Research on Intelligent Fault Diagnosis of Portable ATE Based on Ontology

Jianfeng Li*, Mingqing Xiao and Xilang Tang

College of Aerospace Engineering, Air Force Engineering University, Xi’an, China

*Corresponding author e-mail: 1506556759@qq.com.

Abstract. Aiming at the problems of low diagnostic efficiency and bad knowledge sharing of portable ATE (automatic test equipment), an intelligent fault diagnosis method based on ontology is put forward. Firstly, FMECA results of guiding system are regarded as knowledge source. The ontology model is constructed by OWL ontology description language to map between fault modes and fault causes. Then rule language SWRL is used to describe rules of ontology and build the relationship of classes, properties and instances. Finally, Racer reasoning engine is used for fault diagnosis, and fault diagnosis priority is received. Reasoning results show the priority of the most possible fault location and its weight in all of probable fault position. This method can solve the problems of difficulty of knowledge representation, lack of auto semantic reasoning of portable ATE effectively.

1. Introduction

The portable ATE, used to collect key signals and test whether missiles can work normally or not, plays a vital role in the routine maintenance of missiles. And the performance of portable ATE can affect the efficiency and cost of logistical support, and decide the combat operation. A typical portable ATE is shown in the Fig 1.

However, with the rapid development of complexed equipment, the cost of logistical support and the probability of fault becomes higher and higher [1]. At present, for our fault diagnosis of portable ATE, we mixed the traditional expert diagnosis system and artificial judgement method to solve the fault, but this method has the problems of lack diagnostic knowledge, low diagnostic efficiency and bad sharing of complexed aviation equipment. So how to design a kind of intelligent fault diagnosis system and develop it in the ATE has aroused popular attention [2-6].

Figure 1. The construction of a portable ATE
Recently, a kind of fault diagnosis method based on FMECA and ontology is hot. FMECA is used to analysis the reliability and safety of equipment with inductive logic. It contains all the fault information of each component and is a reliable source of knowledge. By determining the impact of each fault mode on missiles, the single point fault is found and the causality is received according to the severity and occurrence probability of fault modes. However, due to the lack of unified grammar, the fault mechanism and rule description are different resulting in the difficulty of knowledge sharing and reuse. Thus, it is vital to adapt a new kind of description method to represent FMECA.

Ontology, as the basic element of knowledge, is suitable to describe the inner unit of knowledge base and analogy reasoning. OWL is the standard ontology language, used to build the diagnosis knowledge base. SWRL, which is based on OWL, used to represent rules. The knowledge representation and reasoning based on ontology has become a hot research [7-9].

Aiming at the problems of low diagnostic efficiency and bad knowledge sharing of portable ATE, in this paper, an intelligent fault diagnosis method based on ontology is put forward. FMECA results of guiding system are regarded as the knowledge source. OWL ontology language is introduced to build knowledge base, SWRL is used to build rule base. Finally, according to the knowledge base and rule base, fault reasoning will be continued by Racer reasoning engine and the priority of fault location will be received for fault diagnosis.

2. Ontology model
Guiding system is the highest part of occurring fault [10], the fault occurrence of guiding system will have a big influence for safety of missiles and its combat operation. According to the FMECA results, the guiding system is divided into four parts. The specific classification is shown in the Fig 2. The guiding system is composed of computer, actuation device, missile seeker and control surface. And the missile seeker is taken as an example to have a further classification. The guiding system is defined into four levels: system level, part level, component level and element level.

The basic ontology model is= \{C, OP, DP, I\}. C is the set of ontology classes, OP is the set of object properties, DP is the set of data type properties and I is the set of instances. In this paper, classes are defined based on the FMECA, each class contain many instances, object properties are used to build the relationships of different classes, data type properties are used for defining value of different data type. As the key part of the ontology model, the relations among inner units are defined by object properties. Several concept definitions of object properties are given as follows:

**Definition 1:**
- **PartOf:** Description of fault mode and its components.
- **HappenedAt:** Description of fault mode and the location it happens.
- **FaultLocationIs:** Description of fault mode and the location it happens in the element level.
- **TestedBy:** Description of fault mode and its test method.
- **MaintenanceOf:** Description of maintenance method and fault mode.

