Safe Expert System of Chemical Process Based on Neural Network

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Abstract: - safety of chemical process is always an important part of production management of chemical enterprises, and with development of chemical industry, requirement to safe production is increasingly improving. Real-time monitoring and failure diagnosis for equipment in chemical process have significant meaning not only in theory but also in production process. This article prefer a kind of intelligence expert system for safe production use of combination of neural network and expert inference, finding abnormality and equipment failure in chemical process, to eliminate all kinds of chemical accidents. This article design the framework of expert system, providing realization based on J2EE, and analyze performance of expert system.

Key-Words: - Chemical Engineering, Production Safety, Neural Network, Expert System, Artificial Intelligence

1 Introduction

With explosion of production scale of chemical engineering enterprises and improvement of complexity of schedule, production safety of enterprises is playing an important role. In scope of the world, serious safety accidents triggered by equipment failure and neglect take place ceaselessly. The accidents in chemical process not only bring about huge loss to production, threat safety of body seriously, but also cause severely destroy to natural surroundings. Production safety has been an vital problem of chemical enterprises. Therefore, real-time diagnosis, precaution and accident disposal have been increasingly regarded.

Safe production intelligence expert system can make intelligent diagnosis and alarm for chemical production equipment and process and prefer corresponding solving programs. The items of parameters that obtained from analyzing and dealing all kinds of sensors and checking equipment, can check safety condition, analyze failure and predict the trend of deterioration and so on, provide scientific decision foundation to confirm failure point and adopt remedy of repairing and maintaining, to ensure safety and continuity of production process. It is one kind of the critical technology to solve reliability of chemical process system and guarantee production safety. There are comprehensive connection and interaction between it and other subjects such as signal disposal, information technology, automatic control, artificial intelligence and system engineering, etc, it belongs to the field of cross subjects and hi-tech exploration, and it is one of hot research of science circle of international process system engineering and chemical industry. The article demonstrates a kind of safe production intelligence expert system applying to chemical enterprise, which connect neural network with expert inference, put main production equipment in real time monitoring of the system, to diagnose by use of data produced by neural network, realizing location of failure, reason analysis and solving program. To analyze neural network failure of main production equipment can find many faults, when much equipment abnormality emerge at the same time expert system also can infer the origin of failure and prefer integral solving programs

The content and structure of this thesis are schemed as follows: the second section introduces research work internal and external, the third section provides a design of system framework, the fourth section illustrates realization of the system, the fifth section presents analysis of synthetic performance of the system, and advanced work and conclusion are demonstrated in the sixth section.

2 Related Works

Internal and external research about failure diagnosis and check for chemical equipment have been pursuing many years. There are two sorts of principal methods about fault diagnosis: (1) diagnosis method based on model. Such as parameters evaluate based on system model state and diagnosis method of equivalent equation, etc.[1, 2], the disadvantage is the model always difficult to construct and nonlinear

system error is also great. (2) The method independent on dynamic model. Such as the method based on fault tree, the pattern recognition diagnosis method [3], gray diagnosis method, fuzzy diagnosis method [4], expert system diagnosis method and neural network diagnosis method [5], etc. In addition there are methods of signal process and statistic analysis and so on [6, 7]. Every method has its advantage and disadvantage.

With the development of artificial intelligence technology, diagnosis and identification of equipment failure all well up, Peter and others research network failure diagnosis of heat exchanger for factories by use of Takagi-Sugeno-sized fuzzy model [8]. The defect of pure fuzzy model lies in its unavailability of diagnosis for large-scaled and complex systems, because too many rules tends to bring about rules combination and matching conflict.

Expert system diagnosis applies acknowledge and inference rules preferred by experts, imitate experts train of thought of analyzing and solving problems to infer failure equipment and its reason. The expert system makes full use of practical experience, and it can explain its own inference process. The expert system can always solve many unconventional and uncalculated problems, in addition the expert system can also be extended and make the system more perfect by assembling experience of more experts, so that the expert system is made full use of to theory and engineering [9, 10].

As one of most important technology of artificial intelligence, the artificial neural network has the characters of nonlinearity, fault tolerance, parallelism and so on, provide effective approach to realize chemical equipment safety diagnosis. For acquiring acknowledge, neural network don't need intelligent engineers reorganizing , concluding and digesting acknowledge of field experts, but need examples of solving problems of field experts train neural network. Venkat and Chart [11] introduce a kind of failure diagnosis method adopting artificial neutral network, and compare conclusion with system based on acknowledge.

The deficiency of neural network is it can not make full use of precious experience accumulated by experts in many specifically fields, only utilize some definite examples of failure diagnosis, and also need sufficient study samples, thus to guarantee reliability of diagnosis. Acknowledge of the neural network learns from examples of failure are merely distributing weight, not similar to the production rule of logical thinking of field experts. Therefore, the process of diagnosis inference cannot be explained and lack transparency.

