World Scientific Research Journal (WSRJ) ISSN: 2472-3703
www.wsr-j.org

Research Progress on Diagnostic Technology Based on AI-ESTATE

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Abstract: AI-ESTATE standard is the general international standard that applied to the field of fault diagnosis of artificial intelligence technology. It regulates formal diagnostic data, knowledge and services, providing solutions for general utilization of diagnostic systems, knowledge sharing, and portability of diagnostic reasoner. The generation and development of AI-ESTATE standard and its architecture are analyzed, meanwhile, the research and application of this standard at home and abroad are outlined.
Keywords: AI-ESTATE; fault diagnosis; information model; diagnostic reasoner.

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1. INTRODUCTION

With the increase in the performance and complexity of weapons and equipment, traditional test and diagnostic techniques and ideas have exposed a large number of problems. At this stage, weapons and equipment testing and diagnostic systems are mostly aimed at a specific one or a certain type of equipment, and there are common defects such as lack of versatility, scalability, and poor portability, which make it difficult to achieve the sharing and reuse of diagnostic knowledge and data. Not only caused a lot of waste of resources, but also hindered the development of fault diagnosis technology. The IEEE Std 1232 standard, also known as AI-ESTATE (Artificial Intelligence Exchange and Service Tie to All Test Environments), defines the standardized description of diagnostic knowledge, data, and inference engine services, and supports component-based diagnostic structures. Interoperability with other test information sets provides solutions to the above problems. AI-ESTATE has undergone numerous amendments since its establishment, including IEEE Std 1232-1990, IEEE Std 1232-1995, IEEE Std 1232.1-1997, IEEE Std 1232.2-1998, IEEE Std 1232-2002, and IEEE Std 1232-2010 .

2. GENERATION OF AI-ESTATE

In the 1980s, artificial intelligence methods based on expert systems were gradually applied to the field of testing and diagnosis. Although these artificial intelligence methods greatly improved the level of protection of US military equipment, they also brought difficulties due to the lack of universal interface standards. The problem of sharing and reusing diagnostic knowledge and data. So in 1990, the Institute of Electrical and Electronics Engineers (IEEE) agreed to authorize the Electronic System Test and Diagnosis Standardization Working Committee (SCC20) and Diagnostic and Maintenance Control (D&MC) to develop a new test diagnostic standard AI-ESTATE, but at the time AI-ESTATE was mainly It is the fault diagnosis system based on the expert system method that has not been formally promulgated.

In 1995, the IEEE promulgated the IEEE Std 1232-1995 artificial intelligence—an expert system for automatic test equipment. This standard serves as the basis for the AI-ESTATE series, although Only one method of the expert system is embodied, but in fact, it can represent a variety of knowledge-based intelligent diagnostic methods. The standard defines the consistency structure of AI-ESTATE and the correlation among components. It also requires that all data and diagnostic knowledge specifications and interfaces must be unambiguous, making the knowledge information and data portable, and the interface universal. The entire architecture can be expanded and upgraded. The promulgation of IEEE Std 1232-1995 lays a good foundation for the subsequent revision of the AI-ESTATE standard.

IEEE Std 1232-1997, also known as IEEE 1232.1- Artificial Intelligence Switching and Services for All Test Environments: Data and Knowledge Specification Applicable Standards. In IEEE Std 1232-1997, the use of the EXPRESS language for standardized description of data and knowledge in test diagnosis makes it possible to share knowledge and share information in diagnostic knowledge. The standard establishes the Common Element Model (CEM). It has standardized the description of common elements in the field of test diagnosis. Other models are built on the basis of the public element model. Fault Tree Model (FTM) and Enhanced Diagnostic Inference Model (EDM) are given in IEEE Std 1232-1997.

IEEE Std 1232.2-1998, also known as the IEEE 1232.2 standard, standardized the services and protocols provided by the diagnostic inference engine to implement the system diagnostic function. And apply the encapsulated service to establish a fault tree diagnostic service instance.

