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A Study of Equipment Fault Forecast System Based on Virtual Setting

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Abstract. Fault forecasting model based on dynamic fuzzy synthetically Judging and five units model of forecasting coefficient are built up, and method of selecting coefficient is made certain. On the other hand, this paper put forward technical disposing method of fault judging result, and discusses method of fault pattern recognition. Based on these all establishes important foundation of theory and technology, this system has been successfully adopted in detection, evaluation, and maintenance of large-caliber gun based on states.

Introduction

Successfully building up and secondary exploitation of virtual prototype have providing well emulation setting of large-caliber gun fault forecasting as well as established the foundation of virtual test and, making exploitation of large-caliber fault forecasting system possible. This paper mostly discusses model construction of fault forecasting system and questions relevant. In the view of software engineering, system modeling is the key work of studying large-scale software. Therefore, fault forecasting model and building up of relevant technology flat play a very important role in exactly forecasting the time, location and mode of large-caliber gun fault.

In the light of mathematics and physics, forecasting means “science foundation of equipment fault forecasting”. It shows that forecasting model is the logic foundation of judging if large-caliber gun fault is happening. According to the definition above, basic rules of building up forecasting model are made certain as followings:(1) According to forecasting target; (2) Adapt to construction coefficient of large-caliber gun and meeting the need of state parameter changing with time. (3) Able to forecasting the capability of whole large-caliber gun and each subsystem.

Forecast model and coefficient confirming

Forecast model. In fault forecasting much historic static data, test measuring data and virtual prototype evaluation data are referred to, including not only fuzzily uncertain information but also real-time and rational information. Therefore, according to basic rules above, a valuable model fit for fuzzy logic inference should meet following conditions.

(1) Adapt to reality. Foundation of forecasting modeling is making full use of all kinds of forecasting information, so fuzzy logic model that can reflect the real capability of equipment system to some degree.

(2) According to the inference rules and easy to compute.

(3) According to the complexity of large-caliber gun, the chosen fuzzy logic model should meet all purposes.

In fuzzy mathematics, fuzzy information transaction technology is a important method of solving questions of uncertain knowledge and fuzzy knowledge quantifying, mostly carrying out through fuzzy distribution which performance form depending on fuzzy variable and character of fuzzy restriction. It can be figured not only by continuous function but also by discrete data in the subsection. Therefore, several definitions must be defined in order to build up a fuzzy logic model fit for fault forecasting inference.

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Definition 1: $U=\{u_1,u_2,\cdots,u_n\}$ is a set of all possible affecting factors, and $V=\{v_1,v_2,\cdots,v_m\}$ is set of all possible fault mode, subjected to $U=\bigcup u_i$ and $u_i \bigcap u_j=\phi$
When $i \neq j$. Besides, each kind of factor can be divided into several subclasses according to objects, namely $u_i=\{u_{i1},u_{i2},\cdots,u_{ip}\}$. n is affecting factor of chief class, m is number of judging level, and p is number of subclasses affecting factors .
Definition 2: Fuzzy relation: In the territory of U and V, fuzzy relation is a fuzzy set of multiplication space $U \times V$, namely the fuzzy relation between affecting factor and fault should change along with equipment serving states. Therefore, after bringing in continuous variable x dynamic membership figure can be established.

$$r_{ij}=\begin{cases}\mu_{v_j}(u_i,v_j,x) & affected \\ 0 & unaffected\end{cases} \tag{1}$$

x is dynamic variable, symbolizing the coefficient of large-caliber gun in the life cycle. For certain question, 0 and 1 signify if affecting factor is relevant to fault.1 means relevant and 0 means irrelevant; for uncertain questions, fuzzy function r_{ij} is used to express, which is among [0, 1]. Each dynamic variable x is relevant to a fuzzy relation matrix.
When a forecasting target includes q dynamic variables, q fuzzy relation matrix is of same rank. To improve the ration of making use of expert experience knowledge and membership function and make certain equipment run safely, dynamic fuzzy relation matrix R is made certain by factor analysis method, namely

$$r_{ij}=r_{ij}^1 \vee r_{ij}^2 \vee \cdots \vee r_{ij}^q \tag{2}$$

Definition 3: $A=(a_1,a_2,\ldots,a_n)$ is a fuzzy subset in U, among which a_i signifies degree how factor u_i affects, namely weight of u_i,while $\sum_{i=1}^{n} a_i=1$. Similarly, $a_i=(a_{i1},a_{i2},\ldots,a_{ip})$ for u_i and $\sum_{j=1}^{p} a_{ij}=1$.
To be external, weight coefficient should react the affecting degree in the whole equipment life circle, but it is hard to obey certain rule for affection among multifactor and multi-fault. If certain factors obey exponent distribution, than weight coefficient of this factor on different condition can be modified by figure (3).

$$c_i=f(t)\cdot a_i=(1-e^{-kx^2})\cdot a_i \tag{3}$$

According to characteristics of equipment fault, large-caliber gun fault in its whole unit life circle can be divided into three phases: wearing away time, tranquilization time and wearing off time. In figure (3), value of k is different for different parts or at different time. For one part the value can be attained by maximum likely method. Similarly, to the affecting factor following other distribution, relevant distribution function is adopted for $f(t)$.