Concerning adoption of single failure diagnosis and discovery method is difficult to fulfill safe production demands of chemical industry, this article prefer a kind of safe production system program which combine neural network and expert inference. It brings neural network and expert inference into playing each merit, avoiding shortcomings. This system is applied to plastic assistant manufacturing industry, mainly to analyze safe production device of alkylpheonl and anti-oxygen.

3 System Architecture

Frame design of system mainly contains three sections: production data section, subsystem of neural network diagnosis, subsystem of expert inference. The content of framework of system is demonstrated as Fig 1:

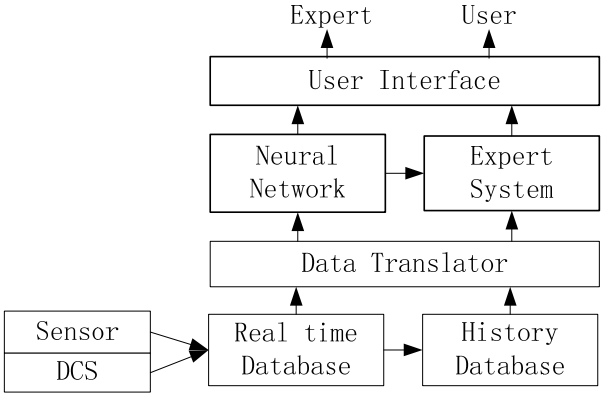

Fig. 1 System Architecture

Data are from sensors and DCS(Distributed Control System), these data are firstly stored in real-time data base, are changed into data adapt to neural system and expert system pattern through conversion of translator, some date must transit filter to get rid of noise of data. The Neural network can calculate these data to diagnose whether equipment failures exist. The expert system can also infer the output of neural network and production data, to conclude the judge of expert system for production process.

3.1 Collection and Management of Data

The collection is a procedure as below: the system gets the data from the Sensor and the DCS at a certain time intervals. All data from the Sensor are original, while some from the DCS are real time or quasi-real time. Having had been input into a Neural Network and an Expert System, the data are in a Data

Translator acted as a Pre-processor. The management involves data filtering and data smoothing.

3.2 Design of Neural Network System

This system adopts BP Neural Network, of which involves many input ports. As is shown in Figure Two-Diagnosis Neural Network System, there are many detecting sensors for temperature, pressure, flow and gas. A Neural Network structure is shown in Fig. 2.

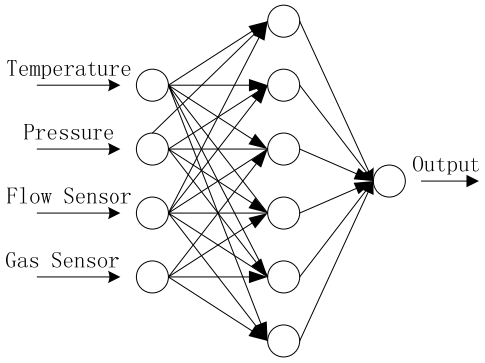

Fig.2 Neural Network Structure

According to equipment failures, output of the Neural Network is set. And then selects samples to train it. So weight values between nerve cells records the fault diagnosis knowledge.

3.3 Design of Expert System

This system includes mainly these sections as following: knowledge database, inference engine, interpreter, process database and dialog interface. The Knowledge Database stores the knowledge regarding to safety chemical production process, offered by experts on knowledge database. The system structure is shown in Fig. 3:

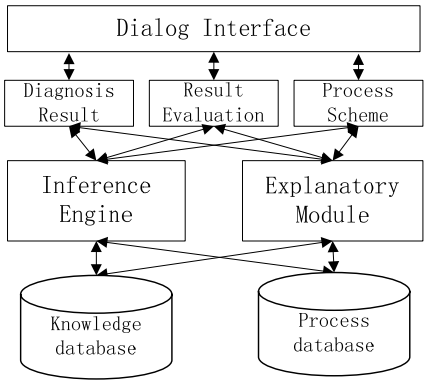

Fig.3 Expert System Structure

The solution procedure works as below: this system, simulating the experts' thought process, in accordance with the rules and facts, makes inferences and judgments and gives diagnosis results. The knowledge Database plays a key role in evaluating the quality of Expert System, namely, the quality and quantity of knowledge in knowledge database determines the quality of the Expect System. In view of expandability of system, the Knowledge Database separates from inference so that we can boost the Expert System by promoting the contents and rules in the knowledge database.

