Research and Implementation of Vehicle Fault Diagnosis Expert System

[1,2]Peijiang Chen, [3]Yongjun Min
[1,] *College of Mechanical and Electronic Engineering, Nanjing Forestry University, Jiangsu, 210037, China*
[2,] *School of Automobile, Linyi University, Shandong, 276000, China, chenpeijiang@163.com*
[*3,] *College of Mechanical and Electronic Engineering, Nanjing Forestry University, Jiangsu, 210037, China, yjmin@njfu.edu.cn*

Abstract

In order to solve the complexity and difficulty of detection and analysis for vehicle faults, a vehicle fault diagnosis expert system based on fault tree analysis method was designed. On the basis of analyzing the reasons of vehicle malfunction and basic measures of fault diagnosis, the composition and structure of diagnosis expert system were brought out. The methods of knowledge acquisition, knowledge representation and reasoning mechanism were studied emphatically. Making the fault diagnosis of vehicle brake lights as an example, the expert system was implemented. The practical operation showed that the reasoning result corresponded to the actual situation, diagnosis result was correct, and the expected effect was achieved. The designed expert system can effectively diagnose vehicle breakdowns and help users to exclude faults and maintain vehicles.

Keywords: *Vehicle Fault Diagnosis, Expert System, Fault Tree, Reasoning Mechanism, Knowledge Representation*

1. Introduction

With the growing number and high usage frequency of vehicles, vehicle breakdowns occur frequently. Traditionally, when a certain part of the vehicle fails, the engineers or maintenance staff determine the types and reasons of the failures and bring out measures to solve them based on their knowledge and experience. But, because of complex structure, complicated professional knowledge and numerous possible failure reasons, it is very difficult to diagnose these faults [1]. Furthermore, the traditional fault diagnosis technology is difficult to adapt to the vehicle development [2].

As an important branch of artificial intelligence, fault diagnosis expert system has been researched and applied in many domains, such as mechanical, medical, etc. The system can bring us great convenience through collecting expert knowledge and using intelligent reasoning methods to complete the fault diagnosis process. The purpose of designing vehicle fault diagnosis expert system is to enable the computers play proper roles as the human experts. The basic idea is that the computers simulate experts in certain fields to solve practical problems. The application of expert system can provide a new and effective method for fault diagnosis of vehicle maintenance and improve the levels and efficiency of test and maintenance for vehicle failures.

2. Vehicle Fault Diagnosis

2.1. Analysis of vehicle fault

Vehicle fault diagnosis is the technology of examining operation states, detecting fault symptoms, analyzing fault reasons and forecasting their development trends. Vehicle fault are abnormal phenomena which can be felt and perceived. It is necessary to analyze the vehicle fault symptoms, which can be divided into functional failure, warning failure and hidden failure according to their characteristics. The vehicle faults have the following features [3].

(1) Uncertainty is an important feature of the system failures, with the characteristics of fuzziness and randomness.

(2) Timeliness means that the system failure and performance are related with time.

(3) Hierarchy, the vertical feature of fault, is determined by the level of system structure. Any failure is linked to a system level; high-level failure can be raised by the low-level, and the latter is bound to cause the former.

(4) Relativity, the horizontal feature of fault, is determined by the connection of various system elements. A subsystem failure is often associated with subsystem or low levels.

The classified definition of vehicle fault reasons is to narrow the fault range and eventually make out the failure points to identify the damaged parts. When classifying the failure causes, we firstly classify the structure of symptoms [4]. Table 1 lists the classification of the vehicle causes. It shows that the faults of lower levels can be seen as reasons of the high classes.

Table 1. Classification of vehicle failure reasons

Level	Structure	Example	Fault reason
1	Whole vehicle	Vehicle	Insufficient power
2	Structure	Engine, Chassis	Insufficient of engine power
3	System, assembly	Fuel system	Mixture of air and fuel is rare
4	Mechanism	Oil feed unit	Low fuel pressure
5	Part	Pressure regulator	Pressure regulator is damaged
6	Damaged place	Oil return valve	Valve leaks oil
7	Fault spot	Oil return valve is damaged	Valve is from closed tightly

2.2. Basis methods of vehicle fault diagnosis

There are three main methods to diagnosis vehicle failures, artificial experience method, instrument detection method and fault tree analysis method.

