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Research on Optimizing the Fault Diagnosis Strategy of Complex Electronic Equipment

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Abstract. Diagnosis strategy is a testing sequence of the fault detection and isolation. For the distribution of the electronic equipment, a feasible engineering maintenance method is put forward based on the questions of test point selection and diagnosis strategy. The concepts of local diagnosis strategy and global diagnosis strategy are introduced. From which the local optimal diagnosis strategy is determined when the local optimal test points have been introduced by using the test information entropy, furthermore, the global optimal diagnosis strategy is determined by coalescing the local optimal diagnosis strategies. At last, the validity of the method is illustrated by an example from which the conclusion can be drawn that it is an optimal diagnosis strategy and the complexity of computation can be reduced.

Keywords: electronic equipments, dependency matrix, optimizing strategy.

1. Introduction

The modern complex Electronic equipments are made up by some sub-systems which are different from structure to function. The sub-systems are linked by LAN or BUS to achieve the respective functions. Thought the functions and the effects of sub-systems are different, the complexity and distribution are similar to solve the problems in the fault diagnosis. Wang [1] has presented a method for the fault diagnosis modeling of complex electronic equipments, which could achieve the FDR (Fault Detection Ratio) and FIR (Fault Isolation Ratio)effectivelly. The objective of the FDI (Fault Detection and Isolation) is to provide an effective and feasible fault detection sequence for the maintenance personal to locate the fault to the LRU (Line Replaceable Unit) in the maintenance task. So a convenient and feasible fault diagnosis strategy is very important for the maintenance of the equipments.

A multi-signal dependency model is akin to overlaying a set of (single-signal) dependency models on the structural model, and, hence, the model corresponds closely to the schematics of the system. The system fault diagnosis strategy corresponding closely to the schematics of the system is the optimal strategy based on the test point selection and dependency matrix which use the relationship between the components and tests. Tian[2] gives an example to show that test point selection can influence the selection of the fault diagnosis strategy. The objective of the fault diagnosis strategy is to isolate fault with the minimal time and expense. Jing[3] has used the method of information entropy to get the fault diagnosis strategy which used the information of test outcome, test cost and failure rate to get the lowest test cost. But there are thousands of test points, and the size of information entropy of test point which test the same function is not adjacent, the valid diagnosis strategy cannot achieved by using the Jing's methods. Therefore, the optimizing diagnosis strategy is presented.

This paper is organized as follows. In section 2, the basic concepts are presented. In section 3, the structure and function of the electronic equipments are decomposed and then the system global diagnostic strategy by coalescent local diagnostic strategy is generated. In section 4, we apply the optimizing diagnosis strategy to the some electronic equipment, and the simulation results are presented. Finally, the paper concludes with a summary in section 5.

This paper decomposes the structure and function of the electronic equipments, then, generates the system global diagnostic strategy by coalescent local diagnostic strategy.

2. Preliminaries

2.1. Dependency Matrix

The directed graph model captures the first order cause-effect dependencies such as A affects B and B affects C. The global dependencies, such as A affects C, are inferred by the reachability analysis algorithms. Specifically, we need to ascertain which of the failure sources can be observed from each of the tests of the test points, thus enabling us to compute the dependency matrix.

Similarly, a test point may have multiple tests associated with it. In this case, if there are m components and n tests, the dependency matrix (D-matrix) is of size $(m+1)\times n$, where $d_{ij}=1$,if the fault component c_i can be detected by the test t_j; else $d_{ij}=0$. The D-matrix summarizes the diagnostic information of the system and all analysis is performed using this matrix.

2.2. Test Point Optimal Selection

The fault detection is to judge whether fault exists on UUT (Unit Under Test), therefore we should choose the signals which associate more composing unit to test in order that we can use the fewest test to determine whether the fault exists. Suppose that the refined dependency matrix is D=$[d_{ij}]_{m\times n,}$ we can use the following formula to calculate WFD_j (the fault detect weight of the test j),

$$WFD_j = \sum_{i=1}^{m} d_{ij}$$

That is, after calculating WFD_j weight of each test, choose the test with the maximum weight as priority test when fault detecting. Dividing the dependency matrix into two parts with corresponding column matrix, we gain two sub-matrixes. According to the test result, we choose the test which has the biggest weight in the sub-matrix as the second test, then repeat above-mentioned process until there is not column matrix any more.