The Inference Engine is comprised of a group of programmers, including three sections-dispatcher, performer and coordinator. Selecting a segment as the next step, the dispatcher controls the whole process of inferences. The performer executes the action selected by the dispatcher and fetches knowledge from the knowledge database and the information from intermediate results. The main function of the coordinator is performing as below: when getting new data or assumptions, it amends former results in order to keep the consistency of results. From initial known facts of the system input, the coordinator finds the matching knowledge in the knowledge database, forms rule collection, and then adopts the conflict-eliminating strategy. The coordinator selects a rule from the rule collection to carry on the inference, and adds the inferred new facts into the intermediate result database as the next inferred the known fact, then selects the suitable rule from the knowledge database to carry on the inference, then repeats this process, until gets the required solution, or there is no suitable rule in knowledge database. The inference engine can be independent to the question solution domain, the change of system function only relying on the change of rule collection.

The interpreter is the program of explaining the inference process, which can record users' inquiries, the system input, the process of the inference and solution, to form the expert system diary. The information will be put on file in order to carry on the inspection, the maintenance and the revision for the expert system. Interpreter may also demonstrate inference process to the user, and let them know the reason and the process to draw the conclusion. The process database is specially used to storage the data, the intermediate result and the conclusion in the inference process ,as the temporary storage area , enables the inference engine to realize repeat inference for many times.

The interactive module is a program and interface for communicate between the system and users. Through this interface, the Expect System outputs the results of equipment fault diagnosis and evaluation of

interface results (confidence) and scheme for solving failures.

Also users can operate the system by the dialog interface, which includes two sections-one for general users and the other for experts/engineers.

4 System Implementation

In this section an implementation will be given according to the upper architecture.

4.1 Realization based on J2EE system.

We have realized a Three-layer expert system based on J2EE, which is shown in Fig. 4.

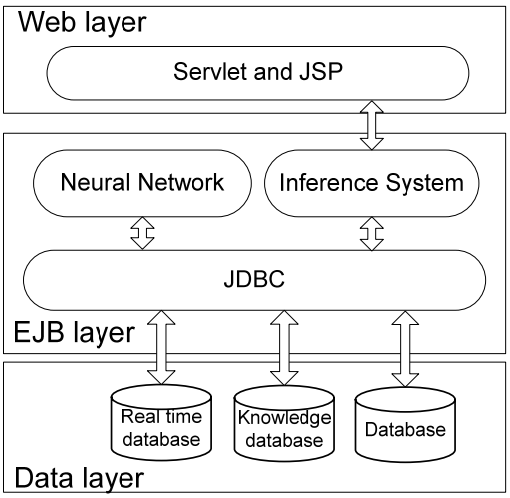

Fig. 4 3-layer Structure of Realization

As shown in Fig. 4, what we have developed is an expert system based on Web and characterized by general purpose and "Plug and Play", adopting software engineering developing thought and method, by means of currently major software developing methods like application facing object, modularization etc to realize the modularization and objectization of system function. Java language integrated with J2EE technology is applied by us to make design of expert system simpler. In the processing of achieving it, our efforts were focused on Neural Network、kernel inference algorithm and flow, rather than wasting time and energy on considering interface realization of each part; because interface definition and realization of J2EE frame are very simple through the data exchange of Servlets and outer application system; inner inference engine function and inference-control strategy can be realized by non-condition conversation EJB, which exchanges data with database and knowledge database through JBDC.

4.2 Technologic Flowchart

We have selected one chemical corporation producing PVC additive to realize system application. There are three main production equipments in this corporation, one alkyl (DTBP) equipment and 2 antioxidants (AT-10, AT0168). Each includes reaction kettle, heat exchangers, pots and towers etc. The following is a simple AT-168 process flowchart:

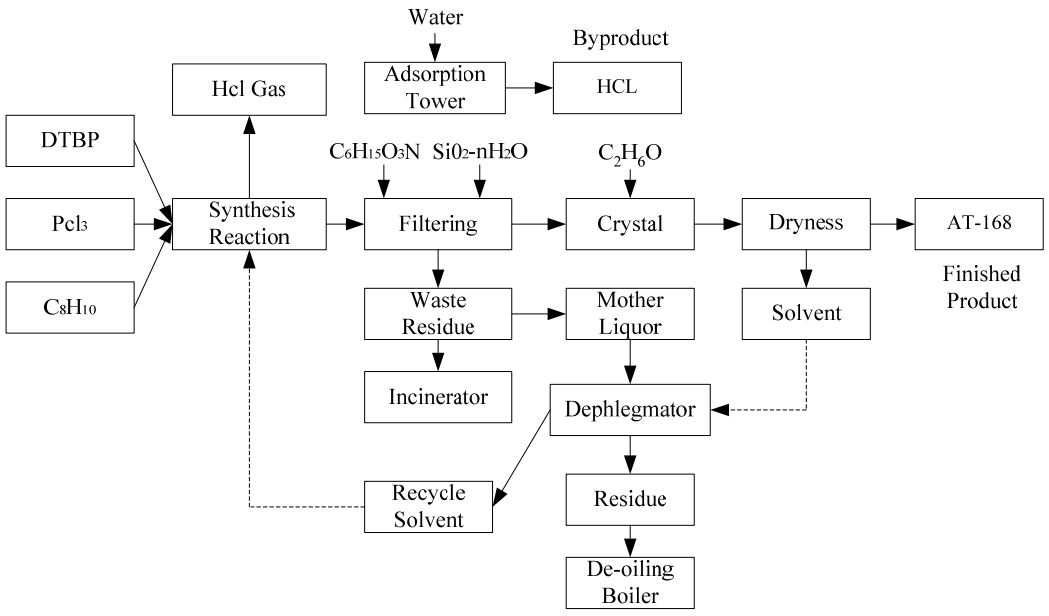

Fig.5 AT-168 Production Flowchart

4.3 Neural Network System

Owing to the variety of production equipments, abundance of production safety parameters and possibility of probable accidents, it is very difficult to use one neural network to realize the safety diagnosis of all the equipments for the plant, thus in practical realization we have designed three neural networks to detect and diagnose the equipments safety of three production equipments separately. The input terminal of neural network consists of production data (temperature, pressure, flow quantity, gas sensor) and data from DCS. Production data, which is raw data, comes from data of equipment sensor, while some data from DCS system is transaction data. Because of the quantity differences of each equipment sensor for the input terminals of three neural network diagnosis subsystems, the quantities of input terminals of neural network are different.

4.4 Expert System

In the Expect System, the Knowledge Database adopts the MS SQL Sever 2000. Intended for large-scaled chemical engineering enterprises, this system includes the large Knowledge Database and the Expect System with low efficiency. So this thesis lists the facts and rules individually. The different combinations of the facts infer various results.

The description of the rules includes the following three sections:

IF<Premise> THEN<Conclusion> WITH<confidence>

For example:

IF(Temperature>120)and(Pressure>2.2)and(Flow<1.2) THEN(the output lane have been blocked) WITH<0.8>

The stagnation points of testing parameters for each device and possible failures are stored in Real Time Database, while the combination of these premises, possible failures and confidence in Rule Database.

Gaining knowledge of Expert System is another question which should be under serious consideration. It is the scheme for resolving the bottleneck of Expert System designing. By gaining knowledge, the content of the Knowledge Database can be enlarged and modified so that it can enrich and improve the database and make the Expert System satisfy more new needs. There are two ways mentioned for gaining knowledge of Expert System. One is hand-input by expert, another is failures checked by Neural Network, which cannot be checked by the relevant knowledge of Expert System and added to the database. The latter is a half-manual way and needs the participating and confirming by experts.

5 System Performance

In the realization and performance of Expert System, considering the inference time and reliability as the important indicators, a lot experiments have been done to check the performance index of Expert System. Performance of Neural System is mainly played on calculating time and precision of the results, so the three-layer multi-input BP Neural Network has been built. The network has 6-8 input premise and over 20 kinds of output results, responding to the possible failures of the equipment. The Training Collection and Checking Collection of Neural Network have been set up by collecting much more real production data. It is proved when the number of Training Collection samples is below 100, the diagnosis accuracy of Neural Network can reach to 80%;while, when the number of Checking Collection samples is added up to 200, the diagnosis accuracy 100%.

There are hundreds of facts and results in Expert System, let alone the inference rules. So checking is focused on the reliability of the inference results for expert System. In the experiments, it is found that the confidence of the inference results for Expert System is all above 0.8, and the accuracy of fault diagnosis is up to 90%. These data can basically satisfy the enterprises.

The diagnosis of Neural Network and inference result of Expert System get the consistency up to 90%. The difference in some individual inference results will be recorded automatically by the system, waiting for the disposal from knowledge engineers and experts. Sometimes it needs to repair Neural Network, and mostly adds inference rules to Expert System.

6 Conclusion and Future Work

The passage is written to offer an Expert System, combined with Neural Network and Expert Inference, so as to realize the production safety diagnosis for the chemical process plants, which takes full advantages of the parallelism and versatility of Neural network, the experts' valuable suggestions in the field, at the same time, avoiding the limitation of Expert System knowledge database and incompleteness of inference rules. The framework system of Expert System is designed in the passage, which has made a detailed explanation for the performance of the system and done the experiments and evaluations for the performance indicators, such as reliability, accuracy, etc.

Besides, there are also much work should be done for the design and realization of Expert System in the future. They are mainly including the parallel study

between BP Neural Network and other neural network models, the development of Expert System knowledge database, the fuzzification of inference rules and the improvement of inference process.

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