Based on the previous versions AI-ESTATE, IEEE Std 1232-2002 expands and deletes some entities and data types in the common element model, expands interoperability services of inference engines, and standardizes diagnostic models and diagnostic process control. Services enable diagnostic inference engines to more effectively control diagnostic processes such as diagnostic analysis, diagnostic reasoning, and generation.

At present, the latest version issued by the IEEE is IEEE Std 1232-2010. IEEE Std 1232-2010 continues to add and delete some entities and data types under the common element model. And in order to describe the probabilistic model of the diagnosis object, the description of the distribution of failures in the diagnosis is further regulated, making the diagnosis model creation, diagnosis process and so on all have standardized description.

3. AI-ESTATE ARCHITECTURE

The AI-ESTATE standard provides the following content [1]:

1) An overview of the AI-ESTATE architecture

2) A formal definition of diagnostic model for systems under test

3) Formal definition of the interchange formats for exchange of diagnostic models

4)A formal definition of software service for diagnosis reasoners.

In order to realize the interaction between the inference engine components and other components in the diagnosis system, and to diagnose the normative definition, portability, and reusability of knowledge, AI-ESTATE uses the method of defining services, as shown in the following figure.

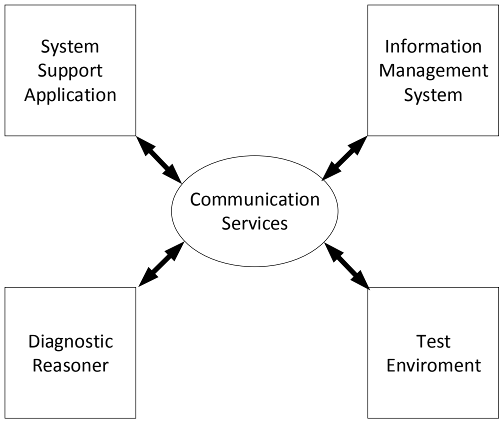

Figure 1. AI-ESTATE architecture

Can be seen from Figure 1, in the AI-ESTATE concept system, the entire system through the information transfer service to achieve information exchange. Therefore, the diagnostic inference engine can interact with other components through already implemented services.

In IEEE Std 1232-2010, AI-ESTATE built a hierarchical structure as shown in Figure 2 in order to share diagnostic information. In this structure, at the top level is the CEM (Common Element Model), which is a standardized description of the common information used in the field of test diagnosis. Typical entities include Diagnosis, Failure, Repair, and Resource. These entities are made up of attributes, including costs, failure rates, and other attributes. The underlying FTM (Fault Tree Model), BNM (Bayesian Network Model), DIM (D-Matrix Inference Model), and DLM (Diagnostic Logical Model) are all based on the elements of CEM, and have certain extensions or Deducted and formed, in turn, can meet a variety of diagnostic reasoning needs. We can also build a diagnostic model that expands on more methods based on actual needs and CEM. The role of the DCM (Dynamic Context Model) is to record the historical information and context of the diagnostic process. It is dynamic and evolves as the diagnostic process proceeds.

