Proceeding of the Korean Nuclear Society Autumn Meeting
Seoul, Korea, October 1998

Integrated Knowledge Base Tool for Acquisition and Verification of NPP Alarm Systems

Joo Hyun Park and Poong Hyun Seong
Korea Advanced Institute of Science and Technology
373-1 Kusong-dong, Yusong-gu
Taejon, Korea 305-701

Abstract

Knowledge acquisition and knowledge base verification are important activities in developing knowledge-based systems such as alarm processing systems. In this work, we developed the integrated tool, for knowledge acquisition and verification of NPP alarm processing systems, by using G2 tool. The tool integrates document analysis method and ECPN matrix analysis method, for knowledge acquisition and knowledge verification, respectively. This tool enables knowledge engineers to perform their tasks from knowledge acquisition to knowledge verification consistently.

I. Introduction

When transitions occur in large systems such as nuclear power plants (NPPs) or industrial process plants, it is often difficult to diagnose them. Various computer-based operator-aiding systems have been developed in order to help operators diagnose the transitions of the plants. Operator aiding systems, such as the fault diagnosis systems, the alarm processing systems, etc., are usually the knowledge-based systems (KBS) which use the knowledge either acquired from the domain experts or accumulated during plant operation.

A construction procedure of the knowledge-based system is described as shown in Figure 1. First, requirements of the knowledge-based system are obtained from users. Second, the knowledge is specified from the requirements. Third, the specified knowledge is acquired from the domain experts or from the documents of the domain system. Fourth, the knowledge-based system is designed and constructed. Finally, the system is implemented in a computer program and operated.

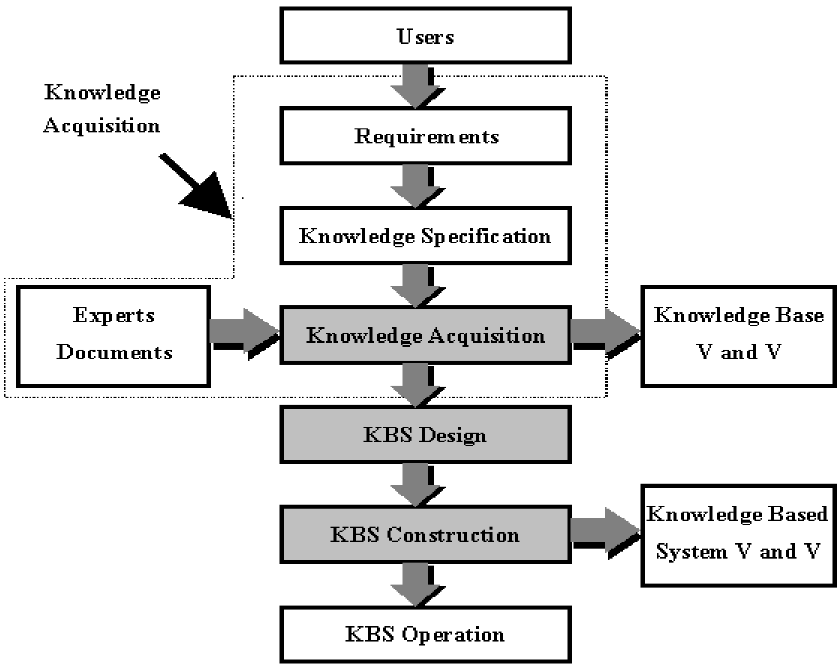

Figure 1. A Construction Procedure of Knowledge-Based System

In the procedure, knowledge acquisition and knowledge base verification are important activities because knowledge acquisition is regarded as bottle neck in construction procedures of knowledge-based systems and knowledge base verification make knowledge base be reliable

[1,2,3]. In this research, we developed the integration tool for nuclear power plant (NPP) alarm processing systems, which can perform process from knowledge acquisition to knowledge base verification consistently. We applied the document analysis method for knowledge acquisition part [4] and extended colored petri net (ECPN) matrix analysis and backward simulation for knowledge verification part [5,6].

We describe the knowledge acquisition method through document analysis in section II and the CPN matrix analysis and backward simulation in section III briefly. In section IV, we describe the integrated knowledge base tool for NPP alarm processing system.

