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Research on the Method for Identification of Defects of Automobile Brake System Based on the Case-based Reasoning

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Abstract: Defect identification is the fundamental prerequisite for the vehicle recall, the previous precedents can serve as the most direct and effective evidences for the following defect identification. This paper explores a defect identification method on the basis of case-based-reasoning, and develops the reasoning database consisting of the typical recall cases and defect modes which take automobile brake system as an example, and then a new defect identification process is proposed. This study provides a practical defect identification method based on the case-based reasoning, and assures the defect judgement is appropriate with uniform standard.

Keywords: Case-based reasoning, defect identification, vehicle recall, automobile brake system

1. Introduction

Recall is an effective measure to reduce the potential vehicle safety risk by correcting the product defects[1], and defect identification is the fundamental prerequisite for the vehicle recall. Since 2004 when China began to implement the defective automobile recall system, total 1,400 automobile recalls have been carried out cumulatively, involving 40.69million vehicles. The former recall cases and defect investigation cases have become important and useful resources for the future defect identification and judgment.

Due to the complicated relations between the defect fault and the risk mechanism, it is hard to effectively and easily obtain characteristic variables according to the type of faults, then it very difficult to carry out fault recognition through the defined models[2]. Case-based reasoning (CBR) conforms to human's way of thinking to solve problems, and is an analogy reasoning mode of using previous experience from solving similar problems to acquire the solution of the current problems[3]. The CBR method is suitable for the research fields without complete and accurate mathematical model but with rich experiences and plenty of historical records[4]. Professor Roger C. Schank with Yale University proposed the dynamic memory theory in 1982, which is considered as the earliest research of CBR[5]. Over more than 30 years of the development, CBR has been applied in many research areas. Doyle developed a case-based reasoning system for flight reservation and choice[6]; Xu Yong and Wang Qing applied case-based reasoning method for quick design of machinery[7-8]; F.Ricci et al introduces CBR into forest fire rescue plan system[9]; LIAO et al proposes CBR-based environmental pollution emergency plan generation method[10]; Yan Jin and Zhang Daisheng et al applied CBR and correlation rules to diagnose the automobile faults and establish vehicle maintenance and repair expert system[11-12]; Cheng Zhonghua applied CBR application to military weaponry RCM analysis process[13]; Gilboa and Schmeidler proposed the case-based decision theory (CBDT) on the basis of decision theory and case-based reasoning method[14]. For the decision issues, the decision makers can apply the previous solutions of the similar problems as the basic plan to solve current problems[15]. The mechanism of the case-based defect judgment is to take previous similar defect cases as the basis and to carry out analysis and modification to get the root causes of the current defect and fault[16].Therefore, this paper explores a defect identification method on the basis of case-based reasoning, and takes automobile brake system defects as examples to build the uniform standard for the judgment of the same or similar defects. The hardware analysis method is applied to classify the promissory layers and coding system of automobile brake system,

and then obtain108 defect modes of automobile brake system through analyzing more than 1000 vehicle recall cases. Then this paper analyzes the defect case presentation and case organization form, and builds the reasoning database consisting of typical cases and defect modes, and then proposes a defect identification process on the basis of case-based reasoning according to CBR reuse and retain principles.

2. Basic principle of case-based reasoning

CBR method is based on the assumptions of regularity, typicality, relative stability and easy suitability of the real world, including two processes of experience reuse and self-study[17]. Classical CBR process consists of “4R” (Retrieve, Reuse, Revise, Retain) (as shown in Fig.1)[18].(1)Case Retrieve: Retrieving database of existing cases according to the characteristics of new case and calculating the match-ability between the cases in the database and the new case to gain the existing case which is most similar to the new case. (2) Case Reuse: Reusing solutions of the similar existing cases to the new case, and revising solutions of the similar existing cases according to the field knowledge and objective restriction, and then making the revised solutions suitable for the new problems and serve as the recommended solution to the new problems. (3) Case Revise: Checking the case reuse process, and making revision according to actual situations, then taking the revised and verified solution as the final solution. (4) Case Retain: Retaining the cases with the final acquired solution, and saving it into the case database, and then realize the cases self-study.

