Method on Fault Diagnosis of Armored Equipment Base on Case Reasoning

Bin HUANG, Tie-ning WANG, Fan YANG and Hao LI
Department of Technical Support Engineering, Academy of Armored Force Engineering, Beijing 100072, China

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Abstract. Most of the CBR-based fault diagnosis research ignore the possibility of case drawing between similar equipments or parts and explore a new fault diagnosis method: Based on the fault case definitions and establishment of fault characteristics keyword dictionary, building an effective case storage and indexing mechanism, in order to improve fault coverage of the source cases in case warehouse, providing a reference for similar type of new equipment fault diagnosis, and verifying it by an example at last.

Introduction
The method of CBR(case-based reasoning) has gotten rid of knowledge bottleneck, and has widely used in many fields, such as aviation remote fault diagnosis [1], making sure civil aircraft repair interval [2], intelligent agriculture [3], teaching guidance and so on. However, many current research mostly focus on the case retrieval. For example, Gao Ming [4] improves nearest neighbor method to realize the fault diagnosis of hydroelectric generating set, Li Feng [5] tries to use BP neural network to design a scheme of case retrieval and case implementation, Cheng Gang [6] puts forward to applying inorganic ring graph support vector machine classifier to case retrieval, but consider little about the influence of different field characteristics. Therefore, this paper, on the basis of field characteristics consideration, is to explore new organization form, and establish the corresponding index wit, so as to improve the coverage of fault case and case-based reasoning efficiency, and better to meet the demand of armored equipment diagnosis.

Characteristic in the Field of Armored Equipment Maintenance Support
The knowledge of equipment field is hard to comprehensive describe in the form of rules, but many knowledge specifically contained in the process of practice cases. The field has the following features:

Empirical Knowledge Dominant
Equipment maintenance is a practical activity, and its skilled maintenance relies on the long time practice experience. Because of the complex failure forms, relying on structured knowledge such as mathematical model is established to solve the problem of maintenance. It is difficult to the maintenance plan of validation but storage is relatively easy, there is no knowledge acquisition bottleneck, so the experience knowledge is still in the leading position in the field of equipment maintenance.

Most Theories Are Qualitative Description
In the field of maintenance and repair field, theoretical research is comparatively mature. But in a more important link, the aspects, such as the threshold, is difficult to support, which have enough practice guiding significance. Even if there is related research also is more qualitative description, and lack of quantitative design.

The Similarities between Different Models of Armored Equipment
Design relies on demand. The demand of firepower, protection and mobile of armored equipment, determines the design of the model. But the technical confine requirements.
Case Retrieval

Case Definition and Presentation

This paper, the fault is defined as a group of five dimension Case=<I,N,T,F,M,E>, I is a serial number of fault, which is also the only fault cases symbol; N is the fault models, including vehicle model and subordinate groups of similar models; T is motor hours’ consumption of equipped, used to identify equipment usage; F={f1,f2,...,fn} is a no empty set, represent the failure phenomenon, signs, conclusion and so on; M is fault conclusion, including the cause of the problem, the failure positions, failure consequence, maintenance plan, failure mechanism of the maintenance plan, etc.; E is the fault of the auxiliary information, including the maintainability description, number and frequency of successfully troubleshooting of retrieval. The structure of the fault cases as shown in table 1.

<table>
<thead>
<tr>
<th>Name</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify of fault case</td>
<td>Number of fault</td>
</tr>
<tr>
<td>Vehicle type of fault</td>
<td>Type and subordinate groups of similar models</td>
</tr>
<tr>
<td>Time of fault</td>
<td>Motor hour</td>
</tr>
<tr>
<td>Characteristic of fault</td>
<td>Fault system, unit, specific phenomena of fault, omen, keyword and weight of fault characteristic</td>
</tr>
<tr>
<td>Conclusion of fault</td>
<td>Reason, unit, consequence, solution, failure reason</td>
</tr>
<tr>
<td>Auxiliary information of fault</td>
<td>maintainability description, number, success frequency</td>
</tr>
</tbody>
</table>

Table 1. Structure of the Fault Cases.

Organization and Index of Case Strategy

Key step to realize this target is to establish a suitable case storage and indexing mechanism. In order to improve the retrieval efficiency, at the same time, we can refer to different models of similar system and component maintenance scheme, the whole case is organized into a multi-layer structure, and then set up the mechanism of layered index. Equipment fault diagnosis and maintenance which are putted forward according to the key characteristics form tree hierarchy index model.

Case Matching

Due to the considerable part of case content is given priority to with natural language, not as accurate as the numerical language described, this will bring the difficulties to the case of accurate matching. So, in order to improve the precision of matching, matching before need to extract the fault feature keyword set up in the dictionary.

