Research on Faults Diagnosis System of an Air to Ground Missile Based on Wavelet Neural Network

Xiaoyu Zhang, Guifang Cai

Department of Aviation Ammunition Engineering, The First Aeronautics College of Air Force，Xinyang,464000,China

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Abstract. The ordinary missile auto-test system has such defects as faults orientation slow, high fault value, database modification hardly and so on. In order to overcome such defects, an faults diagnosis system based on wavelet neural network is designed. The correlative theories of wavelet are introduced, the wavelet neural network structure is analyzed, the network is trained and tested. The tested results illustrate that the system has such advantages as faster execution speed, exact faults orientation, it has widely application foreground.

Introduction

Such kind of air to ground missile has such advantages as far range, high precision, high power and so on, it is an new kind aviation weapon. In order to achieve more excellent capability, the multiple guiding technology, the impetus vector and the pneumatic power multiple control technology are adapted in such kind air to ground missile, so such missile's structure is complex, and it has much more hardware, the faults test and diagnosis difficulty is increased. If the traditional methods are adapted to test such kind missile's faults, the maintenance person must know the correlative knowledge of multiple guide, electric, precise machine, microwave etc, they must have higher theory level and abundant maintenance practice experience, in this way, not only the equipment support difficult is increased, the efficiency of diagnosis and maintenance is decreased, but also when the maintenance persons are changed, the maintenance person quantity will become inadequate, the maintenance level will become lower and the maintenance experience knowledge will be wasted[1,2].

A new kind of faults diagnosis system of an air to ground missile based on wavelet neural network is proposed, the faults of such missile can be located fast and exactly, the maintenance advice can be proposed by building the main capability parameter knowledge bases.

Faults Analysis

Structure of Missile

Such kind air to ground missile is a precision mechanical electrical system[3], it is composed of the guiding system, fuse-battle system, thruster, power system and missile body system. all kinds of guiding information from the target, the missile and the environment are processed by the guiding system; the fuse-battle system is composed of the fuse and the battle part, it is the direct device which is used to attack the target.; the missile's flight power is divided by the thruster, it can make the missile attain the speed and voyage which the flight needs. The power system is composed of the electric power subassembly in missile, the gas power subassembly, the hydraulic pressure subassembly and so on. It is used to provide power for other parts; such above parts are assembled by the missile body system, it must have good pneumatic shape[4].

Missile's Tested Capability Parameters and Faults Types

The typical missile's auto test system frame is shown in the Fig.1.