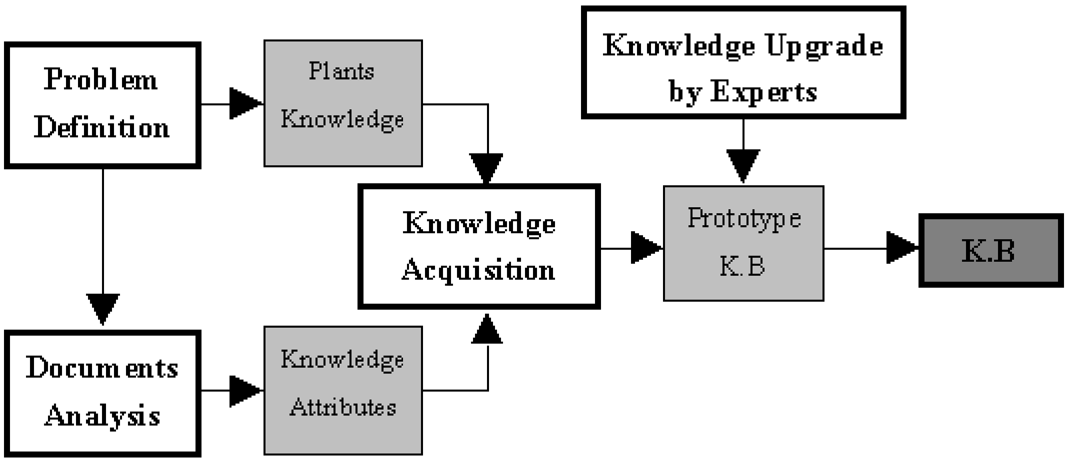

Figure 2. Knowledge Acquisition Procedure through Document Analysis

II. Knowledge Acquisition Method through Document Analysis

The procedure for knowledge acquisition though documents analysis is decomposed into four steps in this work - the problem definition step, the documents analysis step, the knowledge acquisition step, and the knowledge upgrade step as shown in Figure 2. The knowledge attributes are determined in the problem definition step by analyzing the user requirements. The system is analyzed to acquire necessary knowledge in the document analysis step. It is to note that some automatic knowledge acquisition methods can be developed using the relations between the knowledge attributes determined in the problem definition step and the domain system knowledge obtained in the documents analysis step: In the knowledge acquisition step, the knowledge attributes of the knowledge-based system are acquired automatically in the form of the prototype knowledge base using these automatic acquisition methods. The knowledge base is then investigated by domain experts to upgrade and validate the prototype knowledge base.

III. Knowledge Verification using ECPN

Various properties of the Petri Net can be analyzed through matrix analysis. CPN was extended from Petri net. The matrix analysis method for CPN however is not well defined generally. We developed the CPN and ECPN matrix analysis methods and backward simulation method [5,6]. We introduced the knowledge base verification by using ECPN and backward simulation briefly in this section.

Input and output matrixes of ECPN are defined similarly to that of CPN. The different thing is that matrices of ECPN have information on state places. The input matrix with a normal color σ_k, $ED^-_{s_k}$, and the output matrix with a normal color σ_k, $ED^+_{s_k}$, are defined as follows:

$$ED^-_{s_k}[j,i] = \#(p_i, I_{s_k}(t_j)),$$

$$ED^+_{s_k}[j,i] = \#(p_i, O_{s_k}(t_j)) + \#(p_i, I_{s_k}(t_j)),$$

where p_i is place i, $I_{\sigma i}$ is input arc expression function for σ_i, and $O_{\sigma i}$ is output arc expression function for σ_i.

The anomalies in knowledge base can be categorized into three types, which are incorrectness, inconsistency, and incompleteness. Incorrect anomalies are redundant rules, subsumed rules, and circular rules. Inconsistent anomalies are conflicting rules and incompleteness anomalies are unreachable conclusion rules, unreferenced condition rules, mismatching rules, isolated rules, and missing rules. These anomalies can be represented by ECPN. For example the incorrectness anomalies are shown in Figure 3. We can find anomaly candidates of each category by using color sum vectors, $S^-_{s_k}[i]$ and $S^+_{s_k}[i]$, and total sum vectors, $S^-[i]$ and $S^+[i]$, as follows:

$$S^-_{s_k}[i] = \sum_{j \ni T} ED^-_{s_k}[j,i],$$

$$S^+_{s_k}[i] = \sum_{j \ni T} (ED^+_{s_k}[j,i] - ED^-_{s_k}[j,i])$$

$$S^-[i] = \sum_{j \in T} \sum_{s_k \in \Sigma} ED^-_{s_k}[j,i],$$

$$S^+[i] = \sum_{j \in T} \sum_{s_k \in \Sigma} (ED^+_{s_k}[j,i] - ED^-_{s_k}[j,i]).$$

Anomaly candidates of each category can be detected by using those sum vectors.