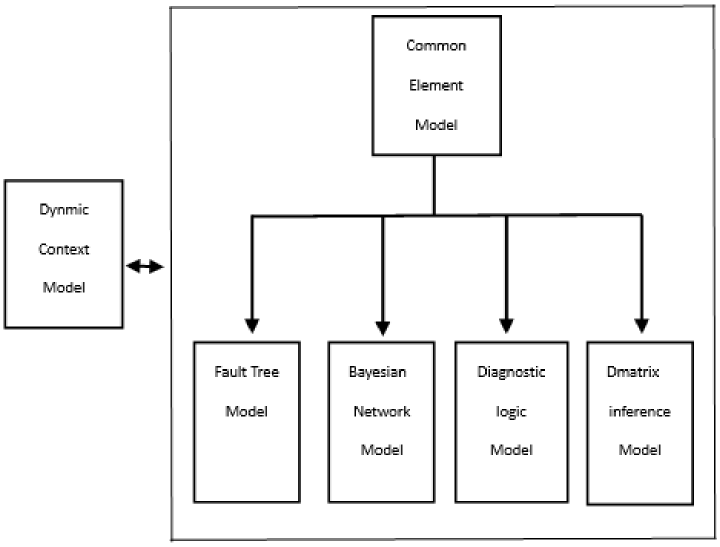

Figure 2. AI-ESTATE model hierarchy diagram

4. FOREIGN RESEARCH

For the AI-ESTATE standard, some foreign companies and scientific research institutions have conducted in-depth research and discussion, which has not only contributed to the development of AI-ESTATE, but also achieved good results in application and development.

In the development of the AI-ESTATE standard, American scientific experts such as John W. Sheppard, Amanda, W.R. Simpson, etc., have done well. After the promulgation of IEEE Std 1232-1995, John W. Sheppard pointed out that there is a problem that the knowledge constraint relationship is not defined in the standard and it is not convenient to implement the diagnosis process [2]. W.R. Simpson discussed in the paper whether AI-ESTATE can be applied to the A Broadband Test Environment (ABBET) and promotes the development of AI-ESTATE in manual testing and semi-automatic testing [3]. John W. Sheppard revised the public element model again, emphasizing that other information models must be extended on the basis of the common element model, establishing the basic position of the common element model [4]. Amanda Jane Giarla outlined how to build an AI-ESTATE compliant information model in this article [5]. Anthony L.Alwardt, after deeply researching AI-ESTATE and open ATS related performance, believes that AI-ESTATE can be applied to the open diagnosis field [6]. In 2005, after John W. Sheppard analyzed the Bayesian network diagnosis method, he established a Bayesian diagnosis model and described it through XML (eXtensible Markup Language) to ensure the integrity of diagnostic information and portability. [7]. Michcllc Harris et al. explained how to build a fault tree model that conforms to the AI-ESTATE standard and how it conveys information between multiple inference engines, and presents several models for analysis [8]. John W. Sheppard et al. focused on the semantic interoperability of models in diagnostic reasoning and verified them with fault tree models and Bayesian models. The results fully embody the effectiveness of semantic modeling in information exchange.]. Liessman Sturlaugson et al. first described a tool called SAPPHURE which includes the implementation of AI-ESTATE in Java and a corresponding GUI (Graphical User Interface) tool. This GUI tool supports the Bayesian network model. Model establishment and diagnostic reasoning. Second, the Bayesian model inference engine service is extended to represent a first-order dynamic Bayesian network [10]. Logan Perreault et al. provided a new predictive model for the next version of the AI-ESTATE standard. In addition, they propose to replace the previously proposed Bayesian network model with a continuous-time Bayesian network (CTBN) to provide an additional model for predictive reasoning and specify a semantic model to represent dynamic shellfish. The network model predicts and finally confirms its validity and necessity [11]. John W. Sheppard et al. argued that the service specification proposed in AI-ESTATE is necessary to realize the interoperability and portability of ATS, and analyzes how to apply the AI-ESTATE service specification in the diagnosis process through the fault tree diagnosis system [16].