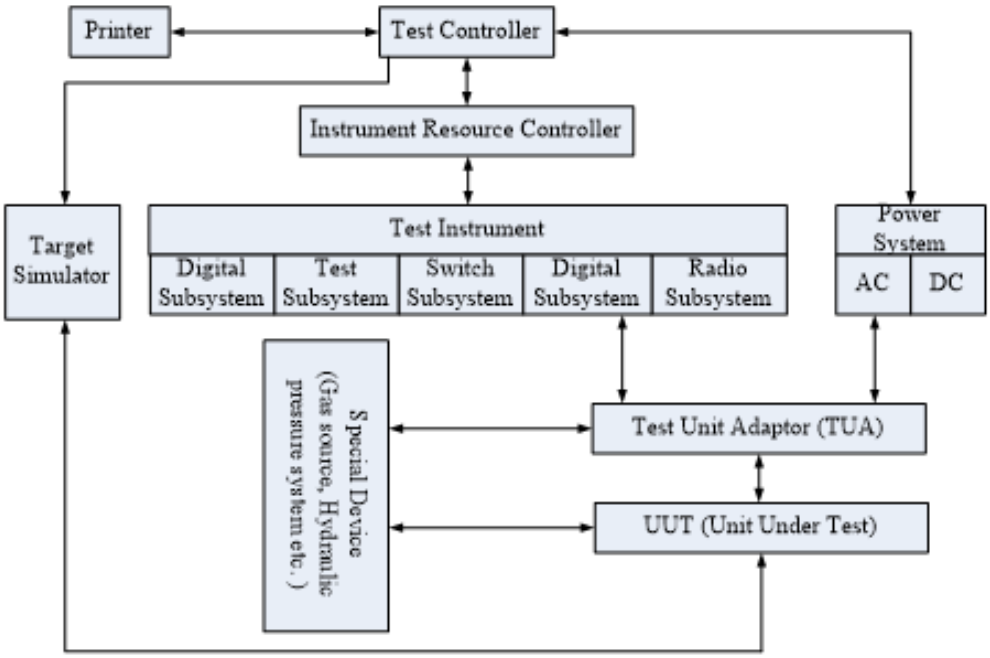

Fig.1: The missile's auto test system frame

When such kind air to ground missile is tested, the main tested capability parameters are as follows. ① Sound Signals. They are used to judge the test capability of missile; ② Peg-top Frequency. It is used to assure the peg-top startup and work normally conditions, then the missile's capability of following up the target can be judged. ③Track Angle-speed and Track Range. They are used to judge the guiding system's track capability and abaxial capability; ④ Moment Parameters. By it the rudder's work conditions can be judged, and the moment parameters can be divided to remain zero moment, zero moment and slope moment; ⑤Delay. By it, the safe devices and uninsured devices work conditions can be judged; ⑥Power Parameters. They include the voltage, current and the power frequency; ⑦Missile's Fuse-battle System Parameters. They are composed of touch fuse circuit, short range fuse circuit and self-destruction fuse circuit; ⑧Ignition Circuit Resistances. They are composed of engine ignition circuit resistances, power ignition circuit resistances and uninsured devices ignition circuit resistances[5].

According to the analysis of the missile's work course and the test capability, the faults are divided into four kinds as follow: test and track faults, fuse –battle and safe circuit faults, flight parameter fault and power parameter fault[6].

The Wavelet Neural Network Construction

Correlative theory of wavelet analysis

The wavelet transform is a new kind of signals transform analysis method, the outstanding feature is that certain features of signals can be extruded abundantly through the math transform. The wavelet transform is a new kind of powerful instrument in the signal analysis region after the Fourier Transform, it not only is use to analyze the smooth signals, and also is used to analyze the mutative Real-timely unsmooth signals[7].

The wavelet is the small wave, the "small" is to say that it has attenuation capability, the "wave" is to say that it is wavy, that is the swing surge form between plus and minus swing.

If $\psi(t)\in L^2(R)$, when the conditions are allowed,

$$\psi(t) \in L^2(R) C_\psi = \int_{-\infty}^{\infty} \frac{|\psi(\omega)|^2}{|\omega|} d\omega < +\infty \tag{1}$$

Then $\psi(t)$ is a radix wavelet function.

To a certain radix wavelet function $\psi(t)$, by operated, a wavelet sequence can be got. For continuous condition, the wavelet sequence is as follows.

$$\psi_{a,b}(t) = |a|^{-\frac{1}{2}}\psi(\frac{t-b}{a}), a,b \in R, a \neq 0 \quad (2)$$

Among it, *a* is flex factor, *b* is parallel motion factor.

If $f(t) \in L^2 R$, then the continuous wavelet transformation of f which is the integral core of $\psi_{a,b}(t)$ is as follows:

$$W_f f(a,b) = \int_{-\infty}^{\infty} f(t)\overline{\psi_{a,b}(t)}dt = |a|^{-\frac{1}{2}}\int_{-\infty}^{\infty} f(t)\overline{\psi(\frac{t-b}{a})}dt$$

The athwart transformation is as follows:

$$f(t) = \frac{1}{C_\psi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(t)\overline{\psi_{a,b}(t)}dt = |a|^{-\frac{1}{2}}\int_{-\infty}^{\infty} f(t)\overline{\psi(\frac{t-b}{a})}dt$$

In actual application, especially carried out by the computer, the continuous wavelet transformation must be dispersed. To the discrete condition, only aim at the continuous measurement factor a and the continuous parallel motion factor b, normally a=a0j, b=ka0jb0, j,k∈Z. For convenience, assume a0>1, then the corresponding discrete wavelet sequence is as follows:

$$\psi_{j,k}(t) = a_0^{-\frac{j}{2}}\psi(\frac{t-ka_0^j b_0}{a_0^j}) = a_0^{-\frac{j}{2}}\psi(a_0^{-j} - kb_0)$$

So the discrete wavelet transformation is as follows:

$$C_{j,k} = \int_{-\infty}^{\infty} f(t)\psi_{j,k}^k(t)dt = \langle f, \psi_{j,k} \rangle$$