(1) Artificial experience method means that the vehicle inspectors determine the vehicle's states by means of simple tools and methods according to their practical experience and theoretical knowledge. The method does not need specific conditions and large-scale equipments, and can be used anywhere. But the diagnosis process is slow, and the accuracy of diagnosis depends largely on their diagnostic skills. This method is generally applicable to small and medium enterprise, which is a common diagnostic method and still has unique practical value.

(2) Instrument detection method is also known as non-disintegration test. It uses indoor equipments to simulate road conditions, test vehicle performance, compare with normal condition, and diagnose the vehicle's faults. This method is more objective, quick and accurate, and can quantitatively analyze, find potential failures, and predict the usage life. It is suitable for large repair companies and inspection stations [5].

(3) The method of fault tree analysis is very safe and reliable analytical technique, and it is one of the most widely used methods of fault diagnosis, which is established on the basis of the experience for system failure. [6].

The basic principle is to make the expected fault condition or failure event as the objectives and starting points, find all factors directly leading to the failure and make them as first-layer reasons, which are seen as the starting points to get their factors in lower layers respectively. Eventually, we find the factors which are original and their failure mechanism and probability distributions are well known. Then, we get a series of events with a certain order and logical relations, which are connected with logical gates in the structure of an inverted tree, we call it fault tree. By analyzing the tree, the fault process and system failure reasons can be obtained.

The fault tree analysis method has several characteristics.

(1) It is a graphical interpretation method.

(2) It has a great deal of flexibility.

(3) It can calculate quantitatively complex system failure probability and reliability parameters and provide data for assessing and improving the reliability of the system.

(4) The process of fault tree analysis can help users to understand the system process [7].

In the actual diagnosis, the above methods are often used at the same time to complement each other to get accurate results.

3. Vehicle Fault Diagnosis Expert System

3.1. Structure of expert system

The expert system was brought out in 1960s which is the most active area of artificial intelligence. It is actually an intelligent computer program based on knowledge and experience in an expert field and taking advantage of human experts' knowledge and problem solving methods to deal with the field problems.

An expert system is generally composed of six parts [8]. The basic structure is shown in Figure 1.

(1) The man machine interface is to exchange data, information between users and system. The function is to identify, interpret and indicate the commands and information offered to system. On the other hand, the interface also offers the results and explanation to users.

(2) The explanation system can explain their behavior and answer questions raised by the users.

(3) The inference engine can simulate the reasoning process of field experts and obtain the final result based on reasoning methods and control strategies.

(4) The knowledge base is used to store the empirical knowledge and facts of the experts and the contents are relatively constant in a reasoning process.

(5) The database is a memory to store initial fact, intermediate result, final conclusion and other information in the reasoning process. The contents of the database can change.

(6) The knowledge acquisition system transmits facts and empirical knowledge to the reasonable types which can be used by inference engine and establish the knowledge base.

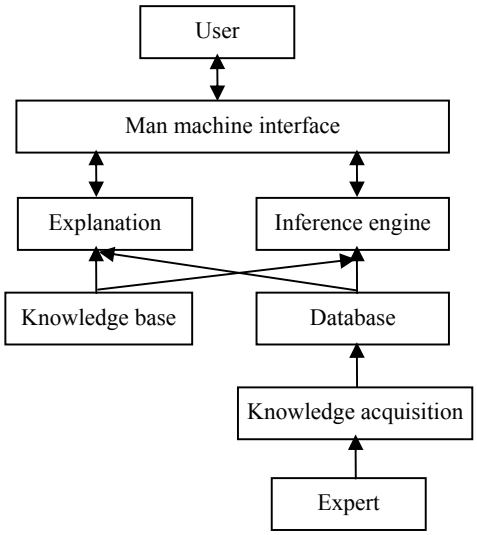

Figure 1. Basic structure of expert system

3.2. Characteristics of expert system

The expert system has several characteristics [9].

(1) The system is developed according to the actual needs, which determines that it is practical.