For backward simulation from Anomaly candidates, input matrices and output matrices, $BD^-_{s_k}$ and $BD^+_{s_k}$, are defined as follows:

$$BD^-_{s_k} = D^+_{s_k} = \#(p_i, O_{s_k}(t_j)),$$

$$BD^+_{s_k} = D^-_{s_k} = \#(p_i, I_{s_k}(t_j))$$

For knowledge verification using backward simulation, first, we transfer the knowledge base to ECPN and analyze the ECPN matrices in order to find candidates of anomalies. Among these candidates, the incompleteness anomaly candidates become the real incompleteness anomalies. Second, we make the backward CPN of the knowledge base in order to find input patterns of candidates of incorrectness anomalies and inconsistency anomalies. Finally, we determine the real anomalies by analyzing input patterns that are found by backward simulation started from these candidates. Using this method, we can carry out the knowledge base verification fast and easily.

IV. Integrated Tool for NPP Alarm System

We developed the integrated knowledge base tool for knowledge acquisition and knowledge base verification of NPP alarm processing system by using G2 tool and C programs. G2 tool is an expert system development tool, manufactured by Gensym, which has been used for developing expert systems in many sites.

The integrated knowledge base tool is composed of three sub-main windows such as knowledge acquisition, knowledge interpreter, and knowledge verification as shown in Figure 4. We developed the user interface part and the knowledge acquisition part by using G2. The interpreter part and the verification part are constructed by using C programs.

The knowledge acquisition window contains three menu buttons such as load, save, and text-file. By selecting “load” button, the schematic diagram for alarm knowledge acquisition appears as shown in Figure 5. If a sensor or a component is selected on the screen, the knowledge table of it shows up as Figure 5. A knowledge engineer fills in these sensor tables manually with the knowledge acquired through document analysis. These tables become the input to the knowledge acquisition system to fill in the blank alarm knowledge table.

The knowledge interpreter window contains three buttons such as load-kb, make rule, and save. The “make rule” button actuates the interpreting program, developed in this work, through G2 standard interface (GSI). The alarm knowledge is saved as text file by using “text-file” button in the knowledge acquisition window. The transfer program changes automatically the text file of an alarm knowledge base to if-then rules in order to use input file of verification program.

The knowledge verification window contains two buttons such as petri net and design/CPN. The “petri net” button makes the verification program operate, which verify anomalies of an alarm knowledge base by using ECPN matrix analysis and backward simulation described in section III. Also, using “Design/CPN” button, we can use the Design/CPN tool as shown in Figure 6.

V. Conclusions

Knowledge acquisition and knowledge base verification are important activities in developing knowledge-based systems such as alarm processing systems. We developed the integrated tool for knowledge acquisition and verification of NPP alarm processing systems. By using this tool, the alarm knowledge can be acquired from the knowledge of sensors easily, based on the document analysis method. Furthermore, the verification of the knowledge base can be performed formally through the tool, based on the ECPN matrix analysis and backward analysis. This tool is expected to enable knowledge engineers to perform the whole work from knowledge acquisition and knowledge verification consistently.

Reference

[1] Gruber, Thomas R. and Cohen, Paul R. (1987), "Design for Acquisition: Principles of Knowledge System Design to Facilitate Knowledge Acquisition", Int. J. Man-Machine Studies, Vol. 26, 143-159.

[2] Badiru, Adedeji B. (1992), Expert Systems Applications in Engineering and Manufacturing, Prentice-Hall, Inc.

[3] R. M. O'Keefe, O. Balci, and E. P. Smith, "Validation Expert System Performance", IEEE Expert, vol. 2, no. 4, 1987.

[4] Joo Hyun Park and Poong Hyun Seong, " Knowledge Acquisition for Alarm Processing Systems for Nuclear Power Plants Using Documents Analysis" Accepted Annals of Nuclear Engineering, 1998.

[5] Joo Hyun Park and Poong Hyun Seong, "CPN matrix analysis and its application to knowledge base verification", submitted IEEE Trans. On Knowledge and Data Engineering,

1998.

[6] Joo Hyun Park and Poong Hyun Seong, "Knowledge Base Verification using ECPN Matrix Analysis and Backward Simulation", submitted Decision Support Systems, 1998.