Fault isolation is a process which isolates fault to the LRU, the process of test point selection for fault isolation is similar to the process for fault detection. Please refer to the reference[4]。

Making diagnosing strategy is based on test's optimal selecting outcome. When the state of UUT is unknown, we select optimal test for fault detection first, if it passes, continue to do optimal test; if it doesn't pass, switch to fault isolation process. Repeating above-mentioned process in turn until the fault detection and isolation finish, we will get a fault tree finally.

3. Optimizing Fault Diagnosis Strategy

3.1. Method of Decomposition for Electronic Equipment Diagnosis

Modern electronic equipment has hierarchical structure, the characteristic of system structure bring the hierarchical faults. Hierarchical fault strategy was generated by adopting hierarchical fault diagnosis, ultimate purpose of which is to isolate fault to LRU effectively, let the technician use these results to isolate the abnormal components. Therefore decomposition system is important.

Systematic decomposition principle is that the subsystem function is clear and the coupling between the function is little as much as possible, so that common component was called little. Generally speaking, Structure decomposition was used in coarse granularity, while function decomposition was used in fine granularity, which was coincide with the thought of designing the embedded system.

In this paper the structure decomposition (Fig. 1.), the function decomposition (Fig. 2.) is carrying out to decompose electronic equipments. Structure decomposition is to division system on structure until the lowest component, based on which we can precisely locate the fault to the physics place.

The function decomposition is to division system function to the sub-function, from which we can get the basic function. Based on above decomposition, the diagnosis strategy algorithm can only search space which contains some components relevant to that function.

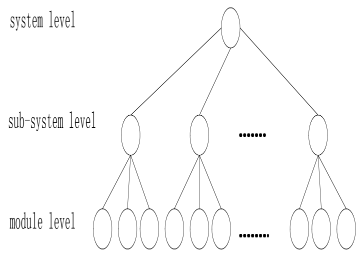

Fig. 1. Structure decomposition

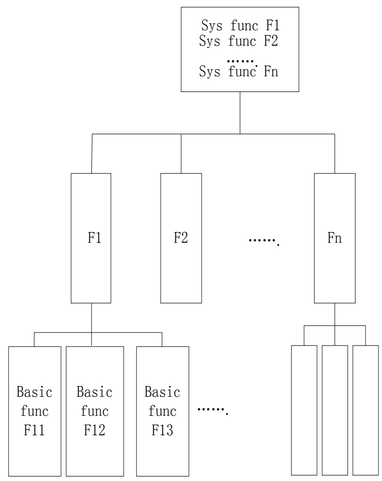

Fig. 2. Function decomposition

3.2. Global Diagnosis Strategies

Hypothesis 1: Regular signal behavior is dependent on all components normally, if any component behavior is abnormal then the signal is abnormal.

Hypothesis 2: 1) the signal of relevant to the function is only limited to the correlative component. 2) the relationship between different signals is uncorrelated.

Definition 1: Local diagnosis strategy (LDS): A diagnosis and isolation sequence for all the components to realize certain function.

Definition 2: Global diagnosis strategy (GDS): A diagnosis and isolation sequence for a certain system

Local diagnosis strategy is a binary tree: the left branch indicates that the test pass, the new binary tree was deployed by selecting the optimum test point for the fault detection, until all the tests pass, which indicates that system is fault-free; the right branch indicates that the test fails, the new binary tree was deployed by selecting the optimum test point for the fault isolation, until all the faults can be isolated. Test point for the fault detection and the fault isolation in the local diagnosis strategy are columns of the local dependency matrix.

In this paper, components partition is two parts: private component and common component; while the private component is contained only in a function, the common component contains in at least two functions. Private component sets may be further divided into sub private component belonging to the different function.

Hypothesis 3: There are N functions in the electronic equipment. There is not coupling between every function, and each function does not share the components. That is: all components in equipment are private components.

The global diagnosis strategy algorithm as follows: if the probabilistic influence for components failure is not considered, and there is not priority for FDI, then any Local diagnosis strategy can be adopted. Form which we can make the root node of the binary tree of local diagnosis strategy as the root node of the global diagnosis strategy algorithm; when all tests in this local D-matrix pass, the root node of the binary tree of the other local diagnosis strategy can be seen as the next node of left branching leaf node of the binary tree of global diagnosis strategy; after all fault may be isolated, the root node of the binary tree of the other local diagnosis strategy can be seen as the next node of right branching leaf node of the binary tree of global diagnosis strategy; Repeating above-mentioned process, until the global diagnosis strategy is formed.

4. Application

Certain equipment is analyzed by the multi-signal model using the TEAMS software [6]. Equipment has functions such as current supply, information display and information processing. From which the functions of current supply and information display are used to illustrate the validity of the method.