(2) The expert systems are usually interactive. It can discuss with experts to acquire knowledge and make dialogue with users to obtain the field facts and reply the queries.

(3) The fundamental task is to solve practical problems and the process is to reason, the expert system must have stronger reasoning ability.

(4) It has expert level knowledge to solve practical problems like human experts.

(5) It has the ability to acquire knowledge to complete the diagnosis tasks.

(6) The system and its behaviors should be understood by the users, that is, it is transparent.

(7) The system should be flexible, since it uses the structure of separating knowledge base and inference mechanism.

(8) It has certain degree of complexity and difficulty to simulate human's mind.

3.3. Development process of expert system

The development of expert system is a process repeated over and over [10]. The general step to create an expert system is shown in Figure 2.

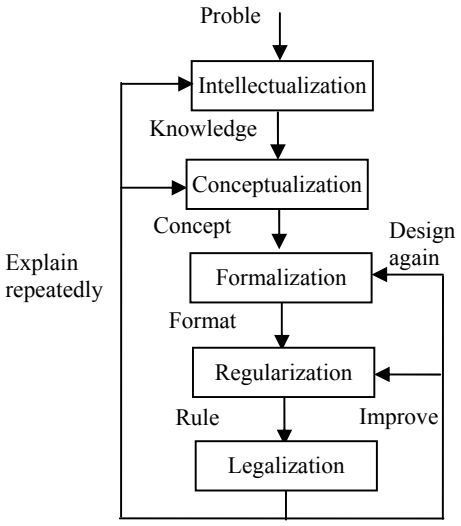

Figure 2. General process of creating an expert system

(1) Design initial knowledge base

To design knowledge base is the most important and difficult task in the process of establishing expert system. The main contents include knowledge based problem, concept based knowledge, format based concept, rule based format and legalization based rule.

(2) Develop prototype

After selecting knowledge representation methods, we establish the experimental subset of the entire system, which encompasses the typical knowledge, and involves only simple test-related tasks and reasoning process.

(3) Improve and summarize knowledge base

Improving the test of knowledge base and inference rules repeatedly, we sum up the better results and allow the system to achieve the levels of human experts.

4. Knowledge Acquisition Mechanism

From the point view of fault diagnosis, knowledge is a complex of facts, concepts, rules, methods, technology and abilities. The field knowledge is obtained by the experts summarizing and concluding the practical experience in the long time of studying and handling problems in certain field [11].

4.1. Methods of knowledge acquisition

In expert systems, an important thing is to realize the acquisition and representation of knowledge. Knowledge acquisition can be obtained by direct or indirect ways. Since the latter way is still very difficult, we usually use direct method to get expert knowledge.

(1) Acquire knowledge by engineers

Acquiring knowledge through knowledge engineer is the most direct and simple access. Knowledge engineers communicate with the field experts, and extract the normal states and failure states of the vehicles and store experience and knowledge into a knowledge base in a proper representation method.

(2) Acquire knowledge by machine learning

Machine learning is a process of intelligent system continuing to accumulate experience and improving the system performance, that is, the computer can simulate the human learning behavior,

automatically acquire knowledge and skills through self-learning, and continuously improve system performance.

4.2. Acquire knowledge based on fault tree

The fault tree building is a detailed process of studying expert system. The most unwilling event is made as the top event of fault tree, and we can get the end bottom events, which are fault reasons, through the establishment of corresponding fault tree. These reasons constitute the collect of bottom events of fault tree, then, we get the failure mode. In a sense, the process of building fault tree is to form fault dictionary which can be used as the knowledge base of expert system. Since the establishment of the fault tree is carried out by the knowledge engineers, the essence of obtaining knowledge based on fault tree is that the knowledge engineers acquire knowledge.

Using fault tree method to obtain knowledge has the following advantages.

(l) The method can not only get necessary knowledge of expert system, but also give a proper base to reason.

(2) The building process of fault tree can help users to understand the system, and then we can fully use the expert system.

5. Knowledge Representation Method

Because the expert system uses knowledge to carry out the reasoning functions, the accurate knowledge representation is an important prerequisite for accurate judgment. Knowledge representation is the process of knowledge formatting and studies the design method of data structures. Then, the knowledge can be represented and stored in the computer.

