COMMUNICATION BETWEEN MULTI-AGENTS IN ROTATING MACHINERY DIAGNOSTIC SYSTEM

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Abstract - This paper is to explore the impact of communication between multi-agent rotating machinery diagnostic systems on the diagnostic system. By constructing a communication strategy based on the communication server and KQML language extension for the multi-agent diagnostic process of rotating machinery, the working condition of the multi-agent rotating machinery diagnostic system is studied. This paper mainly studies the accuracy and stability of the multi-agent diagnostic system before and after the improvement of the communication strategy. Also, the effects of communication systems in three different communication extension languages, KQML, KIF, and FPA-ACL, are analyzed. The research results show that the communication strategy based on the communication server and KQML language extension of the multi-agent diagnostic process of rotating machinery has significantly improved the accuracy and stability of the diagnosis of rotating machinery before and after improvement. Compared with the communication system based on KIF and FPA-ACL communication extension language, the diagnosis system based on the KQML communication language has a significant improvement. It can be known that the improvement of the communication system based on session management and message forwarding has achieved satisfactory results. Therefore, the communication strategy based on the communication server and KQML language extension of the multi-agent diagnostic process of rotating machinery has obvious advantages in the diagnosis effect of many types of rotating machinery. It makes full use of the role of communication language to reduce the diagnostic error rate. The communication strategy based on the communication server and KQML language extension of the multi-agent diagnostic process of rotating machinery meets the requirements of fault diagnosis for rotating machinery. The research on communication between rotating machinery diagnostic systems in this paper has a positive effect on subsequent research.

Keywords: Communication; Rotating Machinery; Agent; Language; Diagnosis.

1. Introduction

As the most important symbol product of industrial society, machinery has become an essential part of our lives [1]. Machinery has brought great help to social progress and the improvement of people's living standards. Whether we travel by cars or airplanes are made of machinery. Machinery is the assembly of a category, which contains many categories, and each category contains a lot of things. Rotating machinery is a very important category of machinery [2]. The rapid development of the rotating machinery industry has brought great convenience to people's lives and society. But at the same time, the rapid growth of rotating machinery has brought another problem. Since people are already very dependent on machinery, the occurrence of the mechanical fault has a great impact on life and work [3,4]. Therefore, a reliable and stable diagnostic system for rotating machinery is very important for the stable operation of rotating machinery [5]. At present, there are still some technical difficulties in the fault detection of rotating machinery, including the failure to share information, missed detection of faults, and early warning capabilities in the face of multiple faults [6]. The research on the diagnostic system of rotating machinery has spread to all levels. At present, relevant departments have invested huge financial resources and energy in this field. Rotating machinery is a very critical type of machinery, and it will also be an important common machine in the future [7]. The improvement of communication systems and strategies for rotating machinery diagnostic systems is a core part. The communication system is the eyes and ears of a rotating machine diagnostic system. All fault information needs to be collected and shared by the communication system. But one of the most difficult problems encountered in the communication strategies of rotating machinery diagnostic systems internationally is the failure to effectively collect and convey fault information under different fault conditions [8]. Improving the communication strategy capability of a rotating machinery diagnostic system is an important prerequisite for achieving stable, safe, and long-term operation of rotating machinery [9]. Rotating machinery has a wide range of functions in daily life and has become a more important category in mechanical systems. Whether in the military, aerospace, industry, and life, it has a wide range of applications. This paper studies the communication strategy of rotating machinery by constructing a communication strategy based on the communication server and KQML language extension of the multi-agent diagnostic process of rotating machinery. Then, it analyzes the role of communication on the diagnostic system qualitatively and quantitatively [10].

The internal and external structure of rotating machinery is very complicated; thus, the diagnosis of its fault is a very challenging task. If accurate fault diagnosis of the rotating machinery can be realized, the economic and time consumption can be reduced to the maximum, improving the working time of the machinery. Without effective diagnosis and understanding, maintenance time and effort for the fault will be greatly increased. Machinery is currently the most stable and efficient working mode, which can replace manual work, and the relative value ratio is relatively high. The in-depth study of machinery is already at a critical stage. Therefore, the research focus of this paper is to construct and design a communication strategy for an efficient diagnostic system of rotating machinery [11].

