Maximum Probability Algorithm for Fault Diagnosis

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Abstract

This paper considers the fault diagnosis by outside fault phenomena.The method only depends on experience and statistical data to set up the fuzzy query relationship between the outside phenomena (fault characters) and the fault sources (fault patterns). From this relationship, the most probable fault sources can be located, and the standard fuzzy relationship matrix is stored as database.

Keywords: maximum probability algorithm; fault diagnosis; fault phenomena-sources tree; servo system

1. Introduction

It is difficult to detect and diagnose the faults for non-linear systems, because it is difficult to obtain its accurate state description[1]. And if there is no particular technique is adopted[2], it is always difficult to set up a complicated detection device based on the state description for this kind of systems.

In an actual control system, it is often difficult to find out where the faults are if only based on the outside fault phenomena (fault characters), but what we often obtain are these phenomena. This paper will discuss how to use these fault characters and some points' measurement to locate the fault sources.

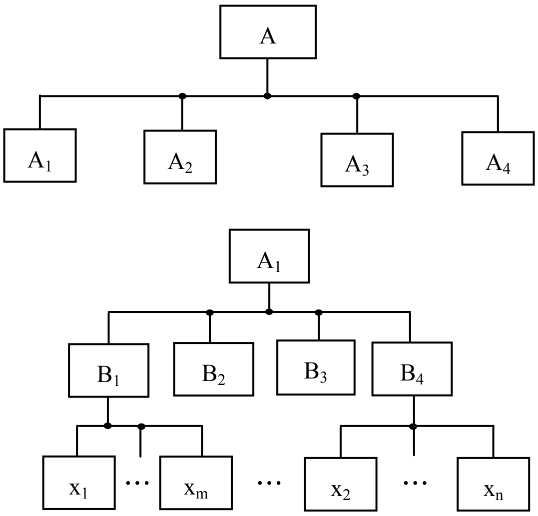
The maximum probability algorithm is based on the theory of fuzzy recognition, has the effect of the expert system. It is to find the position of the most probable fault source that has the maximum fault probability. When the fault occurs, according to the outside phenomena and some points' measurement, all possible fault sources are listed, and they can be examined based on their fault probabilities that are from large to small.

2. Fault phenomena-sources Tree

In an actual control system, there are strong logic bonds between the fault phenomena and the fault sources. The fault tree that describes the system can be built up by verifying the truth and the integrity of this relationship. When the system's fault tree is completed, from which the system's fault phenomena- sources tree (Fig.1) can be obtained.

In Fig.1, A is the top event (the whole system); A_i, B_j are the second and third level events; and x_k are the bottom events (components or the sub-systems).

From the system's fault phenomena-sources tree, the relationship between the system's fault sources and all kinds of fault characters (Table 1.) can be obtained and analyzed. In the paper, there are 14 sensors are mounted on the servo system at the experiment stage[3].



A : system abnormality
A_1: controller cannot rotate
A_2 : system oscillation
A_3 : abnormal noise
A_4 : unsatisfied dynamics

Fig.1 System's fault phenomena-sources tree

3. Fault Diagnosis Approach

When faults occurs, there will be all kinds of fault phenomena, such as x_1, x_2,… The purpose is to diagnose the faults from these outside fault phenomena and some points' measurement results.

3.1. *Fault diagnosis theory*

When one fault state A_i (a sub-system or a component) occurs, it may result in many fault phenomena, such as x_j, designated by x_j =1, otherwise x_j =0.

On the other hand, if a series of fault phenomena X_j ={x_1, x_2,…}, then an array composed of *0,1* for the faulty state of A_i can be achieved.

We want to know, when the fault phenomena X_j ={x_1, x_2,…} occur, how much is the probability that it is the fault state A_i causing these phenomena.

The maximum of this probability $\mu_{Ai}(X_j)$ – the probability that A_i causes these phenomena X_j ={x_1, x_2,…} should be obtained

$$\max_{A_i} \mu_{Ai}(X_j) \qquad i = 1,2,\ldots,n \tag{1}$$

n is the number of fault states.

Thus the maximum value of $\mu_{Ai}(X_j)$ (i=1,2…n) is the maximum probability of the probable fault state.

3.2. $\mu_{Ai}(X_j)$

First, set up a typical fault state A_i, based on the system's fault tree, the corresponding standard fault phenomena (fault characters) X_0^i ={x_{i1}, x_{i2},…x_{ip}}, give each fault character x_{ir} a weight ω_{ir} , then the characteristic parameter that symbols X_0^i results from A_i is

$$P_{Ai}^{\ 0} = \sum_{r=1}^{P} \omega_{ir} x_{ir} \tag{2}$$

where x_{ir} =1 (i=1,2…p), p is the number of fault phenomena that can cause the fault state of A_i (A_i can be obtained from the system's fault tree), ω_{ir} is the weight of x_{ir} in the fault state A_i.

Second, according to a series of fault characters X_j={x_1, x_2,…x_q}, define the parameter that symbols X_j results from A_i is

$$P_{Ai} = \sum_{r=1}^{q} \omega_r \ x_r \tag{3}$$

If x_r (r =1,2…q) is in the X_0^i ={x_{i1}, x_{i2},…x_{ip}}, then x_r=1, $\omega_r = \omega_{ir}$, otherwise ω_r =0.

Then for the obtained fault characters X_j= {x_1,x_2,…x_q}, the probability of all these fault characters result from fault A_i is:

$$\mu_{Ai}(X_j) = P_{Ai} \big/ P_{Ai}^{\ 0} \tag{4}$$

3.3. *Steps*

From the analysis above, the steps of fault diagnosis can be obtained by the following three steps:

(i) Finding: The first step is to analyze and obtain the system's fault sources and all kinds of fault characters.

