k) = 10\%u_{max}$, the max error of the identification is 4.1%, and the error is less than 1.2% when accelerating. The errors of the identification of $a_1, a_2$ and alterable amplitude parameters are all less than 4%. The process of the parameter identification and comparison is omitted here because of the poor space.

V. CONCLUSION

After it is analyzed that the mine elevator system runs in safety according to the seven order speed layout, the sync tracing method based on improved genetic algorithm neural network is presented aiming at the nonlinearity of frequent start-stop and variational load. The improved genetic algorithm and BP neural network is fused, so it can search entirely and control in sync. For example, the character of the elevator system, 400Kw, with 10% noise is traced and identified according to the seven orders layout. As a result, the max trace error is 4.1% when speed varying. Comparing with the noiseless trace, the trace error is less than 1% and the error of identification less than 4% when runs with constant speed. The experiment result shows that the precision tracing and identifying with STIGANN is better than with BP neural network. Consequently, it can be popularized for the other nonlinear system.

REFERENCES