The athwart transformation is as follows:

$$f(t) = C\sum_{j=-\infty}^{\infty}\sum_{k=-\infty}^{\infty} C_{j,k}\psi_{j,k}(t)$$

It is attested that ψ(0) is a continuous function, it can be attested that ψ(0)=0 by the limited capability, that is to say:

$$\psi(0) = \int_{-\infty}^{\infty}\psi(t)dt = 0$$

It is illustrated that $\psi(t)$ is a concussive function, and from the equation(1), it is known that $\psi(t)$ is a short wave which attenuate rapidly[8].

Wavelet neural network structure

The wavelet transform is a new kind of signals transform analysis method, the outstanding feature is that certain features of signals can be extruded abundantly through the math transform. The wavelet transform is a new kind of powerful instrument in the signal analysis region after the Fourier Transform, it not only is use to analyze the smooth signals, and also is used to analyze the mutative Real-timely unsmooth signals.

The wavelet neural network structure in this paper is similar to the single cryptically layer BP neural network structure, it can be approached to continuous function in any interzone by any precision, that is to say that it can accomplish any mapping of N~M dimensionality.

According to the grads decline theory, the weight value's metamorphic item Δωkj is in direct proportion to ∂E/∂ωkj, suppose η is a learning efficiency, η is positive number, then:

$$\Delta\omega_{kj} = -\eta\frac{\partial E}{\partial\omega_{kj}} = \eta(O_k^{'} - O_k)O_k(1-O_k)O_j$$

The weight's amendatory equation is as follows:

$$\Delta\omega_{kj}(n+1) = \omega_{kj}(n) + \Delta\omega_{kj}$$

That is to say:

$$\Delta\omega_{kj} = -\eta\frac{\partial E}{\partial\omega_{ji}} = \eta O_j(1-O_j)x_i\sum_{k=1}^{M}(O_k^{'} - O_k)O_k(1-O_k)\omega_{kj}$$

$$\omega_{ji}(n+1) = \omega_{ji}(n) + \Delta\omega_{ji}$$

When the error function E meets the requirement, the knowledge acquirable course of neural

network is over, the inter knowledge bases are built[9].

The faults diagnosis course is divided into two stages, the first stage is the learning stage. Recur to such above learning arithmetic, the variable values which can be used to represent the system's dynamic characteristics, the modeling errors and the interferences are the neural network's input, the corresponding statue codes are expectable output, the input and expectable output samples are got. By training the neural network, the weight and threshold of neural network are confirmed, and they are frozen after learning convergence. The second stage is the faults diagnosis stage. In this stage, the neural network which is trained well is in the anamnestic state, as a certain input, a corresponding output can be produced, the faults can be located easily by comparing the output with the faults codes[10].

Design and Implement of System

The whole system is composed of knowledge base, discursion mechanism, general database, people-machine interface, explaining implement and knowledge edit instrument, the knowledge base and discursion mechanism are the cores of it. The structure of it is shown in the Fig.2.

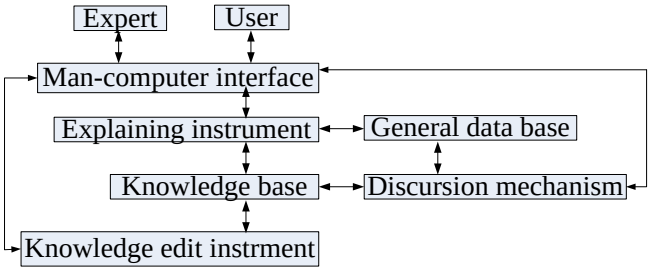

Fig.2: The System structure

When work normally, the ordinary users login and then can only carry on faults query, but when experts login, they can cancel and renew the data of knowledge through the knowledge base edit instrument. The knowledge bases are used to store the expert knowledge of the system, they are achieved from the fault diagnosis expert's experiences and the army equipment service rules; the integrated databases are used to store the faults original data and the middle data which are gained by reasoning. They can provide necessary references for the fault diagnosing of system when data which are tested by missile test system is not enough. The explaining instrument is used to explain the test course of system. In fact, the discursion mechanism is a set of programme which is used to control the system's running, the reasoning and search can be carried on though it by the knowledge of the knowledge base, then the faults diagnosis course is completed[11].

