A Knowledge Acquisition and Management System for Fault Diagnosis and Maintenance of Equipments

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Abstract: - Equipment maintenance is one of the essential tasks for manufacturing industries. There have been a number of information systems developed to cope with equipment malfunctions. Most fault diagnosis systems are applications of expert systems which have two drawbacks with regard to knowledge acquisition. One is the lack of knowledge continuity; the other is the limited source of knowledge being incapable of combining knowledge of entire workforce. In this study, we propose an equipment maintenance decision support system architecture with a flexible knowledge maintenance methodology. A case implementation to a sewage management company with multiple distributed plants is introduced to show that the proposed approach helps more efficient utilization of experience-based knowledge in maintaining equipments.

Key-Words: - Knowledge acquisition, knowledge management, equipment maintenance, decision support, computer-supported cooperative work

1 Introduction

Continuous improvement of business IT applications has become widely recognized as important for enterprises to be further competitive. Since proper equipment maintenance is one of the essential tasks to keep higher productivity of manufacturing industries, many of decision support tools have been reported recently. Both architectural model and the implementation details of an Internet-based knowledge acquisition method capable of acquiring and managing knowledge in a cost-effective manner are presented in [1]. A prototype of an expert system for fault diagnosis in scooters platform using fuzzy-logic interference with adaptive order tracking technique is developed in [2]. Hongmei *et al.* [3] presented the design of a novel missile fault diagnosis expert system based on neural network ensembles. Their system can not only make up the incapacities of traditional diagnosis expert system, but also make full use of the fault diagnosis knowledge in performing missile fault diagnosis.

Most of the fault diagnosis systems are applications of expert systems. They use a knowledge base that consists of domain specialists' knowledge (e.g., rules generated on the basis of their experience) and try to solve real-world problems as domain specialists do. The expert systems use a consulting framework, which is depicted in Fig. 1**.** The left side of this figure represents that the limited number of experts are the knowledge-supplier to the system. The right side of this figure illustrates that the majority of users are just the beneficiaries. Typically, one expert (or sometimes several experts) provides knowledge and many other novice users utilize it [4].

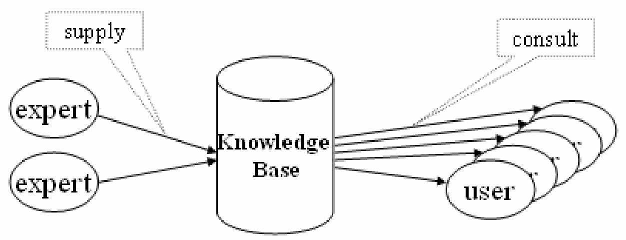

Fig. 1. Architecture of conventional systems.

There are two main disadvantages during knowledge acquisition stage within such architecture. First, these systems focus on the knowledge of the limited number of experts being incapable of combining knowledge of entire workforce. In workgroups, people have diverse skills, experience, and heuristics [5]. The speed and power of the computer-based systems can be harnessed to enable individuals and teams to try out as many options as possible, as efficiently and quickly as possible, and to share what they learn with their colleagues [6]. Second, knowledge acquisition in such systems lacks continuity. The knowledge base built up initially is not updated as promptly as new valuable tips are increasingly accumulated. When system users become accustomed to the system, they may begin to find that the system answers based on initial knowledge are rather limited or predictable. It may further happen that the cases they are familiar from prior experiences are not handled by the existing system. In order to address these disadvantages, we propose a fault diagnosis decision support system that allows *continuous* knowledge acquisition from the *entire workforce*. This web-based system is designed to acquire and manage knowledge from the contribution of individuals distributed over several plant sites.

The remainder of this paper is organized as follows. In Section 2, the problem situation, which gives the context and objectives of our system, is briefly introduced. In Section 3, the fault diagnosis decision support system design is proposed; the 3-tree knowledge structure, knowledge acquisition method and quality assurance issues are detailed. Architecture and implementation of the decision support system are described in section 4. Finally concluding remarks are provided in Section 5.

2 The problem situation

The sewage treatment group (STP) is a state-owned wastewater utility with assets of 1 billion dollars and operates seven middle scale wastewater treatment plants around a city. The principal activities of STP are to collect and dispose sewage after proper treatment of wastewater which play an important role on water pollution control and water environment improvement.

Since the capacity of sewage treatment facilities is not enough, it requires all the STG plants are running at peak performance 24 hours a day. Capital facilities are the life-blood of STG. Their economic return will determine the success of the STP. Facility performance is critical because productivity and downtime issues will erode margins and profit. The day-to-day risk of operating these critical facilities demands high-quality and speedy troubleshooting.

