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Intelligent system architecture for process operation support

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Abstract

This paper presents a generic intelligent system platform, namely INTEMOR (INTElligent Multimedia system for On-line Real-time application), for process operation support. INTEMOR is developed by combining artificial intelligence, computer system and information technology into a unified environment. It integrates various function modules to perform operation support tasks, including communication gateway, data processing and analysis, on-line process monitoring and diagnosis, on-line operation manual, equipment maintenance assistance, reasoning system, knowledge-base creator and multimedia interface. The industrial applications of INTEMOR on a boiler system and a chemical pulping process are illustrated.

Keywords: Intelligent system architecture; Process operation support; Artificial intelligence

1. Introduction

Modern industrial systems have become more and more complex. Plant managers and operators have to deal with vast amount of raw data in production planning, maintenance scheduling and process operation. The data and information "overload" may cause the operators confusion, leading to cognitive errors. It is true especially in time critical situation, such as equipment failure. Operators may find it difficult to quickly detect, diagnose and correct the fault. The growing complex of industrial processes and the practical need for higher efficiency, greater flexibility, better product quality and lower cost have resulted in increasing requirements for enhanced operation and management support.

The advent of computer technology has allowed us to implement more advanced process control and management systems such as process operation support (POS) system. An operation support system generally consists of on-line operation manual, fault diagnosis, equipment maintenance management and multimedia interface. Extensive research on the related topics, such as fault diagnosis expert systems (Kramer, 1991), intelligent monitoring systems (Murdock & Hayes-Roth, 1991) and knowledge-based maintenance systems (Berzonsky, 1990), have been done on chemical processes, electronic devices and mechanical equipment. The systems of such kind have shown significant benefits to the industries.

In the past decade, many different methods have been applied in developing operation support systems. Neural networks, because of their capability of learning complex and nonlinear relations, have attracted much attention in real-time data calibration, model identification of poorly-understood or complex systems (Leonard & Kramer, 1993). Rule-based expert systems can be used in solving engineering problems that depend heavily on experts' experience. However, it is difficult to maintain and extend the knowledge-base (Vargas & Raj, 1993). Case-based reasoning (CBR) shows a great deal of promise for use in diagnostic systems (Gonzalez, Xu & Gupta, 1998; Stottler, 1994). CBR uses past problem-solving knowledge, including success or failure results, to find a solution to new problems. It reflects domain experts' experience and natural problem solving. However, the CBR system is generally difficult to solve novel problems. Each individual method has its advantage in one situation, but has limitations in another. The integration of various methods will provide superior result by compensating the limitation of the individual methods.

Integrated distributed intelligent system technology was proposed for the above purpose (Danielson, Bowes, Yang & Wang, 1995; Rao, 1991; Rao, Wang & Cha, 1993, 1996). It is intended to: (i) integrate various problem solving methods, such as rule-based, model-based and CBR methods, as well as neural networks; (ii) integrate various types and levels of knowledge representation, such as integrating rule sets, past solved problems, process models and real-time data in an object-oriented environment; and (iii) integrate multiple problem solving tasks and application

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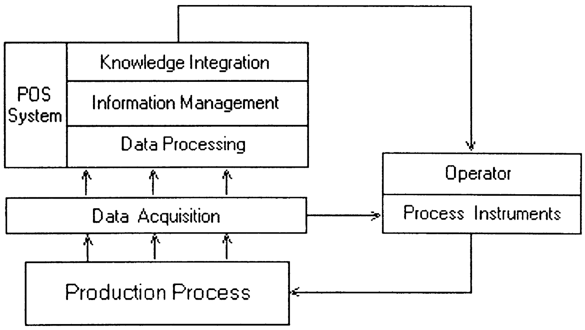

Fig. 1. Generic information flow architecture for POS systems.

systems, such as condition monitoring, fault diagnosis and maintenance support (Ursenbach, Wang & Rao, 1994).

In this paper, an intelligent POS system platform, INTEMOR (INTElligent Multimedia system for On-line Real-time application), is developed based on the integrated distributed intelligence technology. It integrates condition monitoring, fault diagnosis and analysis, information management, on-line manual and maintenance support in a unified system environment. INTEMOR employs multiple knowledge representation, combines forward chain, backward chain and CBR mechanics, and runs in a real-time distributed environment. Industrial applications of INTEMOR in a power plant and a chemical pulping process are presented.

2. System architecture

In order to realize the intelligent on-line POS system, an integrated distribution system environment is required. The development of the system architecture is based on following five requirements. First, the system is required to be able to monitor the data and evaluate its significance according to experts' experience. Second, a troubleshooting or diagnostic system has to be developed to help operators. Third, an on-line operation manual is needed to assist operators in process operation. The fourth requirement is to implement a user-friendly interactive information system, with such utilities as on-line manuals and maintenance records. Finally, there is an impetus to store the knowledge and experience to prevent the loss that occurs if some experts leave the employment of the company. In a nutshell, it is desired to create a system that will make the work of the employees more efficient.

As we know, collecting data, processing and analyzing data, and sending useful analyzing results and information back to process instruments and to operators and managers are the main tasks of control systems. In general, there are three levels of data analysis in industrial processes: data processing, information management and knowledge integration. Data, information and knowledge are at different levels. Data are individual measurement of objects. Information represents the relationship among the correlated data. Knowledge describes connection among the structure information. The POS system emphasizes application and integration of knowledge.

For the POS system, there exist two system architectures: information flow architecture and physical logic architecture. Information flow architecture shows the sequence of data analysis and the flow direction of data and information. Physical logic architecture presents the logic connections of instruments, equipment and information. The proposed information flow architecture for POS systems is shown in Fig. 1.

In data processing method, raw real-time sensor data will first undergo preprocessing techniques such as data calibration, conversation and compression to extract significant information and trends from the original mass of noisy real-time data. Data calibration and conversation processes involve filtering raw data, standardizing data and arranging data format. Data compression allows storage of only important and relevant information into a historical database for future reference. The functions of information management are to find relationship among the correlated data to produce report forms, alarm information, production planing, etc. Knowledge integration will find deep causes of events, diagnose fault, find the method to solve problem, extract expertise with knowledge-based techniques and then provide decision-making support for operator.

The intelligent system for POS is internet-based system, whose physical logic architecture is demonstrated in Fig. 2. The POS system can access real-time process data through data gateway that communicate with distributed control

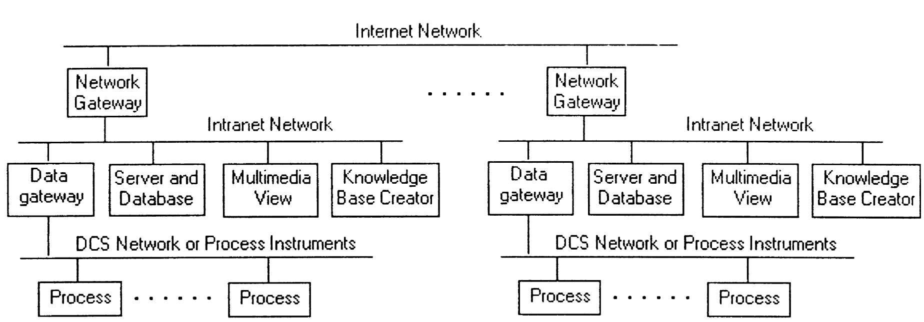

Fig. 2. Physical logic architecture for POS systems.