Design of Knowledge Bases

Knowledge bases are the core of the fault diagnosis system, they are stored in the database, the application value of diagnosis system is decided by them. The inner knowledge bases are each layer nerve cell's weight and limen value which are confirmed by training neural network through sample data. The outer knowledge bases are mainly used to save the expert knowledge which is inputted by users, such expert knowledge can be gained from instance knowledge of production time, also can be gained from production rule knowledge which is got from domanial expert or literature data, or may come from mix of above two knowledge. The instance set is divided into sample instance set (data set which is used to train neural network) and diagnosis instance set (record set which is diagnosed by system). When the developmental and timely expert knowledge is needed to express, the expert knowledge is represented by the rule set, when the sample data are abundant and reliable, the expert knowledge is represented by the sample instance set[12].

Normally, it is easy to get the sample instance set, but sample data has many problems such as knowledge expression logical relationship unobvious, inconvenient to express the complicated knowledge and developmental knowledge which includes timely relationship, however the neural network has advantage at the way of dealing with latent knowledge. To the enough and representative sample data, the neural network can be gained such latent knowledge by using itself strong knowledge acquisition capability and account appearance capability, then the defects of

system are amended, the knowledge acquisition bottleneck problems are settled[13].

Design of Discursion Mechanism

The discursion course of system based on wavelet neural network is different from traditional deduction discursion, it is a kind of collateral compute course[14], The neural network computes the input data simultaneously, and the results are inputted the next layer nerve cell, the computability of the same layer nerve cell is not affected each other, the time of searching and matching is shortened, the discursion efficiency is enhanced. Because the fault diagnosis data are completely from the missile's auto-test system, and the data which are needed in diagnosis can be collected, the directivity discursion is adapted. The complete course is as follows: the tested parameters are putted into system by missile's auto-test system, according to the information of knowledge base, the parameters are estimated to be in gear or not. If such component is in fault, the corresponding sub network is carried on. The input data is converted to the feature information on the pre-memory convert matrix, and they are processed compositely. The discursion course based on neural network in fact is the network compute course, according to a certain arithmetic, through the knowledge of neural network, serial compute is carried on between layers until the answers are achieved, at the same time, the explaining instrument is transferred by discursion mechanism to explain the discursion course.

Implement of the system Software

The system software is the important component of some kind air to ground missile auto-test system, it is integrated by fault diagnosis, knowledge records, providing maintenance suggests, assistant teaching. The Windows XP is the development platform of software, VC++ is used as the programmed developed tool, the basic databases are built by using SQI, the programmed flow is established according to the test principles[15].

Application Examples

The familiar faults of some kind air to ground missile guiding head are the diagnosis objects. The fault phenomenon is corresponded to the input nodes, the faults are corresponded to the output nodes. Defining the fault phenomenon is represented by i, j, k, the fault is represented by m. Among them, i represents alternating current signal invalidation, j represents hydraulic pressure instruction invalidation, k represents mechanical signal invalidation, m represents guiding head fault. The latent layer nodes are nine.

When the iterative number is 100, the example samples and the output results are shown in Table 1 and Table 2.

Table 1: Example Samples

i	1	0	1	0	1	0	1	0
j	0	1	0	0	1	0	1	1
k	0	0	1	0	0	1	0	0
m	1	1	1	0	1	1	1	1

Table 2: Training Results

i	1	0	1	0	1	0	1	0
j	0	1	0	0	1	0	1	1
k	0	0	1	0	0	1	0	0
m	0.93	0.96	0.95	0.01	0.97	0.92	0.99	0.94

With the iterative number is increased, the system error becomes lower. When the error range meets the precision requires, the training is stopped and the weight and the limen value are stored in the knowledge base.

Conclusions

According to such above examples, it is known that the wavelet neural network whose wavelet base function is adapted as nerve cell stimulant function is used to build and train fault diagnosis

model, it is applied in some kinds of air to ground missile's fault diagnosis, because of its high mistakes toleration, approaching capability and learning capability, the fault diagnosis efficiency and exactly can be enhanced greatly, it has important significance for the faults diagnosis of such kind of air to ground missile.

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