5. DOMESTIC RESEARCH

Since the promulgation of AI-ESTATE, experts and scholars of scientific research institutes at various institutions in China have conducted corresponding explorations and researches. However, they mainly focus on tracking research developments of the US military, and there is still a certain gap with Western countries led by the US military. . Cai Liang first introduced the AI-ESTATE architecture in his paper, completed the interface design of three information models (common element model, diagnostic reasoning model, and fault tree model), and established the AI-ESTATE standard using COM component technology. Diagnostic module and data mining module [14]. Li Hui first analyzed the hierarchical structure of AI-ESTATE in his dissertation, proposed the use of XML Schema to implement the standardized information description of the diagnostic model, and described the common element model and the fault tree model [12]. Yang Zhancai et al. made an in-depth analysis of the AI-ESTATE standard and proposed to use the XML language to implement the diagnostic inference engine that conforms to the AI-ESTATE standard, and applied it to the graphical test software GTest to realize the life-time diagnosis of the aircraft system. Information model sharing [13]. Zhao Xia et al. used XML language to describe diagnostic information, DCOM components to implement inference engine, realized sharing of diagnostic knowledge information and portability of inference engine, and based on this, established a remote system that conformed to AI-ESTATE standard. Fault diagnosis system [15]. In his thesis, Wang Xuejin first applied the Visio control to implement the fault tree drawing function, established the fault tree model conversion module according to the AI-ESTATE standard, and generated an interactive fault tree model file. Based on this, the IEEE1232 protocol was developed. Circuit diagnostic software [17]. After analyzing the AI-ESTATE standard, Sun Xiaojin et al. combined with Bayesian network technology to establish a Bayesian network diagnostic information model, designed a software architecture based on Bayesian network fault diagnosis, and provided corresponding verification [18]. Liu Chunxia et al. deeply studied the mapping mechanism of various data types in the EXPRESS language adopted by the AI-ESTATE standard into the XML language, and used XML Schema to describe diagnostic information [19]. Based on the research of the common element model, Liu Chunxia and others briefly introduced the fault dictionary diagnosis method and Bayesian network technology and established a fault dictionary diagnosis model and a Bayesian network diagnosis model based on the AI-ESTATE standard.[20]][twenty one]. Jiang Huixia et al. in his article briefly analyzed the standardization of diagnostic knowledge in the ATS, divided all entities in the CEM into five families, and standardized description of the entities according to STEP28, simplifying the conversion process from EXPRESS to XML. Jiang Huixia et al. studied the consistency of diagnostic information description, studied Schematron's constraint representation principle, proposed Schematron's AI-ESTATE constraint description method and completed standardized description. In 2013, Jiang Huixia and others learned from Kruchten's “4+1” perspective model method, combined with AI-ESTATE, established the structure diagram of the four views of diagnosis system organization, function, information and process, and studied its composition and operation method. A reusable, interchangeable fault diagnosis system architecture was built. In 2017, Jiang Huixia and others explored the architecture and information transfer model of the service-oriented AI-ESTATE fault diagnosis system. The static diagnosis model service diagram and the UML sequence diagram were used to analyze the interoperability services in the inference engine and other components. The process of interaction and model management service exchanges during model indexing and editing have laid a good foundation for the development of diagnostic systems. Wang Yuehai and others extended the diagnosis model in AI-ESTATE and proposed a knowledge base generation protocol containing multiple artificial intelligence diagnosis methods. The automatic generation system of TPS (Test Program Set) was designed and verified by simulation. Xu Menghan realized the TPS automatic generation, through extensive research on the standard, expanded the diagnostic information model, increased the neural network model, support vector machine model and artificial immune system model, and the support vector machine algorithm and AI- The standard fault tree given by ESTATE was merged to realize the automatic generation of the fault tree. The experiment proved that this method has strong universality and improved the accuracy of automatic generation of fault trees After researching the AI-ESTATE standard and BP neural network algorithm, Li Jiaojiao established the BP neural network diagnosis model and the BP model file conversion module and the corresponding diagnosis inference engine. Based on this, the prototype of the simulation circuit simulation and data management software was realized. System, and through the test circuit board for fault diagnosis experiments, verify the feasibility of the system.

6. SUMMARY AND OUTLOOK

The AI-ESTATE standard is an important part of the next-generation diagnostic system platform. It enables the sharing of data and information in the diagnostic system, the diagnostic model, the diagnostic inference engine portability, the effective use of test and diagnostic resources, and the cost of fault diagnosis. . As the AI-ESTATE standard continues to be updated and updated, its research direction is also becoming more and more extensive, not only confined to the construction of static diagnosis models, but also focuses on the management of the entire test diagnosis process and the evaluation of various resources. This laid the foundation for building open, interoperable and standardized remote fault diagnosis systems. With the rapid development of test technology, diagnostic technology based on AI-ESTATE will be an important direction in the field of test and diagnosis.

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