The modeling process for the equipment can be got from the Wang[1]. Modeling analysis for the equipment is to get the testability analysis and assessment of the BIT capability. For locating fault more precisely, more test means and test equipment should be needed.

After analyzing and assessing the modeling, the fault diagnosis strategy was generated. When not taking into account local diagnosis strategy, fault diagnosis strategy of the equipment is generated directly. Fault diagnosis strategy of power supply is discontinuous nodes in the global strategy，it is not instructional meaning for maintaining the power supply.

After carrying out structure and the function partition on equipment, adopting local diagnosis strategy, (the fault diagnosis strategy is as follows,

Fig.3.) It is a whole diagnosis strategy.(Fig.3(b). and Fig.3(c). is respectively the right branch and the left branch for the Fig.3(a). in proper order.)For maintenance personal, it is convenient to locate the fault.

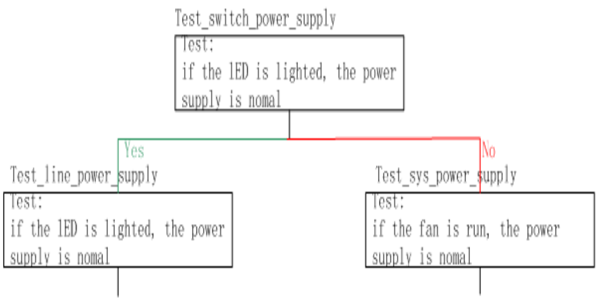

Fig. 3(a). The root node of power supply diagnosis strategy

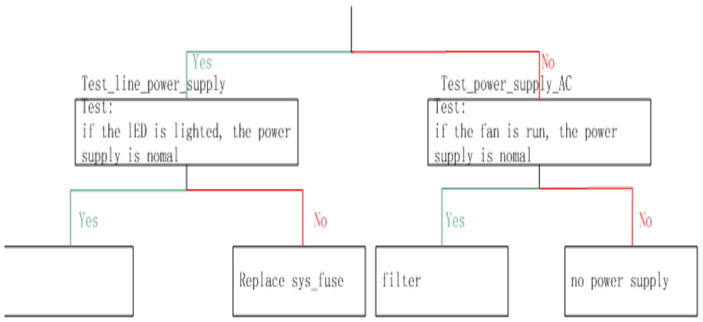

Fig. 3(b). The right branch of power supply diagnosis strategy (Fig. 3(a).the right successive node)

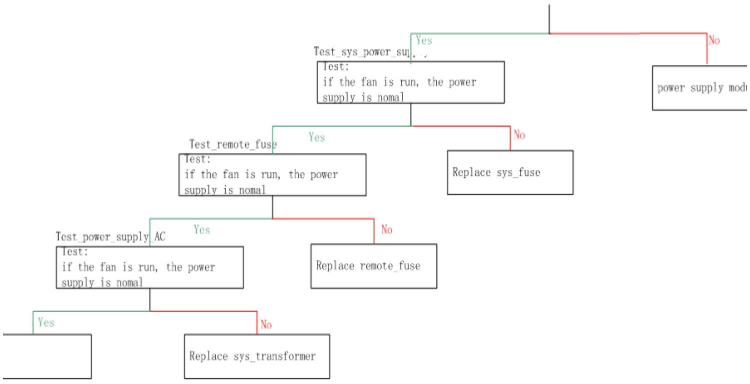

Fig. 3(c). The left branch of power supply diagnosis strategy (Fig. 3(a).the left successive node)

Fig. 3. Power supply diagnosis strategy with local diagnosis strategy

Assume that a complicated electronic equipment has M independent mutually functions, each of which is composed of N different components, furthermore, each function doesn't share the common component. For this system, using the multi-signal model and sorting the test according to information entropy, faults can not be detected and isolated, if the adjacent test is test different functions, the faults can not be detected and isolated. If the diagnosis strategy got from this paper is adopted, the test independent with the function is not called. The computational and storage complexity can be reduced by the optimal and near-optimal test sequencing algorithms for the fault diagnosis strategy.

5. Conclusion

For the distributing of electronic equipment, introducing local diagnosis strategy and adopting appropriate search algorithm, so the global diagnosis strategy is formed. The validity of the method is illustrated by an example from which the conclusion can be drawn that it is an optimal diagnosis strategy which can prove the diagnosticability and maintainability, meanwhile the complexity of computation can be reduced. But if the equipment contain common component in its structure, the extension for the search space should be considered in the following study.

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