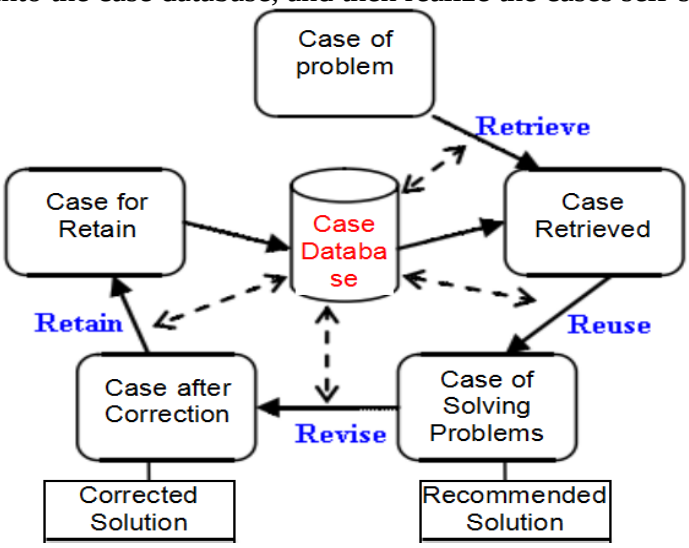

Fig. 1 Basic Process of CBR

The CBR-based classical cognitive model takes previous vehicle recall activities as source cases and then the case database is established. when facing the new defect identification (target case), the case retrieve process is conducted to obtain the existing case (compare similarity between the target case and the source cases), and find similar source case as the reference for the defect judgment (recommended solution), which is the case reuse process. If there is not existing case which matches the new defect identification, other models can be applied to identify the defect, and then the new case can be added into the database as a source case for the new reference to the other new problems, which is called the self-study process. Case-based reasoning process consists of case retrieval, case adjustment and case database[19]. Case database is the core of the case-based reasoning, including the case representation and the case organization [20].

Case representation. Case representation means how to extract characteristics from problems for solutions and the relations between the characteristics, and then store them into the database to provide basic conditions for reasoning. J.L.Kolodner[21] defined cases as follows: knowledge representation of previous experiences with certain relations, recording basic lessons or experiences that must be drawn for achieving certain goal. A typical case mainly consists of three parts of

information:1) Description of problems or scenarios, namely the problems which needs to be solved or the state of scenarios when the case occurs; 2) Solutions, namely the solutions to the relevant problems; 3) Result, namely the results from execution of the solution or the new state of scenarios. Therefore, case knowledge representation includes three parts, such as problem description, solving problem, effect description.

Problems from different fields have different representations[22]. Reasonable case representation can not only make it easier to get a solution and also with high efficiency. According to the relevant content of the Recall Plan of Defective Automobile, the knowledge of vehicle defect case is identified as Defect Description, Recall Measures and Expected Effect.

Case organization. Case organization means case sort-out and classification according to case characteristics and retrieval needs on the basis of the case representation. The fault of automobile caused by its inherent problems during use under the specific conditions is called intrinsic fault of automobile. Defect always occurs in the form of fault, and defect is called as intrinsic fault involving personal and property safety and with characteristics of batch. Referring to the concept of fault mode, defect indication form is defined as defect mode, which consists of defect-related system or assembly, root cause of the defect and the consequence of the defect. Without specific equipment, it is hard to confirm definite meaning of defect modes. This paper refers to GJB/Z-2006 to carry out classification of vehicle promissory layers and preparation of the coding system, so as to embody defect modes to min component layer[23].

3. Analysis of brake system defect modes

The promissory layer classification basis and definition are as shown in Table 1.

Table 1 The Promissory Layer Classification Basis and Definition

Description	Definition
Initial promissory layer	Product level, defining the vehicle as initial promissory layer
Other promissory layer	Classified into promissory layer No.2, No.3 and No.4 according to the subordination relations of the vehicle structure
Lowest promissory layer	End promissory layer, generally take the vehicle component as the lowest layer

The coding system is formulated according to the classified promissory layers. The coding system should meet the following requirements:1) Conforming to the upper-lower relations of the structural layers; 2) Able to describe high/low layer's relations; 3) Unique, applicable and concise for all components of the main system; 4) Conforming to the product scale and to be traceable to certain extent.

To classify different layers and make coding system of vehicle brake system according to the definition of classification of promissory layers and coding system, as shown in Fig. 2. Brake system consists of four assembles of boost device, electronic control device and sensor, hydraulic unit and mechanism unit, with 30 components in total, to classify defect modes. Through analysis of 2004~2014 brake system recall cases, 108 defect modes are extracted. Taking brake pedal unit as an example, it is further classified into two kinds of lowest components of brake pedal and brake pedal linkage 2, including 7 defect modes, as shown in Table 2.