Assuming that X = {X1, X2,..., Xn}, X represents the target case, finite set is empty, Xi (1 ≤ i ≤ n) in fault case is the target characteristic values of the number i set in the same way. In the same way, Y = {Y1, Y2,..., Yn}, Y represents the source case, also is a finite set, Yi (1 ≤ i ≤ n) in fault case is the target
characteristic values of the the number i; Wi is the corresponding weight coefficient of the key attributes (W1+W2+... + Wn = 1), considering the importance of experience in the process of armored equipment fault diagnosis and the complexity of the knowledge in this field and weight coefficient is given by experts, the target case distance between X and Y source case as formula (1). In which X, Yi is case X and Y respectively the number i attribution. A (X, Y) is defined as formula (2). According to the above, the similarity between case X and case Y can be calculated as formula (3).

\[
\text{DIST}(X, Y) = \sqrt{\frac{\sum_{i=1}^{n} (X_i - Y_i)^2}{\sum_{i=1}^{n} W_i}}
\]

(1)

\[
\Delta(X, Y) = \begin{cases} 
0, & \text{if } X_i, Y_i \text{ is discrete and } X_i = Y_i \\
1, & \text{if } X_i, Y_i \text{ is discrete and } X_i \neq Y_i \\
\frac{|X_i - Y_i|}{\max X_i - \min Y_i}, & \text{if } X_i, Y_i \text{ is continuous}
\end{cases}
\]

(2)

\[
\text{SIM}(X, Y) = 1 - \text{DIST}(X, Y) = 1 - \sqrt{\frac{\sum_{i=1}^{n} W_i \Delta(X, Y)}{\sum_{i=1}^{n} W_i}}
\]

(3)

**Example**

Now, we take an example to prove the equipment diagnosis method based on case-based reasoning. A new type of M vehicle's power system is XXA, a new type of N vehicle's power system is XX, this two have all been equipped and established the source putted forward.

According to the requirements of 3.1 in the case organization, the extraction of M type engine fault information, f= \{load operation conditions at a large number of black smoke, insufficient power\}, form the target case C1, the fault feature set is in table 2.

<table>
<thead>
<tr>
<th>Property</th>
<th>$f_{11}$</th>
<th>$f_{12}$</th>
<th>$f_{13}$</th>
<th>$f_{14}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table 2. Fault Feature set of Fault.

Table 3. Fault Feature Subspace of Source Case.

<table>
<thead>
<tr>
<th>Ci</th>
<th>$f_{11}$</th>
<th>$f_{12}$</th>
<th>$f_{13}$</th>
<th>$f_{14}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_i$</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>$C_{i2}$</td>
<td>0.2</td>
<td>0.1</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>$C_{i3}$</td>
<td>0</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>$C_{i4}$</td>
<td>0.5</td>
<td>0.2</td>
<td>0</td>
<td>0.3</td>
</tr>
<tr>
<td>$C_{i5}$</td>
<td>0.4</td>
<td>0.3</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>$C_{i6}$</td>
<td>0.2</td>
<td>0.4</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>$C_{i7}$</td>
<td>0</td>
<td>0.4</td>
<td>0.6</td>
<td>0</td>
</tr>
</tbody>
</table>

In the table, fi1 is taking a lot of black smoke in the load case; f2 is reducing the power of engine; fi3 is having fire phenomenon in the process of equipment; fi4 is having high exhaust temperature.

Because of M type infantry fighting vehicles still in the phase of real vehicle test, there is no corresponding source case matching, so select similar case retrieval models - N type equipment, get relevant fault feature subspace Ci and the corresponding weights, as shown in table 3.

Matching similarity calculation of fault feature subspace and the source of the target cases set of fault feature subspace using by formula, the results as shown in table 4.
Table 4. Similarity of Match.

<table>
<thead>
<tr>
<th>Case</th>
<th>$C_{i1}$</th>
<th>$C_{i2}$</th>
<th>$C_{i3}$</th>
<th>$C_{i4}$</th>
<th>$C_{i5}$</th>
<th>$C_{i6}$</th>
<th>$C_{i7}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>S (similarity)</td>
<td>0.876</td>
<td>0.814</td>
<td>0.763</td>
<td>0.735</td>
<td>0.933</td>
<td>0.749</td>
<td>0.631</td>
</tr>
</tbody>
</table>

The table shows that the $C_{i5}$ matching degree is the highest. Taking the source of $C_{i5}$ to guide the fault maintenance case. If still cannot solve the problem, then we should take some actions according to the rules of the corresponding reasoning or consult experts to solve the problem, and put forward the case into the new equipment as the source case.

**Conclusions**

According to the characteristics of the armored equipment maintenance support areas, we improve the existing case retrieval process, and offer the relative structure of the organization and put a new solution to the new type of equipment failure after equipped. We refine the fault diagnosis and maintenance of the similar equipment or parts to reduce the storage space and improve the retrieval efficiency. The method puts the case-based reasoning technology to better adapt to the requirements in the field of armored equipment maintenance support.

**Reference**