(ii) Inspection: Obtain the system's fault tree and set up the standard fuzzy relationship matrix of X_0^i-A_i (Table 1.) off-line.

Table 1. Standard fuzzy relationship matrix ($X_0^i - A_i$).

ω_{ir}	X_0^i			
	x_{i1}	x_{i2}	…	x_{ip}
A_1	ω_{11}	ω_{12}	…	ω_{1p}
A_2	ω_{21}	ω_{22}	…	ω_{2p}
:	:	:	:	:
A_i	ω_{i1}	ω_{i2}	…	ω_{ip}
:	:	:	:	:
A_n	ω_{n1}	ω_{n2}	…	ω_{np}

When faults occur, they are identified by using the sampled data. After removing noise signals, the faults can be found according to the maximum probability algorithm by analyzing the fault tree and the fault information on-line.

(iii) Detection, diagnosis and precaution: Give the alarm and the results of the fault diagnosis.

3.4. *The algorithm diagram*

Fig.2 gives the flow chart of the algorithm. And the fault searching steps are as follows:

For the certain relationship between fault phenomena and fault sources, once the phenomena occur, the fault components can be found easily.

For the relationship with fuzzy characters, they are queried based on the method presented in the paper.

All the probable fault sources, which have non-zero fault probabilities, are listed from large to small.

For the unsolved faults, a method for isolating faults is presented.

4. Experiment

Based on the above approach, the software is developed using C language. The standard fuzzy relationship matrix is imported to the computer as a system database.

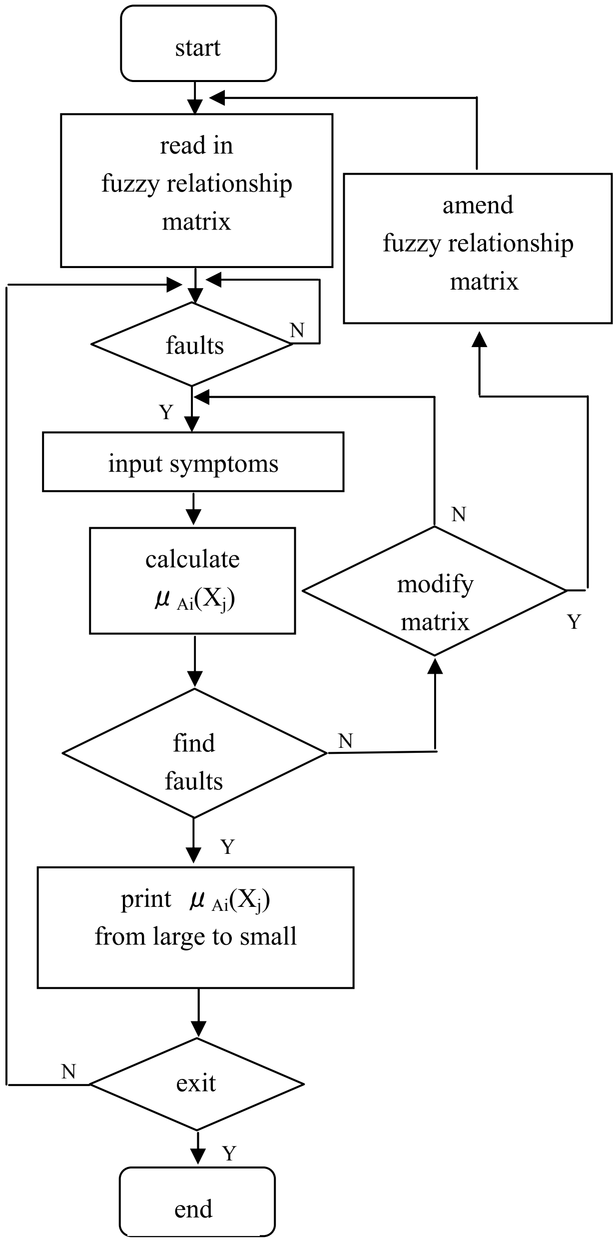


Fig.2 The algorithm diagram

Some faults have been set intentionally, and they all can be detected. The detailed analysis is given by Ref. 4.

For the purpose of detailed explanation, an example is given in Table 2.

Table 2. An example.

ω_{ir}	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8

A_1	1	0	15	5	100	0	2	10
A_2	5	10	100	0	0	2	4	7
…	…	…	…	…	…	…	…	…

If there are symptoms of x_2, x_3, x_4, that is $X_j=\{x_2, x_3, x_4\}$, then

$$\mu_{A1}(X_j)=\frac{0+15+5}{1+0+15+5+100+0+2+10}=0.15,$$

$$\mu_{A2}(X_j)=\frac{10+100+0}{5+10+100+0+0+2+4+7}=0.86.$$

Then from symptoms of x_2, x_3, x_4, the probability that the fault state is A_2 is larger than A_1. Because the weight of x_3 in A_2 is very large, if symptom x_3 happens, the most probable fault state is A_2. Of course this is a simple example, but the principle is the same.

5. Conclusion

Based on experience and statistical data, accurate fuzzy relationship matrix between the outside fault phenomena and fault sources can be identified after a series of training. This relationship can be stored in the computer as a database, and the important parameters can be on-line sampled and analyzed. When faults occur, the faults can be found, alarm is given[5].

One thing worthy of mention is that this method does not provide the exact fault positions, but the maximum probability of fault sources. To detect and diagnose the faults quickly and accurately, the key work is to optimize the X_0^i-A_i standard fuzzy relationship matrix and obtain the perfect weight ω_{ir}.

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