TR-173

Development of Expert Systems in the Fifth Generation Computer Systems Project

by

Yasuo Iwashita and Jun Sawamoto

May, 1986

ICOT

Mita Kokusai Bldg. 21F
4-28 Mita 1-Chome
Minato-ku Tokyo 108 Japan

(03) 456-3191~5
Telex ICOT J32964

Institute for New Generation Computer Technology

Development of Expert Systems in the Fifth Generation Computer Systems Project

Yasuo Iwashita and Jun Sawamoto
Fifth Research Laboratory
Institute for New Generation Computer Technology
Tokyo, Japan

Keywords : *Expert Systems, Expert System Building Tools, Fifth Generation Computer Systems Project in JAPAN.*

Abstract : This paper describes the work on building expert systems in various domains and designing expert system tools in the Fifth Generation Computer Systems Project's logic programming environment. The ICOT research center, together with the collaborating companies, is building demonstration systems such as Diagnosis for Electronic Switching System, and the Project Planning & Management System. Some are at the demonstration stage and others at the design stage. Various logic-based experimental expert systems are described. This paper also summarizes our experiences in designing and developing a prototype version of an expert system tool in the project.

1 INTRODUCTION

One of the most appropriate applications for testing and verifying the applicability of AI technologies is the expert system since it requires almost all the AI technologies, including problem-solving, knowledge representation, knowledge acquisition, knowledge base management, and intelligent man-machine interfaces.

The Fifth Generation Computer Systems (FGCS) Project is now in its four-year intermediate stage after completing three-year initial stage. We are currently working on verification and enhancement of the fifth generation computer technologies from the viewpoint of applications in order to ensure the capability of the new generation computer now under development. For this purpose, R&D on expert systems has been selected as our main theme.

In this paper, we first clarify the requirements for expert systems or expert system construction environments at the current tend of the technology. Then, we discuss our research and development program for effectively implementing these requirements. Various experimental demonstration expert systems are being developed mainly on the logic programming environment, i.e. PSI or CHI, which are Prolog machines developed in the initial stage of the project. Finally, we outline the prototype version of an expert system tool on the PSI machine. We plan to evaluate the logic programming environment given by the PSI or CHI in this stage and, in the final stage of the project, that given by the parallel inference machine.

2 REQUIREMENTS FOR EXPERT SYSTEMS AND TOOLS

Among the wide variety of application domains to be covered by expert systems are interpretation, diagnosis, design, planning, monitoring, and control. What facilities should the tool provide for building expert systems covering these divergent application domains? And how should expert systems perform as application programs?
The following requirements have been taken into consideration:

(1) Flexibility of Knowledge Representation
Expert knowledge in various domains must be expressed efficiently. The tool should, therefore, support a number of knowledge representation schemes.

(2) Flexibility of Inference Mechanism
Basic inference mechanisms (forward and backward chaining) have to be incorporated into an expert system as required. If neccessary, a user defined inference method should be used. Dynamic switching of inference methods by means, for example, of heuristics from knowledge in each problem domain must also be provided.

(3) Ease of Use for Expert System Building
Powerful support facilities are required by experts who participate in system development. Knowledge aquisition and knowledge base management are major bottlenecks in building expert systems as real application programs. And the inference process explanation facility appears to be useful for both expert system builder and user.

(4) High Efficiency
High efficiency is essential in operating an expert system in real time as well as building a large-scale computer system.

(5) Interfaces to Existing Systems
Interfaces that allow expert systems to communicate with existing data bases, and other expert systems, are also necessary.

3 RESEARCH AND DEVELOPMENT PROGRAM

The intermediate stage is divided into two two-year halves. In the first two years, various expert systems and a prototype of the expert system tool will be developed. This prototype will be applied to the development of various expert systems in the next two years (this will be a collaborative effort with the project-affiliated companies). With the prototype evaluated and improved, a research version of the tool will be completed in the second two years. We will describe mainly the activities scheduled for the first two years below.