When an equipment fault occurs, STP workers of each plant try to handle it by themselves. When a fault happens, the worker reports the problem to the equipment management department. The department designates certain staffs to handle the problem. If they can not handle the problem, they call the specialized outsourcing repair companies incurring some cost. The work process is represented in Fig. 2.

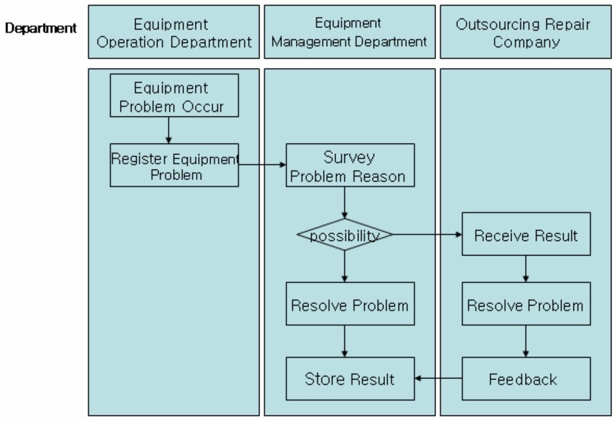

Fig. 2. Work process before implementing the systems

Every year, a large proportion of operation costs are spent on the repair fee. Reduction of maintenance request orders to the outsourcing companies will save time and costs. For STG, all plants have similar facilities; they may encounter same maintenance issues. A fault encountered in a plant could also have occurred before in other plants or itself. In addition, workers of STG have attained qualified skill level and some of them are expert mechanics. A system is required to collect the experience and wisdom of employees of STG and utilize them to find the solutions of equipment faults.

3 Decision Support System Design

3.1 System Overview

There is no denying the fact that enterprises nowadays live in an overflow of information and knowledge from both inside and outside: enterprises must face a knowledge-based economy and knowledge-based competition. Knowledge itself is the source of profit and productivity. In STP, knowledge means reduction of maintenance costs and better operation of equipments. It helps the plant to increase profit directly. Proposed fault diagnosis decision support system is used to acquire and manage distributed knowledge from the contribution of individual workers. Anyone in the company can benefit from the combined knowledge of the entire workforce.

Our system is built on a platform where most participants have equal opportunities to access knowledge, as depicted in Fig. 3. Users including experts share knowledge as equal participants. Selected experts do the role of knowledge administrators of the system. They both contribute and utilize the system. But the main role of them is to manage and maintain the knowledge base to assure the quality of it, rather than just simple knowledge suppliers. They play a different role from those depicted in Fig. 1.

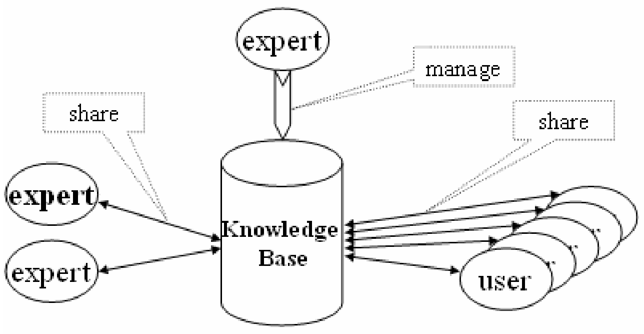

Fig. 3. Proposed architecture of our systems.

As we know, people learn by asking and answering questions. The system offers a shared space where users can ask questions and other users can collaboratively answer those questions. When a worker meets an equipment fault, she first search the answer in the system. If she can get the answer, she benefits from the system directly. Or she can add an item of fault phenomenon. The problem will become a new case item of the system and contribute for future uses. After solving the fault, she can provide reasons and solutions to the fault. The experience and result of the repair process could also improve the correctness and rationality of related knowledge. Questions and answers are saved in a categorized, searchable database so that they can be found, read and modified at any time. System users can learn from others' questions and solutions as well as by their own questions and solutions. The system also provides a hierarchical directory structure to manage knowledge and a mechanism to assure the quality of the knowledge. Knowledge structure and problem solving (and new knowledge acquisition) process is described in more detail.

3.2 Ontology for Facility Fault Diagnosis

Our system organizes the knowledge in a tree style structure which can be divided into three sub-trees. On the top is the equipment tree which represents the hierarchical structure of equipments as depicted in Fig. 4 (a). Independent equipment or equipments of same type are represented as leaf nodes. Each type of equipment has its own specifications and corresponding components or parts. This BOM (Bill-of material) style information is represented by specification-part trees, as depicted in Fig. 4 (b). A fault may have several reasons, and each reason may have several solutions, as depicted in Fig. 4 (c). Each node of specification tree can be the root of fault tree. Fig. 5 illustrates a sample screen shot of navigating knowledge trees. The left-hand side of this figure represents the equipment tree, while the right-hand side shows the detailed information of this category. The system allows easy (re)allocation of any new or existing knowledge in the tree structure. Powerful search functions are also provided for the immediate search and locating.