To sum up, this paper studies the accuracy and stability of the diagnosis system by constructing a communication strategy based on the communication server and KQML language extension of the multi-agent diagnostic process of rotating machinery. Also, the effects of communication systems in three different communication extension languages, KQML, KIF, and FPA-ACL, are analyzed. The research shows that the communication strategy based on the communication server and KQML language extension of the multi-agent diagnostic process of rotating machinery has obvious advantages in the diagnosis effect of multiple types of rotating machinery and reduces the detection error rate. The communication strategy constructed in this paper meets the requirements for the diagnosis of rotating machinery.

The innovation lies in the analysis of the communication link of the diagnostic system.

At present, most of the research directions are in the rotating machinery diagnostic system itself. Therefore, this paper has a very important value for the subsequent research on the communication strategy of the rotating machinery diagnostic system.

2. Methodology

2.1. Multi-Agent system

Multi-Agent system refers to a collection composed of multiple computable agents.

Each Agent is a physical or abstract entity that can communicate with other Agents, acting on itself and the environment. MAS is a distributed system. There are multiple asynchronous and loosely coupling problem solvers in the system, and they work together to complete tasks that cannot be completed independently by a single solver [12]. Asynchronous means that the problem solvers operate in parallel and loose coupling indicates that more of the problem solving is internal calculations rather than communication with each other.

The structure of the Agent is shown in Figure 1.

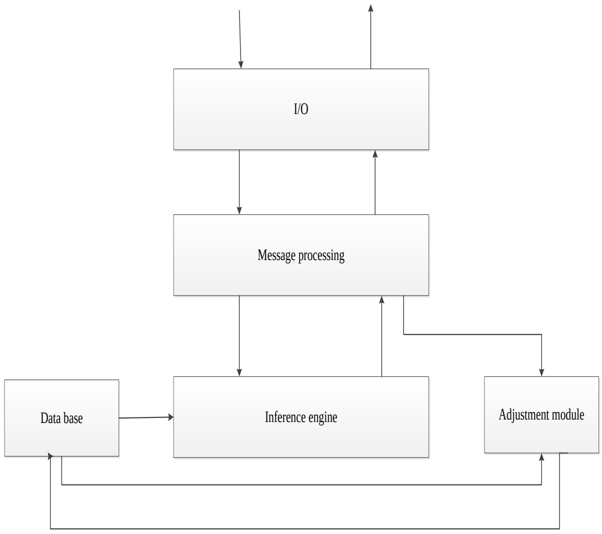

Figure 1: The structure of Agent

2.2 The Communication modes between Agents

Communication is the key to achieve collaborative work among multiple agents. The communication between each Agent is realized through the interaction between the agents. There are four communication modes. Distributed problem solving: This collaborative problem-solving method is to perform a collaborative solving through a loosely coupling knowledge base set scattered across different nodes. Adoption: A certain Agent realizes the goal of another Agent as its own goal to achieve collaborative work [13]. Collaboration: Each Agent has its own goals. Either they cannot complete their own tasks, or the purpose is to better achieve their goals. Therefore, they reach mutually beneficial agreements with each other, achieving collaborative work through collaboration. Impact: A certain action of one Agent may affect the goal achievement of another Agent.

The above four communication modes can be almost divided into "blackboard" and "messaging" [14].

2.3 The characteristics of agent communication language

Communication languages and protocols have completely different structures and settings. Both are the same in that they are used to solve technical problems in communication and related layers. In general, the distinction between protocols and communication languages is very clear. The communication protocol mainly includes the meaning of three aspects: The first layer is a communication content transmission protocol similar to SMTP, TCPIP, and HTTP. The second layer is the links between high-level frameworks, such as games, planning, and negotiation. The third layer is the restriction and exchange of communication language [15].