5.1. Principles of knowledge representation

Knowledge in different areas generally has different characteristics, and also has its own advantages and disadvantages. We can combine two or more methods to represent certain domain knowledge to get more benefits. Good knowledge representation methods have the following features [12].

(1) In favor of knowledge use

In order to make expert system efficiently solve various problems in certain field, the representation method should facilitate the usage of knowledge. If the data structure is too difficult to understand, it is bound to affect the reasoning efficiency, thereby reducing the ability to solve problems.

(2) Easy to implement

The representation model of knowledge should be easy to understand, which requires that it is consistent with the habit of human thinking.

(3) Adequately represent field knowledge

When determining knowledge representation model, we firstly consider whether it can adequately represent the field knowledge. We should deeply understand the characteristics of knowledge and representation pattern.

(4) Facilitate knowledge management

Because different representation correspond different organization, in order to store knowledge into computer, the knowledge should be rationally organized. At the same time, after building an intelligent system, we may add some new knowledge, modify or even delete some existing knowledge, that is, the organization, maintenance and management of knowledge are necessary.

5.2. Knowledge representation based on fault tree

In order to implement the expert system, we adapt the method of combining the framework and rules to represent knowledge. The concept of fault tree is integrated with the framework of knowledge representation, the minimal cut set of fault tree is combined with the rules of knowledge representation, and the bottom event of minimal cut set is connected with the conditions of rules. Then, reasoning process of the expert system based on knowledge becomes the reasoning process of fault tree based on minimal cut set. In this way, the vehicle fault diagnosis expert system is designed based on fault tree.

In the expert system based on fault tree, the framework maybe a separate fault tree. The framework is di vided in to tw o types, di rect framework and i ndirect framework. Direct f ramework means t he reasons of the malfunction des not need investigation, which can be directly obtained, corresponding to the bo ttom ev ent in the fault tree. The f ailure cause of ind irect framework requires further anal ysis, corresponding to the middle or top events of the fault tree [13].

6. Reasoning Mechanism

6.1. Reasoning machine

The reasoning machine is the core module of expert system dealing with problems, which uses the knowledge stored in knowledge base to gradually solve problems with certain reasoning strateg y [14]. Reasoning mechanisms can be divided into forward reasoning, reverse reasoning, and forward-reverse reasoning. Fo rward reas oning gradual l y ded uces f ault so urce s tarting f rom k nown f aults. Backward reasoning firstly assumes a fault source, and then verifies its authenticity.

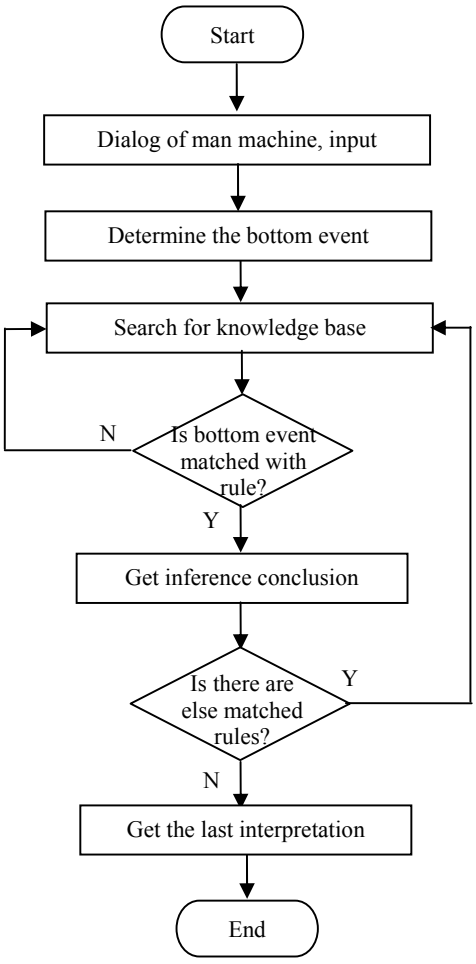

Figure 3. Process of reasoning

6.2. Reasoning process

We use the method of combination of forward reasoning and backward reasoning. The key idea is to memory the previous similar cases and to use their knowledge to solve new problems [15]. The process of reasoning is shown in Figure 3.