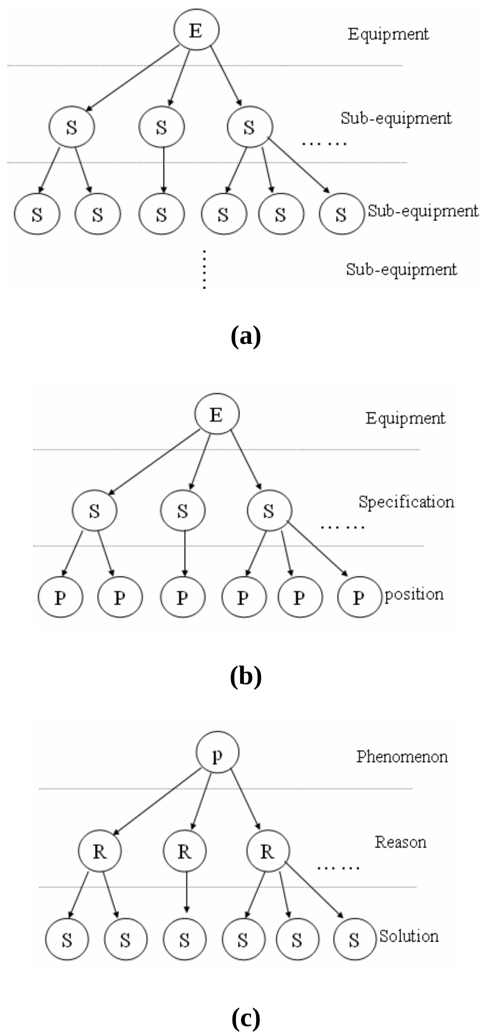

Fig. 4. Knowledge representation in 3-tree structure: (a) equipment tree, (b) specification-part tree and (c) fault diagnosis tree.

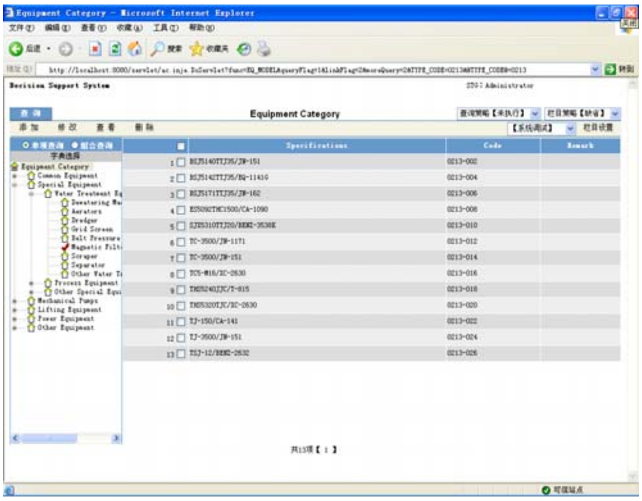

Fig. 5. Sample screen shot of knowledge tree navigation.

3.3 Knowledge Acquisition

As depicted in Fig. 6, the work process starts when a user meets an equipment fault. The proposed system acquires new knowledge from two sources. One is the answers given by other intra-STG workforces; the other is the repair report summarized by the outsourcing companies. The knowledge acquisition process is first check whether the knowledge in the system is enough to handle the equipment fault. This can verify the knowledge and improve the quality of the knowledge. If there is not enough knowledge, users need to turn the second step and ask a question by describing the phenomenon of the fault. If nobody answers the question, the user has to process the third step. The third step is to give the task to a repair company and submit a report to the system. The results of step 2 or 3 are utilized to enhance the system knowledge, by improving the quality as well as by extending the quantity of the knowledge base.

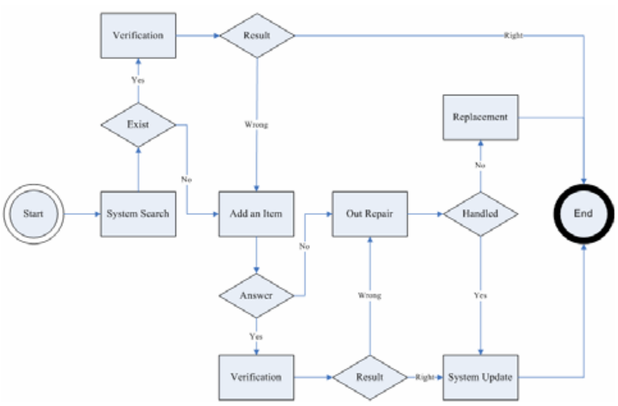

Fig. 6. Knowledge acquisition work process.