![Figure 2. The hierarchy of the guiding system](image-url)
BelongsTo: Description of one component and its sub-component.

Rules play a vital role in the rule representation, without rules, the knowledge can’t build the relations between classes, the intelligent fault diagnosis system also can’t conclude the correct priority of fault location. SWRL can describe ontology knowledge base properly based on OWL language and insert into OWL text by ATML grammar, which is easy to be identified by computer and is universal. Several concept definitions of rules are given as follows:

Definition 1:
Rule 1
FailureMode (x) ^ hasHappened (x, true) ^ Element (y) ^ HappenedAt (x, y)
→ FailureLocationIs (x, y)
Rule 2
MissileComponent (x) ^ MissileComponent (y) ^ SameLevelOf (x, y) ^ MissileComponent (z) ^ SameLevelOf (y, z) → SameLevelOf (x, z)
Rule 3
MissileComponent (x) ^ MissileComponent (y) ^ BelongsTo (x, y) ^ MissileComponent (z) ^ BelongsTo (y, z) → BelongsTo (x, z)
Rule 4
FailureMode (x) ^ hasHappened (x, true) ^ Component (y) ^ FailureMode (y) ^ HigherInfluenceIs (y, x) ^ hasHappened (y, true) → ElementLevelCauseIs (x, y)
Rule 5
FailureMode (x) ^ hasHappened (x, true) ^ Component (y) ^ FailureMode (y) ^ HigherInfluenceIs (y, x) ^ hasHappened (y, true) → ComponentLevelCauseIs (x, y)
Rule 6
FailureMode (x) ^ hasHappened (x, true) ^ Part (y) ^ FailureMode (y) ^ HigherInfluenceIs (y, x) ^ hasHappened (y, true) → ComponentLevelCauseIs (x, y)

Rule 2 is taken as an example to make the explanation: is missile component x and missile component y are in the same level, if missile component y and missile component z are in the same level, then the conclusion is that missile component x and missile component z are in the same level.

3. Fault reasoning
According to the FMECA research report, the fault modes of this guiding system have 26 types. The ontology construction software protégé is used to build the fault diagnosis system platform. The classification of guiding system is shown in the Fig 3.

![Figure 3. The classification of guiding system](image)

The description of FMECA class relationships is shown in the Fig 4. Taking the fault of Dewar as an example to describe the relationships among different classes in the different level.

Racer reasoning engine adapts the fault search positioning to reasoning the possible fault in the guiding system. By building the FMECA class relationships, receiving the priority of different fault location probability when a kind of fault happens according to the electrical signals, which is tested by portable ATE.
Taking the fault of the infrared detector as an example to see the occurrence possibility of each fault location, which is shown in the Fig 5. When the electrical signals indicate that there is something wrong with infrared detector, then according to the knowledge base and rule base, the fault location priority of each possible fault will be reasoned by Racer reasoning engine. As the vital component of the infrared detector, refrigerator breaks is the main cause of fault, which weight about 33.6%. Moreover, there are some other causes that result in the fault of the infrared detector such as chip cracks and Dewar fails to seal.

Making the comparison with the FMECA results, the result is almost the same. Therefore, this intelligent fault diagnosis method can reduce the steps of fault check and realize the quick positioning of fault location. Furthermore, the method based on ontology can normalize fault information, which realize the reuse and share.

4. Conclusion
Aiming at the problems of low diagnostic efficiency and bad knowledge sharing of portable ATE, in this paper an intelligent fault diagnosis method based on ontology is put forward. FMECA results of guiding system are regarded as knowledge source. The ontology model is constructed by OWL ontology knowledge base and SWRL rule base. The relationships of classes, properties and instances
are built. Reasoning results show the priority of the most possible fault location and its weight in all of probable fault position. This method can solve the problems of difficulty of knowledge representation, lack of auto semantic reasoning of portable ATE effectively.

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