Making c_i unitary and obey $\sum_{i=1}^{n} c_i'=1$, namely $C'=(c_1',c_2',\cdots,c_n')$ is weight coefficient after modified.
Definition 4: Fuzzy Contain: Assuming A and B are fuzzy sets defined in U,V, fuzzy contain signified by $A \to B$ is a special fuzzy relation defined in $U \times V$, whose membership function is defined as $\mu_{A\to B}(u,v)=\mu_A(u)\circ\mu_B(v)$.
Among which $\mu_A(u)\circ\mu_B(v)$ is a synthesizing operation of A and B. According to definition 4, fault forecasting basic model can be attained by synthesizing operation of C' and R.

$$B=C'\circ R \tag{4}$$

$B=(b^1, b^2, b^j, \ldots, b^m)$ is a fuzzy subset in V. Considering all factors' affecting degree, "weighing average type" is recommended to be chosen as synthesizing operator.

Forecast parameter confirming. It can be seen during process of fault forecasting modeling that many forecasting parameters is referred to by judging and forecasting of equipment operation states. Verisimilitude of these parameters is closely related to reliability of forecasting result. In figurer (1) and (3), at least three changeable coefficients are related to modifying function and membership function. It cannot meet the reality need to describe forecasting coefficient by two dimensions structure. On one hand, this paper divides unit life cycle of large-caliber gun into three fault phases. Value of weight modifying function coefficient k is different in different phase; on the other hand, most of large-caliber gun belongs to recovery equipment with many regrouping states. To making sure it run safely, in the same fault mission phase, coefficient of membership function or weight modifying function changes with working mode.

Based on above analysis, five units model of forecasting coefficient is put forward:

F=（ a， b， k， s， p ）,among which （ a， b， k ）signifies value of forecasting coefficient; s signifies regrouping state or work mode of equipment; p signifies fault phase. Since value of a， b， k is of relativity to certain one factor, the five units is called as fuzzy forecasting coefficient net, among which （ a， b， k ）is one of base net.

In three phases of large-caliber gun, each phase is marked by value of certain weight modifying function as table 1.

Table 1 Control command of k value

Phase choosing rule 1	IF p=1 THEN $k=$
Phase choosing rule 2	IF p=2 THEN $k=$
Phase choosing rule 3	IF p=3 THEN $k=$

Suitable choosing of fuzzy forecasting coefficient is important precondition for exactly forecasting running state of equipment. Value of a,b is made certain mainly according to maintenance rules and parts fitting relation of large-caliber gun; value of modifying coefficient k is made certain according to the need of weight modifying function.

Transaction method of fault judging result

Technical transaction of judging result. When there are many fault factors referred to, weight value of each affecting factor is not large. After primary judging of dynamic fuzzy synthetically judging model, otherness s of judging result from forecasting system is little. It is a urgent problem how to transact judging result and transfer reliability data to user or virtual prototype to analyze and evaluate.

According to dynamic fuzzy synthetically judging model, outcome information is a group of fuzzy subsets $B=(b_1,b_2,\cdots,b_m)$ of judging level V. To make sure the objectivity and reliability, four basic transacting rules are put forward:

(1)Identically transforming rule. When there are many affecting factors, weight value of each factor is small. Purpose can be achieved that each affecting factor is rectified through magnifying or contracting weight value by certain suitable non-zero constant multiplied by C'. Primary distribution ration of weight will not be affected since it is identically transforming;

(2) Some zero factors of B are not considered because “zero” means no information outcome. Outcome information of Non-zero element is judged from “level” to “quantity”;

(3) When outcome information clearly concentrates into some item, the one of maximum judging result is chosen as the forecasting result, abandoning other unimportant information with maximum membership degree rule.

(4) When there are many judging levels and judging information concentrating at several choice and value of these choices is much bigger than other choices, system forecasts them at one time and give an alarm after tested by virtual prototype.

Judging of whole work state. Whole work state parameter s of large-caliber gun is closely relevant to all kinds of fault symptoms. Therefore, all kinds of fault are synthesized to make certain the relevant parameter by weighting average rule. Parameter s can be attained by setting b_j as the weight, namely

$$s = \sum_{j=1}^{n} b_j s_j \Big/ \sum_{j=1}^{n} b_j \tag{5}$$

s_j is relevant to the prescribe value s for v_j.

$$s = \sum_{j=1}^{n} b_j^h s_j \Big/ \sum_{j=1}^{n} b_j^h \tag{6}$$

To make clear the most possible fault, parameter s can be attained by weighting average method using power of b_j can be used as weight to judge whole work state of equipment, namely

$$s = \sum_{j=1}^{n} b_j^h s_j \Big/ \sum_{j=1}^{n} b_j^h \tag{7}$$

Value of h can be made certain on condition and generally h=2.
Because judging result has been made unitary, whole work state of large-caliber gun can be described after parameter being divided into levels.