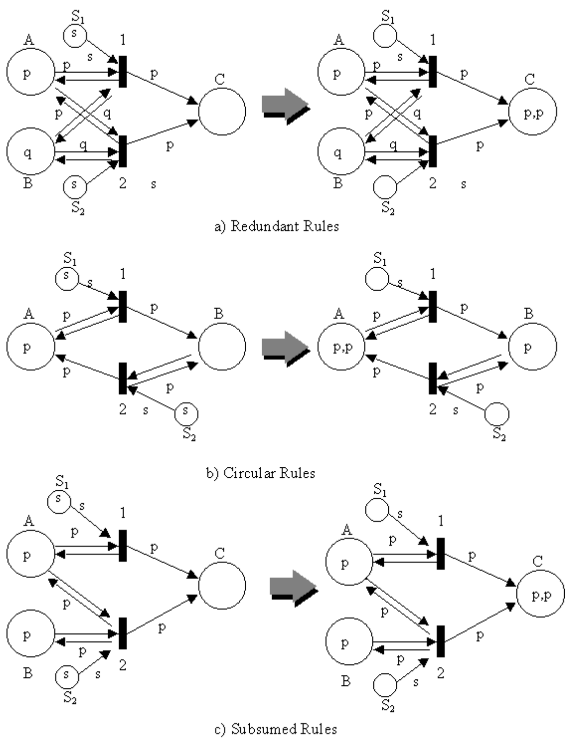

Figure 3. Incorrectness Rules in ECPN

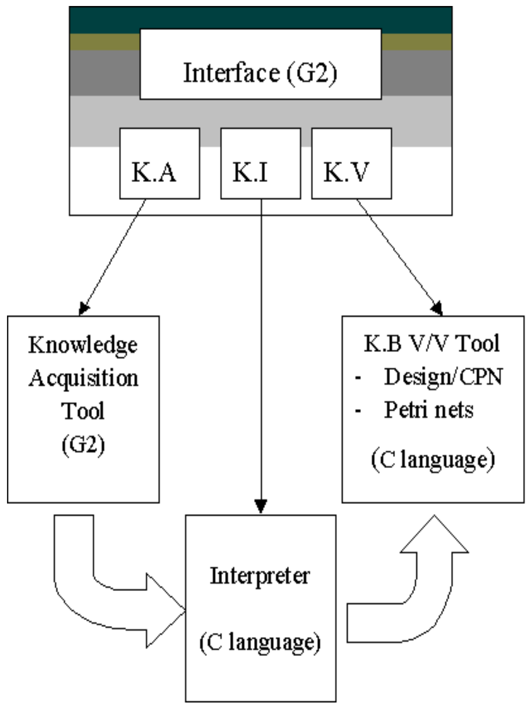

Figure 4. Diagram of Integrated Tool

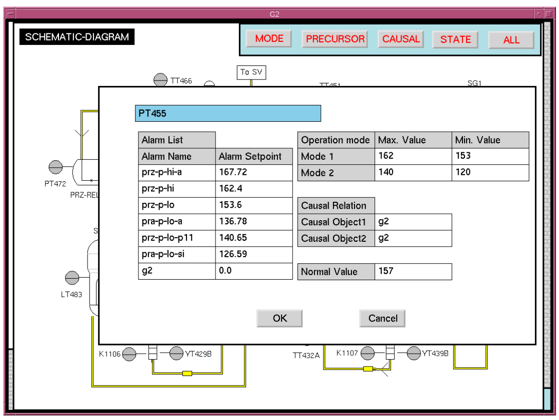

Figure 5. Knowledge Acquisition Window

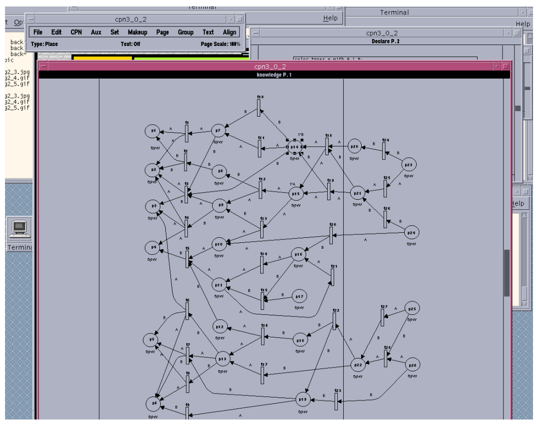

Figure 6. Design/CPN