The communication model of KQML is shown in Figure 2. For the design of the communication language of the rotating machine diagnostic system, the first layer protocol can be used as a transmission medium of communication content and information. The second layer protocol is regarded as the implementation method of the communication system, and the third layer protocol is regarded as part of the communication language and communication boundary. There is a subordinate relationship between communication protocols and communication languages. The intelligent agent communication language is generally divided into 7 levels of reliability, environment, network, semantics, content, implementation, and form [16]. A communication language that can meet these requirements at the same time has a very important practical application value. Meanwhile, the settings between these 7 levels may conflict. Thus, the design of the homophonic language needs to be fully considered and analyzed [17].

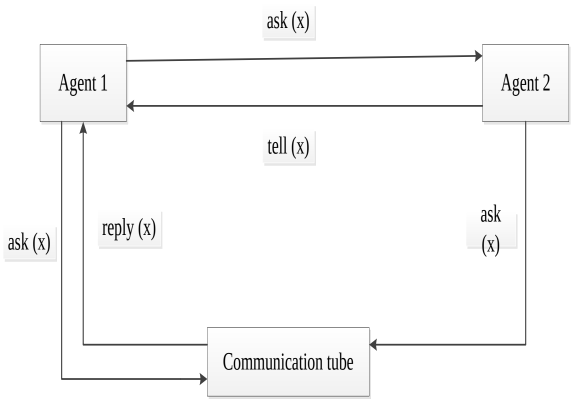

Figure 2: The communication model of KQML

2.4 The diagnosis process of intelligent diagnosis system for rotating machinery

The communication strategy based on rotating machinery multi-agent diagnosis process requires cooperation and information sharing among multiple agents. The communication manager is downloaded and installed through a browser.

The main function of the communication manager is to obtain the user's instructions all the time, to understand the time and fault type of the user regarding the diagnosis object. The Agent user port mainly uses two language translators of Java and KQML that can convert each other. The main function of the converter is to collect the user's operation instructions and convert these instructions into the KQML communication language format. The main task of the decomposition agent is to process the messages and data transmitted by the communication system, re-divide the diagnostic tasks and transmit them to the relevant agents to perform the diagnostic tasks. At the server port, except for the fault mode agent and the signal processing agent, after receiving the diagnosis task about the rotating machinery, all other relevant agents first need to obtain the relevant fault characteristic data from the database. Then, the KQML information is converted into messages in Prolog language mode, and these messages are interpreted as diagnostic tasks that need to be performed.

2.5 The communication requirements of the multi-agent diagnostic system

The communication model of the intelligent diagnosis system for rotating machinery is shown in Figure 3. For the communication strategy of the rotating machinery multi-agent diagnostic system, the problems that need to be solved are mainly concentrated in three aspects: communication protocol, communication language, and session management.

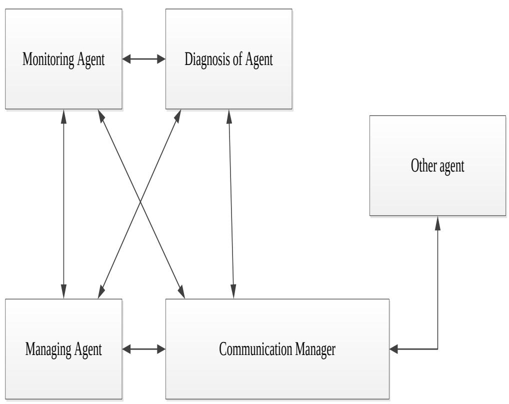

Figure 3: The communication model of the intelligent diagnostic system for rotating machinery

Communication protocol: The communication protocol refers to a broad-level protocol, including a lower-level transmission protocol and a top-level message dialogue protocol. The message dialogue protocol mainly expresses the possibility of fault corresponding to the message during the diagnosis process. The lower-level transmission protocol refers to some relevant transmission mechanisms, such as SMTP, TCPIP, and HTTP. Communication language: The communication language is the medium for information transmission and communication in communication systems. Both parties have the same definition of semantics, grammar, and pragmatics. Session management: Once the communication consciousness and channel are formed, multi-cycle messages are required to complete the purpose of communication. There is a certain causal relationship between the messages. Understanding message intent not only depends on the message itself but also adds the context and the past of dialogue. Therefore, session management is a very necessary link, which can add messages to the communication protocol.