Fault mode recognition and fault reasoning mechanism.

Fault forecasting of gun system mainly includes two parts: one is to forecast potential fault of gun system which has never been failure in service ; The other is to locate fault based on abnormal state, namely making certain which part is failure and forecasting relevant rest life. The whole process of forecasting contains large numbers of historic data, fuzzy information and expert knowledge. Firstly, fault recognition is carried out based on the prototype. Secondly, "qualitative" is closely combined to "quantitative" with evaluation result and other relevant information provided by "virtual prototype". Lastly, capability condition is judged by forecasting and reasoning with method of virtual prototype and fuzzy theory composition to forecast fault symptom, locate failure part and provide maintenance consultation.

Fault mode recognition based on virtual prototype. Potential fault forecast of equipment is carried out through fault diagnosis and virtual prototype evaluation analysis based on capability judging. Evaluation test of virtual prototype can greatly improve real-time of fault forecasting system and play a crucial part on pre-maintenance avoiding fault of germination.

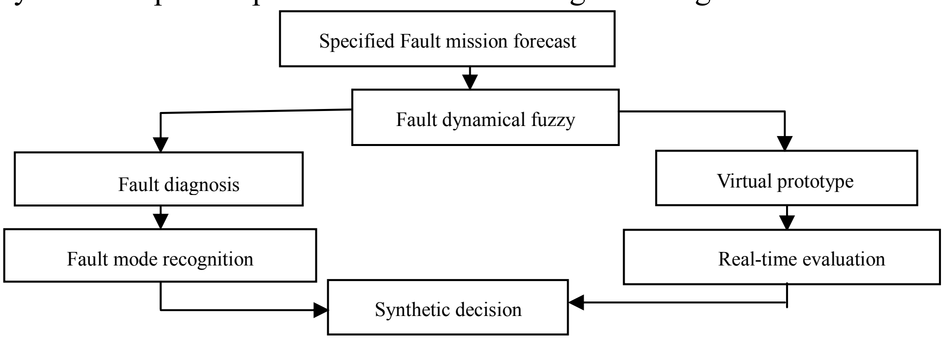

Figure 1 Mode recognition based on virtual prototype

Method of recognition of fuzzy synthetically judging, fault diagnosis and real-time evaluation fuse is described in figure 1. It can be seen from fig 1 that current alarm of fault and relevant fault location are firstly provided by dynamic synthetically judging model and mode recognition is carried out by fusing the expert experience and virtual prototype. Recognition methods are like followings:
(1) Dynamic fuzzy judging model is used to forecast the current of fault symptom to judge the future fault current;
(2) Fault location is carried out by expert diagnosis. In the mean time, forecasting system (server) presents application of synchronization tracking test to virtual prototype (client) to judge fault evaluation;

(3) Client responds for the server to evaluate and compute the character parameter of fault part, attain parameter value immediately and transmit to server through data communication.
(4) Forecasting system make certain fault mode and effect through synthetically diagnosing based on judging rules.

Qualitatively reasoning based on fuzzy judging. In the view of mode recognition, fuzzy reasoning of fault forecasting system is a mode classifier showed as figure 2. Fuzzy relation matrix R_i and weight coefficient set A_i are modes to be classified, and quality state of equipment is relevant to outcome mode of mode classifier.

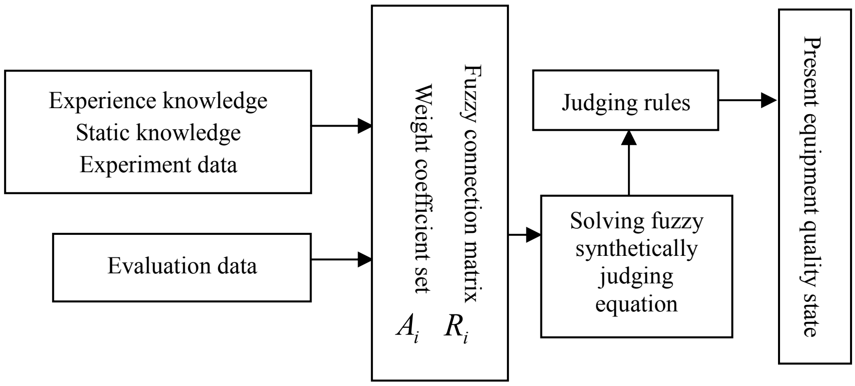

Figure 2 Mode classifier

Summary

This paper studies problem of exploitation and realization of fault forecasting system. The relevant software has been applied on a type of large-caliber gun taking on the mission of state detecting and work state judging. It is a scientific indemnification method with which condition-based maintenance is realized. Low maintenance outlay and high reliability are both guaranteed. Novel idea of this paper for forecasting large-caliber gun fault not only is fit for gun system but also can be extended to heavy equipment such as proper motion gun, missile and so on.

Acknowledgements

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