(1) Select the necessary information, such as vehicle type, vehicle parts, failure appearance and determine which bottom events occur.

(2) Search the rule sets of knowledge base. If there is a bottom event matching the rule, the reasoning conclusion can be given. If not, this is event is logged in the knowledge base and will be matched the next time.

(3) Determine if this conclusion can also match other rules, if match, repeat step (2); else, we get the final result of fault detection.

7. System Implementation and Analysis

7.1. Fault diagnosis of vehicle brake lights

We make the fault detection of vehicle brake lights as an example to illustrate the application of fault tree analysis. Assuming that a brake light does not shine, which reasons maybe the failure of the barrier line, the damage of brake light bulb or the damage of brake light switch, etc. These failures may occur alone or at the same time [16]. The fault tree of brake light is shown in Figure 4.

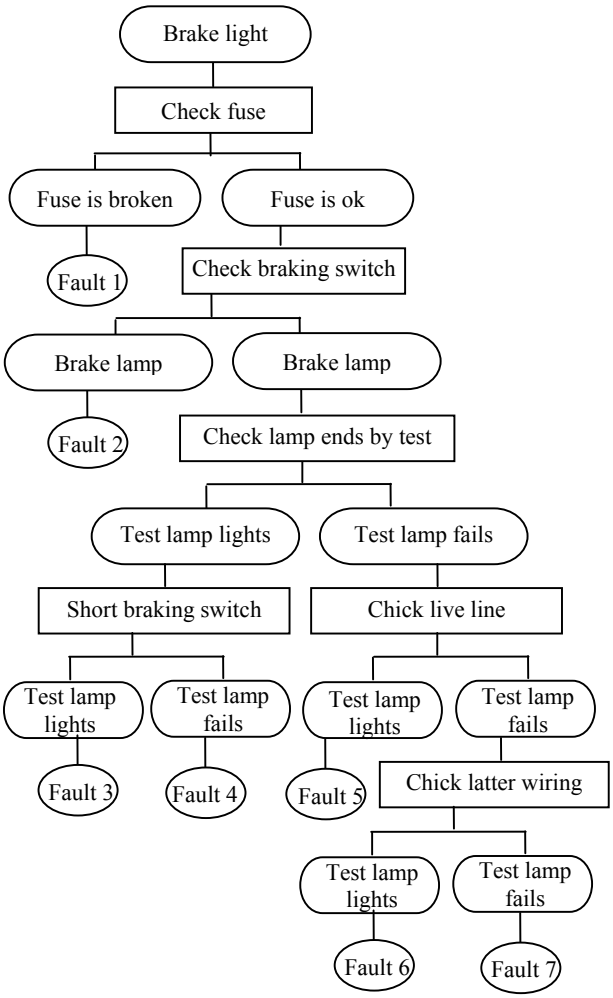

Figure 4. Example of fault diagnosis expert system

7.2. Experiment analysis

The test result shows that system achieves the desired objective. When offered detection data, it can give correct diagnosis which can be used as the basis for failure judgment. The users can exclude the failures of brake light through certain process and give some advice for repair and maintenance of these faults.

Through the using feedback, the system has high stability and can give the exception handling results for various unusual circumstances. Even if the system lacks of some fault information, it can also bring out diagnosis results. This expert system analyzes the vehicle's condition, considers every part, reasons carefully and presents possible results to the users which can be selected by considering carefully.

When building the knowledge base, the system establishments a case database to store the reasoning results. The system can directly query it and feedback to the users which improves the efficiency of reasoning and the real time of failure diagnosis.

8. Conclusions

The vehicle fault diagnosis expert system is designed and implemented based on fault tree, combining with the current commonly used technologies in fault diagnosis fields, which realizes the function of intelligent reasoning. The system has flexible man-machine interface, easy operation, and it can provide many useful functions, such as diagnosis, inquiry, maintenance, and so on. It can quickly and accurately find the reasons of the vehicle malfunction and propose the methods of prevention and repair. The reasoning result in the application is in line with the actual situation, which proves that the expert system is effective and has strong application value.

9. References

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