2.6 The design of communication manager

In the rotating machinery fault diagnosis system, to realize the communication between the diagnosis systems, the first step is to require the capability, address, and name information of the Agent. It mainly includes the following two methods. The communication manager in the intelligent diagnosis system of rotating machinery is shown in Figure 4.

In the communication system, the Agent needs to save messages of all other relevant Agents. Therefore, this method will require massive storage space, and the stored messages will remain stable. In general, this method cannot meet a wide range of agent systems. Once some agent messages are disordered, it will cause a large range of message confusion.

This method uses a tailor-made communications manager to manage diagnostic messages. Each Agent diagnostic module transmits its information to the communication manager when starting work and deletes the information when stopping work. The method can solve the storage and confusion problems that may be caused by a large amount of Agent information storage, but it is necessary to increase the management capacity of the server. In special cases, a combination of the two methods can also be adopted. The first method is adopted when the relationship is close, and the second method is adopted for other needs.

The address of the communication interface is based on the address provided by the KQML interface and converting it into a physical address by a converter. Then, the message is processed and transmitted to realize the establishment and transmission of the network. Its role is to control the transmission of all messages, provide ports and interfaces for message reception and transmission. Also, it connects and transmits messages to other agents.

In the process of diagnosis of rotating machinery, each separation process needs to be cycled to achieve. The communication interface mainly transmits and sends messages according to the KQML communication language. The network communication mode adopted can process and reorganize the KQML communication language.

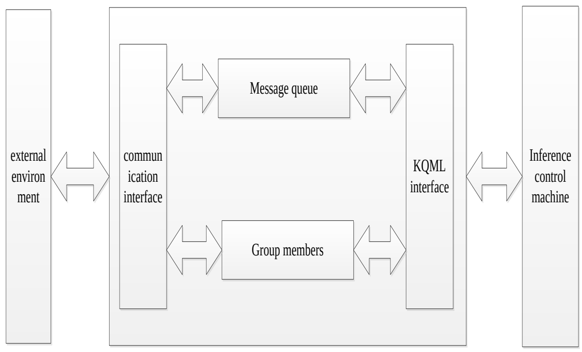

Figure 4: The communication manager in the intelligent diagnostic system for rotating machinery

2.7 The communication function of Multi-Agent diagnostic system

The communication agent for intelligent diagnosis system of rotating machinery is a special Java applet that is deployed on the clients participating in diagnostic work. And it provides network communication services such as sending, receiving, packaging and unpacking messages for diagnostics. Each communication agent only has a two-way communication link with the message forwarding agent, which is a centralized message communication mechanism. The packaging and unpacking services between various primitives and KQML messages are provided.

The message forwarding agent in the intelligent diagnostic system of rotating machinery is a special Java application that accepts messages sent by all communication agents participating in the diagnosis user registration. According to the content of the message, it is forwarded to the communication agent of other diagnostic clients, or processed by contacting object management agent, session management agent, and interface agent.

The communication process is saved to the database of the diagnostic system. Therefore, the message forwarding agent in the intelligent diagnosis system of rotating machinery is equivalent to a router, which is fully responsible for the communication and connection between the communication agents. It provides a comparison relation between the logical name of the Agent and the actual address. For the user, this Agent address is transparent, and only the name of the Agent can be known. In this way, the communication agent does not need to show its specific physical address and can move dynamically. The message forwarding agent maintains information such as the capabilities and status of all agents in the system.

In the intelligent diagnosis system of rotating machinery, the use of the message forwarding agent has the following advantages. First, the message forwarding agent can serve as a directory service, providing a communication mechanism between different communication agents and other service agents. Secondly, the message forwarding agent has a strong message cache and queuing mechanism. If one Agent is down or multiple messages are sent at the same time, the messages will not be lost, making asynchronous connections possible.

The message transmission model is shown in Figure 5. In most cases, the session management module of the rotating machine diagnostic system is installed on the server. It is a procedural expression, which communicates with the message forwarding agent and the session management agent in most cases.

