Knowledge aided expert system for failure analysis of electronic components

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Abstract. Aiming at the importance of failure analysis of electronic components, the complexity of the knowledge system and the high dependence of experts, this paper conducts in-depth research on the application of expert systems. According to the characteristics of component failure analysis, the reasoning fault tree analysis engine is innovatively designed, and the active knowledge assistant technology is introduced to assist analysts to obtain failure mechanism information in real time. The low threshold and high output of failure analysis of electronic components are realized, which fills the gap at home and abroad.

1. Introduction
After the development, production and even delivery of electronic components, various quality problems often occur, resulting in partial or complete failure of the product functions, so quality analysis or quality return to zero is required.

Failure analysis can find the failure mode, determine the failure mechanism, and feed back to the production process, so as to improve the reliability of components rapidly. For example, the failure rate of integrated circuit of missile guidance computer in the United States has decreased from 0.07% / 1000h in six years to 0.0008% / 1000h in six years. The failure rate has been reduced by two orders of magnitude, and the cost has been gradually reduced [1].

In the past, there was no purpose in data accumulation, so when there were problems of quality, experts should be organized to discuss and analyze, form a fault tree, and analyze and eliminate each event. At the same time, the failure mechanism is not clear, experts cannot be on site in time or the technical personnel experience is not enough and so on.

If the previous failure cases, experience, mechanism are sorted out and summarized to form an intelligent auxiliary system for failure analysis, once problems occur, it can be quickly compared and analyzed, so as to significantly improve the efficiency of problem solving and avoid the impact of failure problems. Failure can be avoided intelligently and effectively in the production stage [2].
The earliest research on the expert system was initiated by Feigenbaum, Lederberg, Shortliffe and Buchanan of Stanford University in the early 1970s. At present, the more mature expert systems in the world include EMYCIN and prospector. The research of expert system in China started late, and it began to develop vigorously in the 1990s. For example, the expert system for crop pest prediction developed by China Agricultural University has been widely used, but it has not been applied in the field of electronic components [3].

2. Failure analysis of electronic components

Failure analysis is a necessary link of product quality management, a technical guarantee of safety engineering, a guiding basis for product maintenance, and a theoretical basis for realizing multi life cycle. It has significant social and economic benefits. For higher and higher integrated chips, any failure point can lead to its scrapping. At this time, the failure analysis personnel must have comprehensive and solid professional knowledge, master the necessary analysis methods and destructive analysis experience, so as to find out the key problems, put forward reasonable suggestions, improve the technology, and improve the yield.

Failure analysis is a detailed work and should be carried out step by step in a planned way

1) Determine the failure mode and establish a preliminary guess based on the observed events and effects to determine which phenomena are examples of failures.

2) Through the style, size, condition, color, chemical composition, physical structure, etc., understand the fault phenomenon and experience, determine the fault characteristics, and explain the physical characteristics and other factors of the relevant fault parts.

3) According to the theory and experience of material properties and manufacturing process, the possible causes of failure are analyzed. For example, the short circuit caused by oxide layer in integrated circuit may be caused by pinhole of oxide layer, mechanical scar of oxide layer, poor dielectric strength and thin oxide layer.

4) The above hypothesis is verified by experiments.

3. Design of expert system for failure analysis of electronic components

The expert system for failure analysis of electronic components first investigates and analyzes the needs of users for failure analysis of electronic components, and then builds a basic framework combining with the experience of experts in the field, literature and other information, and establishes the database, data warehouse, knowledge base, reasoning engine, etc., forming the prototype of the system and improving it iteratively.

3.1. Knowledge base establishment

There are three ways to acquire failure analysis knowledge:

1) Manual acquisition: the failure analysis knowledge of component experts is mined, analyzed, sorted and summarized, and stored in the knowledge base.

2) Semi-automatic acquisition: use knowledge acquisition system to help failure analysis experts mine and summarize knowledge by asking questions and guiding, and record them into the knowledge base.

3) Automatic acquisition: automatic acquisition of knowledge through the system's own mechanism or special machine learning system.

According to the characteristics of various knowledge sources, the system takes professional books of failure analysis as the main source, network information as supplement, and finally refined and corrected by experts, so as to obtain the most accurate knowledge and store it in the knowledge base.

The failure of the system can be expressed in the form of expert knowledge. The system combines the characteristics of various failure analysis knowledge of electronic components and the advantages and disadvantages of the following kinds of representation methods, and also uses a variety of representation methods to store failure analysis knowledge [4].
1) Predicate logic representation: predicate logic is close to human language, easy to store and can be processed accurately. It is suitable for expressing factual knowledge and rules. However, there are some limitations: it cannot express uncertain knowledge; it may form combinatorial explosion, the reasoning process is cumbersome and inefficient.