Knowledge enhancement is achieved by one or more of the following ways: 1) Utilize and verify the existing knowledge; 2) Modify the existing knowledge; 3) Append a new item to the knowledge base. Case 1 is for when a user can find the knowledge and use it to handle the fault. When a user can find the knowledge but fails to handle the fault, cases 2 and 3 can be activated. When a user can not find the knowledge, then case 3 is activated. By this way, the system allows progressive expansion and further enhancement system knowledge.

3.4 Knowledge Quality Assurance

Since the system allow free access and open for all the related employees, on one hand, it can gather collective intelligence. On the other hand, it increases the chances of knowledge degradation. The fault diagnosis decision support system handles the quality problem with the following methods. First, all the historical changes are recorded. Inappropriate changes can be resumed and the authors of them can be identified. Second, the knowledge verified by diagnostic processes for several times will be locked and will not be modified since then. Finally, the authors of locked knowledge will be encouraged and awarded by their employer.

4 Architecture and Implementation

Proposed fault diagnosis decision support system is fully web-architected, enabling users to supply and utilize knowledge over any Internet or intranet connection. The application of VPN technique integrates the plants and headquarters into one centralized system, by using the shared public lower-cost infrastructure. Comparing to the two-tier client-server model, it is more flexible and costs less with just a simple server side system update.

Fig. 7 shows system users' workstations of seven plants are connected to the servers of headquarters by internet and VPN techniques. At headquarters, server systems and clients' workstations are connected through the LAN. Figure 8 shows the system architecture with components in J2EE environment, where shaded boxes represent those defined in the system and implemented. Client workstations just need web browsers to communicate with the server by http protocol. Component-based application design allows reusing those components, within the application as well as when to integrate with external applications. The components in application layer which is used to express business logic are built on the components which supply fundamental services in basic layer. The workflow component in basic layer supports the automated work processes like the processes depicted in Fig. 6. The Resin (Caucho Technology) is utilized at the web application server.

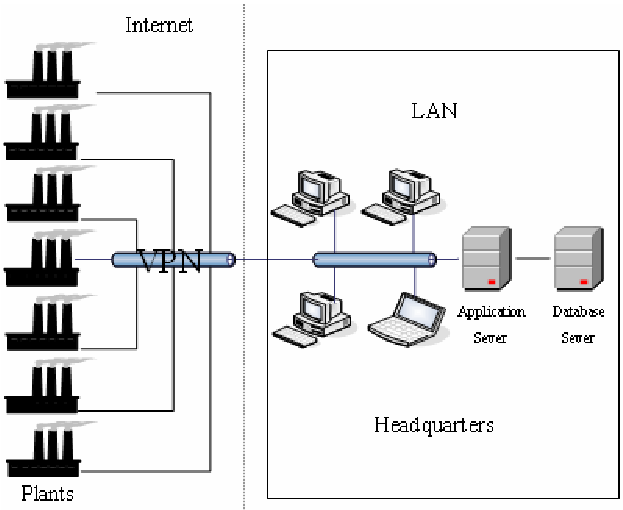

Fig. 7. Overall system environment.

In addition, a MVC structure is also adopted in the system implementation. JSP acts as a viewer and generates dynamic webs to interact with users. Objects in application layer and basic layer are as models. And the servlet, as the controller, processes and responds to events and invokes changes on the model and the view. The JSP and objects can only communicate with the servlet.

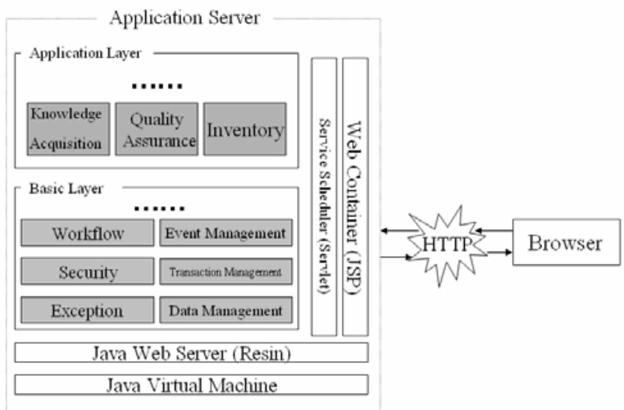

Fig. 8. System architecture with components in J2EE environment.

5 Conclusion

In this paper, we introduced a web-based equipment fault diagnosis support system which allows continuous enhancement of the system knowledge from the entire workforces. The system utilizes the collective intelligence, rather than depending on limited number of experts. Domain knowledge is represented in tree structures and allows easy navigation and expansion. In order to prevent the degradation of knowledge, three methods to assure the quality of knowledge are also introduced. The component-based architecture in J2EE environment allows cost savings in system maintenance. Finally, this system helps enhancing entire workforces as well as saving costs of equipment maintenance by providing integrated knowledge distributed over several plants.

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