The main functions include session control, program management, floor control, access right control, and dialogue policy management, which are almost equivalent to the functions of a server.

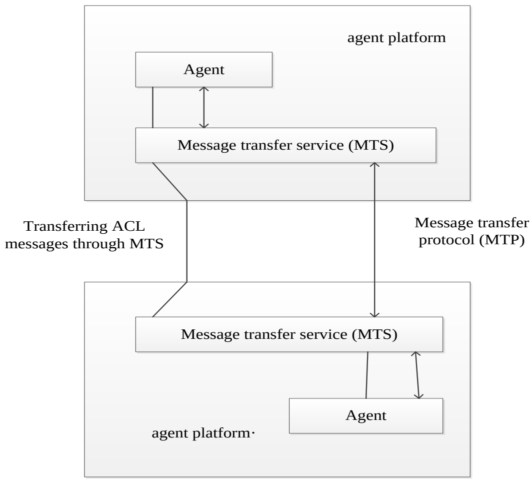

Figure 5: The message transfer model

Session control includes the processing of creating a new session, closing a session, joining a session, and exiting a session.

The floor control of the session includes authorization control of shared resources in the collaborative session, which is used to resolve conflicts caused by concurrency control. This paper adopts a floor control mode based on a combination of token and centralized control.

The collaborative users who need to speak make a request, and after the speaker actively releases the token, they can get the floor. At the same time, the session administrator can directly interrupt the current floor and authorize it to another diagnostic user. Access control is used to restrict the session user's right to the operation of session resources.

This paper uses role-based access control.

In addition, the session management agent is also responsible for the management of the retrospective diagnosis meeting, contacting the database, and maintaining the diagnostic session database.

2.8 The design and implementation of the communication agent

The communication between agents is shown in Figure 6. According to the functions to be implemented by the communication agent, the communication agent in the system only selects two components of the communication manager and the user interface in the general agent structure. There are only two components in the communication manager: the communication interface and the KQML interface database.

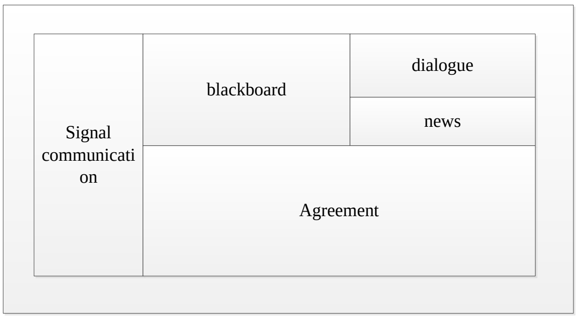

Figure 6: The communication between agents

When implementing the multi-agent communication in the intelligent diagnosis system of rotating machinery, JAT Lite is selected as a template, and some classes are derived to complete some functions of the agent. JAT Lite provides a template for creating agents using high-level languages and protocols, which includes 5 layers: abstraction layer, basic layer, KQML layer, router layer, and protocol layer. Developers can easily choose any layer to create their own application system and extend the class database it provides according to their needs. After changing one layer, the other layers are not affected. JAT Lite has the functions of registering the Agent on the router with a name and password, connecting the Agent to the Internet or disconnecting it, sending and receiving messages, and transferring files. Also, it is particularly convenient to build an Agent that uses KQML to send and receive information. It enables the Agent to communicate under open standards, which solves a series of problems including the communication language and communication protocol in the intelligent diagnosis system of rotating machinery. Then, it reduces the development cycle of the Agent and fully reflects the software development ideas of code reuse.

The working process is roughly described as follows: The communication agent starts initialization and initializes the data of all members. Then, the Connect method is used to connect with the message forwarding agent to establish a message transfer channel. A communication thread is created, and an interception node is started to listen to the message at the Socket. The communication interface enters the message loop: unpacking or packaging the KQML message and sending the message out.

The design of the message forwarding agent: According to the functions to be implemented by the message forwarding agent, the message forwarding agent in the intelligent diagnosis system of rotating machinery selects components such as communication manager, inference control machine, rule base and user interface in the general structure of the agent.