Table 2 Typical Defect Modes of Brake Pedal

Components	Defect Mode Coding	Definition
Brake pedal 0102010101	Z1a	Brake pedal deformation, with movement interference by mat, poor automobile brake
	Z1b	Brake pedal break, unable to input braking force; brake failure
	Z1c	Brake pedal crack, causing pedal break; brake failure
Brake pedal linkage 0102010102	Z2a	Brake pedal connecting road deformation, occurrence of movement interference
	Z2b	Brake pedal return spring break, unable to release brake
	Z2c	Brake pedal locating pin break, unable to brake
	Z2d	Brake pedal pusher shaft sleeve break, unable to apply braking force

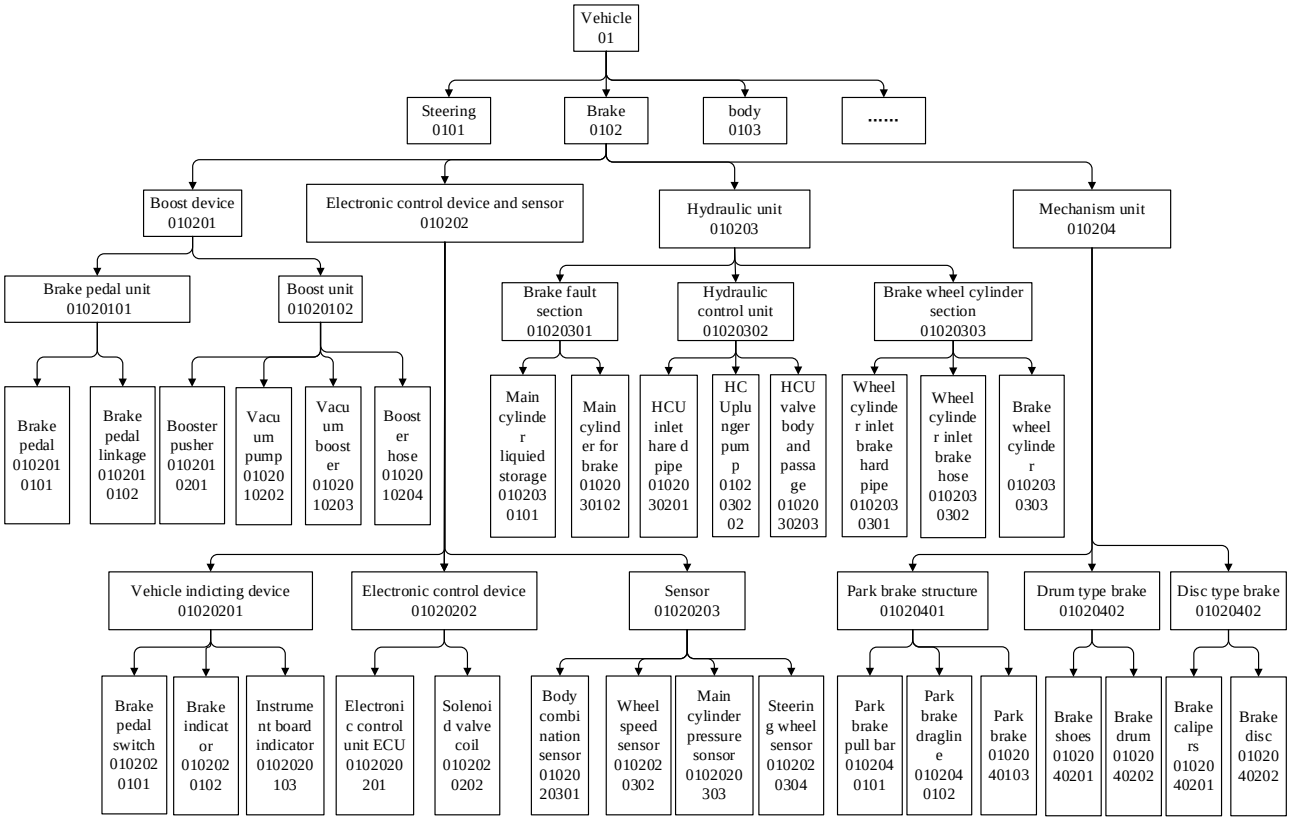

Fig. 2 Classification of the Layers of Automobile Brake System

4. Process of product defect identification on the basis of case-based reasoning

The product defect identification process is built on the basis of CBR Reuse and Retain principle, as shown in Fig.3. As CBR has Reuse and Retain functions, so database building and reasoning application are considered into the whole process. The red line marks database building process, and the green line represents reasoning application process.