2) Generative representation: it is applicable to the knowledge that represents the causal relationship. Because the rules have the same form, it is convenient to modularize the rule base, and it is easy to handle when adding, deleting or modifying the knowledge. However, it cannot express structural knowledge and its efficiency is not high enough.

3) Semantic network representation: this method represents knowledge through concepts or semantic relations, which is suitable for expressing structural knowledge with strong expression ability and natural way. Its deficiency lies in the lack of a strict representation system, and there may be ambiguities.

4) Frame representation: this method supports information sharing and conceptual abstraction, and is also suitable for representing structural knowledge, but not for procedural knowledge.

5) Object oriented representation: this method has inheritance, encapsulation, polymorphism, modularity, and is easy to maintain, which is suitable for the development of large knowledge base.

3.2. Design of reasoning engine
Fault tree analysis (FTA) is a traditional failure analysis method, which is widely used in various fields. However, the traditional fault tree analysis method ignores the logic level and priority of the analysis and reasoning process. It is only suitable for experts to discuss and analyze, but not suitable for the expert system of computer operation. Therefore, the system innovatively designs the reasoning fault tree analysis method, redesigns the traditional fault tree analysis process and analysis logic.

The establishment of fault tree for electronic component failure reasoning analysis is shown in Figure 1. Selecting failure mode as the first level event. Generally, it is a common failure mode of components. Then, according to different failure modes, the possible causes of failure are analyzed, the targeted failure analysis sequence is specified, and the failure analysis method is taken as the second level event. Through the analysis method, the failure cause is found, the failure mode is analyzed, and the failure mechanism is regarded as the third level event.
Finally, it is necessary to refine the design of the inference engine, make reasoning according to the corresponding control strategy and reasoning method, and get the answer to the problem. In this system, the reasoning process is forward reasoning. The order of each method is deduced by the inference engine, and then executed by the interpretation actuator according to the order. The reasoning process is as follows:

In the first step, the user input the failure background to be analyzed.

In the second step, the system stores the known facts and matches them with the rules in the knowledge base. If the matching fails, check whether it is a new rule; if it is a new rule, add new knowledge; if not, it means input error and end reasoning; if the matching is successful, call the corresponding rule to form the rule set.

The third step is to call the corresponding reasoning method to carry out reasoning.

In the fourth step, the user determines whether the reasoning result is reasonable, and if so, the reasoning ends.

In the fifth step, if it is not reasonable, then input the query information again for the second time.

4. Knowledge aided design for failure analysis of electronic components

The knowledge structure of failure analysis of electronic components is very complex and difficult to master. In addition to failure analysis by using failure analysis expert system, failure analysis engineers need to use intelligent technology to help them make up for the knowledge points needed by failure analysis. Therefore, this paper designs an active knowledge aided system for failure analysis engineers to promote the application of failure analysis in related enterprises, reduce the investment in personnel training, and improve economic benefits [5].

The system has the following characteristics

1) It can provide the engineers with the required knowledge of failure analysis without user pre-learning.
2) The knowledge provided matches with the needs of users.
3) Knowledge assisted process is fast and efficient.

According to the requirements of expert system and active knowledge assistance for failure analysis knowledge and cases, the knowledge architecture of the system is designed as four layers:

1) Knowledge source layer: it contains all failure analysis knowledge of electronic components, including failure knowledge, expert auxiliary knowledge and failure cases.

2) Knowledge storage layer: the original data must be processed and transformed into a form that can be recognized by human beings.

3) Knowledge processing layer: it is mainly to receive tasks, analyze, generate personalized knowledge demand model, search for matching knowledge in the knowledge base and process to obtain personalized knowledge.

4) Human computer interaction layer: this layer is mainly to identify the information input by the user and transform it into a form that can be recognized by the system, and display the interpretation made by the system to the user. The client subsystem is divided into two functional modules, including six categories of electronic components. Users can choose according to the task.

5. Realization of knowledge aided expert system for failure analysis of electronic components

Based on the cross research of expert system technology and active knowledge assistant technology, this paper designs and implements the knowledge aided expert system for failure analysis of electronic components. The system structure is shown in Figure 2. Users can analyze failure cases in an all-round way through the functions of sequence analysis, user-defined analysis, knowledge assistance and case demonstration. The knowledge aided interface and sequential failure analysis interface are shown in Figure 3 and Figure 4 respectively.

Fig.2 System structure diagram
Fig. 3 Knowledge aided failure analysis

Fig. 4 Sequence failure analysis
6. Conclusion
In this paper, the expert system technology and knowledge assistant technology in the field of artificial intelligence are introduced into the failure analysis of electronic components for the first time. The knowledge aided expert system for failure analysis of electronic components is formed, which enables the failure analysis personnel to quickly use the information provided by the system to complete decision-making, improve the reliability of electronic components, and fill in the blank of failure analysis expert system at home and abroad.

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