The general description of the working process is as follows: The message forwarding agent is started to initialize all member data. The requests from external agents are received to connect or register. After that, the handshake with the external agent is achieved to establish a channel for message transfer. According to the environment variables set at start-up, the interception node is started to listen to the network messages. The communication manager is shown in Figure 7. The KQML message is got from the Socket, and the analytical attach is performed for it. After contacting the internal rule base, the inference control machine is used to infer. Then, the capabilities and status of all agents are maintained in the system. The conflicts between agents need to be negotiated when necessary, and the messages are forwarded to other agents.

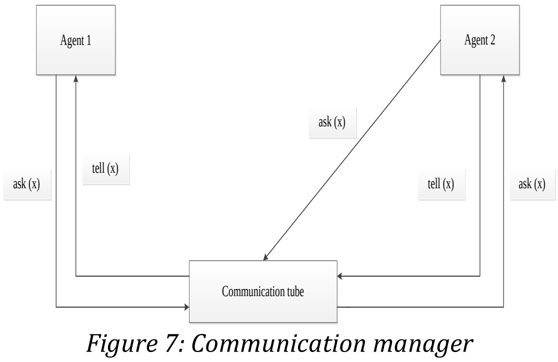

Figure 7: Communication manager

The design of the session management agent: According to the functions to be implemented by the session management agent, the session management agent in the system needs to use all the components in the general structure of the agent. These components include the communication manager, the inference control machine, the rule base, the user interface, and the behavior performance interface.

The general description of the work process is as follows: The session management agent is started to initialize all data members.

The requests from the message forwarding agent are received to connect and register. After that, the handshake with the message forwarding agent is achieved to establish a channel for message transfer. According to the environment variables set at start-up, the initialization method of the communication interface is used to initialize the data structure of the network communication. Also, the interception node is started to listen to the network messages.

Then, it enters the message loop: The KQML message is got from the Socket and parsed to get the message text.

After contacting the internal rule base, the inference control machine is used to infer and processing the message text. Then, the message is returned by accessing the database. After packaging the message, it is sent to the message forwarding agent to end an elimination cycle.

3. Results and Discussion

The research on accuracy before and after the improvement of rotating machinery diagnostic system communication is shown in Figure 8. From the figure, as time goes on, the improvement of the multi-agent diagnostic system communication of rotating machinery has a significant gap in the fault diagnosis rate of rotating machine steam turbines, gas turbines, centrifugal pumps, axial compressors, and wheels compared with before improvement. The research shows that the multi-agent communication strategy for the rotating machinery diagnosis based on the communication server and KQML language extension has significantly improved the diagnostic accuracy of rotating machinery such as steam turbines and gas turbines. Therefore, the multi-agent communication strategy used in this paper has an excellent performance in the diagnosis of rotating machinery.

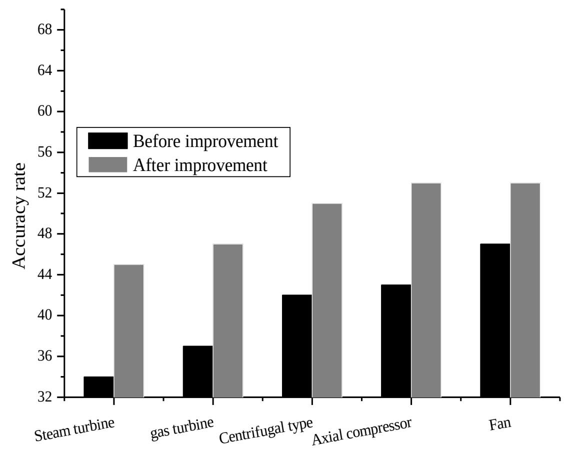

Figure 8: The research on accuracy before and after the improvement of rotating machinery diagnostic system communication

The research on stability before and after the improvement of the multi-agent diagnostic system communication of rotating machinery is shown in Figure 9.