Database building process: According to the relevant content of the Recall Plan of Defective Automobiles, to analyze the recall cases reported by manufacturers, and then to extract the typical knowledge representation from the vehicle recall case (Vehicle Information B, Defect Description C and Defect Remedy D) to build typical case database. According to definitions of promissory layer classification and coding system, the Promissory Layer is classified. Based on the vehicle recall cases, the defect modes are extracted. In the database, one defect mode can related to more cases, on the contrary, any case in the case database has a related defect mode. The case database and defect mode jointly constitute reasoning database.

Reasoning application process: After determining the case for investigation through defect information analysis, to analyze its Fault Phenomenon Y (including vehicle information and fault description), and obtain the knowledge representation and then identify the related defect mode according to the fault-related component. If the defect mode is confirmed, the case related the confirmed defect mode can be searched, and then the defect judgment can be conducted. If no related defect mode in the database, the other methods can be considered to identify the defect. When the case is identified as a defect, to transfer to the database building process, and then to analyze the recall report information to extract the knowledge representation and defect modes, and the new typical case is obtained finally.

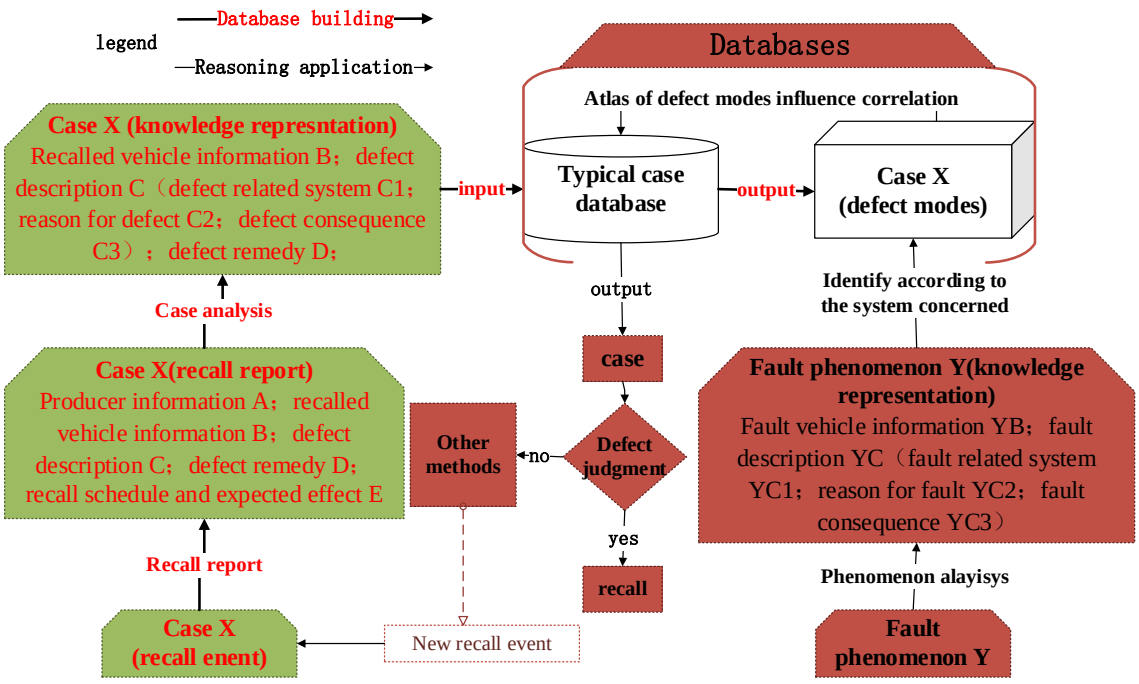

Fig. 3 Flow of Product Defect Identification Process Based on the Case-based Reasoning

5. Conclusions

Reasoning often involves professional knowledge of many research fields. General reasoning method needs complete knowledge of the fields, while case-based reasoning is a method to solve new problems by applying previous solutions of the cases, and can directly simulate human's thinking logic when solving the new and complicated problems, and the required knowledge is just previous historical and similar cases. On the basis of case-based reasoning method, this paper firstly classified different promissory layers and coding system of automobile brake system, and obtains 108 defect modes through analyzing former vehicle recall cases, then the defect case representation and case organization are described. This paper developed the reasoning database consisting of typical cases and defect modes, and proposed a defect identification process on the basis of case-based reasoning according to CBR Reuse and Retain principles.

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