From the figure, the stability of the diagnostic system before the improvement of the rotating machinery multi-agent diagnostic system communication is relatively poor, with significant fluctuations.

There is a significant difference between the five sets of test data obtained by the same experimental subject under the same conditions.

It shows that the stability of the diagnostic system before the improvement of the communication system is relatively low.

After the improvement of the multi-agent communication strategy in the diagnosis of rotating machinery based on the communication server and KQML language extension, the stability of the diagnostic system has been significantly improved.

The results obtained from experiments performed under the same conditions are consistent.

Therefore, the stability of the diagnostic system after the improvement of the communication system is relatively high, and the obtained results have high credibility.

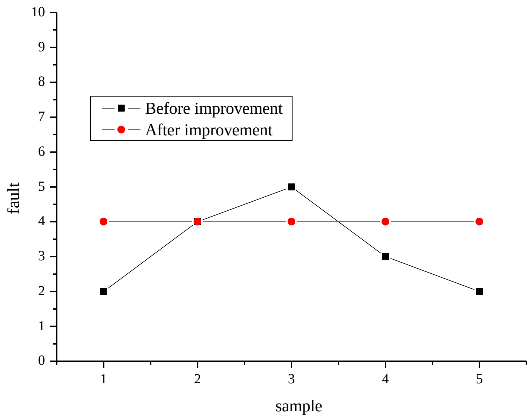

Figure 9: The research on stability before and after the improvement of the multi-agent diagnostic system communication of rotating machinery

The research on accuracy before and after the improvement of different communication in rotating machinery multi-agent diagnostic system is shown in Figure 10.

From the figure, under the action of three different communication languages, the accuracy of the diagnosis results of the multi-agent diagnostic system of rotating machinery has different performances. Compared with KIF and FPA-ACL language extension, the diagnostic accuracy of the rotating machinery diagnosis system based on KQML language extension is significantly improved.

Regardless of any kind of equipment such as rotating machinery steam turbines, gas turbines, centrifugal pumps, axial compressors, and wheels, the accuracy of the diagnostic system under the KQML language extension in this paper is the highest.

Therefore, the multi-agent communication strategy has an excellent performance in the diagnosis process of rotating machinery based on the communication server and KQML language extension.

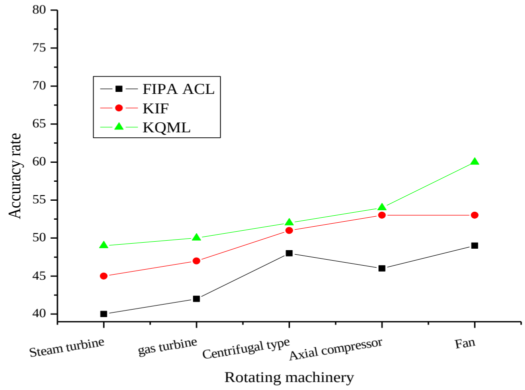

Figure 10: The research on accuracy before and after the improvement of different communication in rotating machinery multi-agent diagnostic system

4. Conclusion

This paper analyzes the accuracy and stability of the diagnostic system through the rotating machinery multi-agent diagnostic process communication strategy of communication server and KQML language extension. Also, it analyzes the effects of the communication system in three different communication extension languages KQML, KIF, FPA-ACL.

The research results show that the communication strategy based on the communication server and KQML language extension of the multi-agent diagnostic process of rotating machinery has significantly improved the accuracy and stability of rotating machinery diagnosis after improvement. Compared with the communication system based on KIF and FPA-ACL communication extension language, the diagnosis system based on the KQML communication language has a significant improvement.

Therefore, the improvement of the communication system based on session management and message forwarding has achieved satisfactory results.

There are also some shortcomings in the research process of this paper.

The diagnostic systems and communication systems for rotating machinery should be studied simultaneously.

At present, the conclusions obtained are more in the theoretical stage, and there are still many factors and problems for actual field operation.

In the experimental stage, many external factors are ignored.

Thus, the results are not convincing.

But it provides a valuable reference for the research of the communication strategy of the rotating machinery diagnostic system from a qualitative perspective.

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