(1) Surveys and Studies

Samples of existing expert systems and tools will be collected from study reports in various application domains, and used to investigate the techniques for facility implementation, such as inference engine, knowledge representation, knowledge acquisition, and intelligent man-machine interfaces.

- To achieve this, two technical committees on application systems (mentioned later) are to be set up, in which next generation tools and various phases of knowledge acquisition in expert systems will be discussed.

- Problems involving the capability and performance of commercially available tools (e.g., ART, KEE, and KC, etc.) will be investigated.
- The results obtained from these investigations will be analyzed to clarify the correlation between the techniques used in the facilities and various application domains, that is, the requirements for the expert system tools.

(2) Research and Development of Expert Systems and their Tools

- From study on existing expert systems, the concepts of potential tools, using PSI or CHI as a premise, will be discussed to determine the target prototype version tool.
- Topics related to expert system tools and somehow unique to ICOT will be selected, and goals for the research version tool which comes after prototype will be set. Topics which should be discussed are as follows:

- Knowledge Aquisition
  - Case studies of knowledge aquisition process
  - Knowledge extraction
  - External knowledge representation schema
  - Knowledge transformation
  - Design technique for knowledge systems
- Knowledge Representation and Problem Solving
  - General knowledge representation model
  - Dynamic knowledge optimization
  - Strategic knowledge for problem solving and its mechanism

- It is difficult for ICOT to recruit experts in very specific applications. Collaborative effort with the project-affiliated companies is, therefore, important. For this purpose, various expert systems will be developed by the companies during the first or second two years. Some of these expert systems are to be used to evaluate and verify the prototype version tool. Table.1. shows the technical points of these expert systems.

(a) Diagnosis System for Electronic Switching System(ESS)
(b) Intelligent Office Secretary System
(c) CAD for Computer Room Facility Layout
(d) VLSI Logic Design System
(e) CAD for Analog LSI Layout
(f) Project Planning & Management System

4 COMMITTEES

(1) Introduction

In R&D on expert systems, advice from experts in relevant application domains is crucial. Accordingly, R&D at ICOT should concern itself with the expert system tools rather than the expert system itself, but expert advice is still required. To proceed with the work smoothly, the following committees have been established consisting of experts from the outside ICOT.

(2) Technical Committee on Knowledge Systems Tools

This committee will study the fundamental concepts regarding expert systems that can be used in various phases such as design, construction, and operation. The committee will discuss the functionalities required for the tool in order to build such expert systems, and propose new techniques to provide the required capabilities.

(3) Technical Committee on Knowledge Acquisition

This committee will work on the acquisition of expert knowledge, and discusss the techniques used in existing expert systems, problems with these techniques, and subjects to be studied for future applications which will help build a knowledge acquisition support system.

5 PROTOTYPE EXPERT SYSTEM TOOL ON PSI

The prototype tool is scheduled to be developed and tested in the first two years of the intermediate stage. Fig.1. shows the diagram of the tool currently being designed.

5.1 DESIGN CONSIDERATION

In this section, the concept and the design decisions of the tool are discussed in terms of the three major components:

- Knowledge representation
- Inference mechanism
- User interface

(1) Knowledge Representation

To provide an ideal knowledge representation scheme, external forms with which various kinds of knowledge for each application domain can be freely described, and internal forms which are appropriate for problem solving in that domain, are to be considered. Knowledge representation methods most appropriate for the knowledge in the following three categories are provided in our tool:

- Static knowledge of problem domains
- Knowledge on problem solving heuristics
- Knowledge on meta-level strategies

Static knowledge is the knowledge required for modeling problem domains. A domain could be described in terms of its structural elements, attributes and values of elements, and operations on elements. For this type of knowledge, the frame representation is most suitable as it can clearly show the hierarchy of the domain.

Knowledge on problem solving heuristics is the expert's know-how used for problem solving. Because of its excellent expressive power, we selected rule-based representation for this type of knowledge.

Knowledge on meta-level strategies is used for selecting heuristic knowledge, or deciding inference mechanisms appropriate for a given situation.

(2) Inference Mechanism

The most appropriate method of inference should be selected according to the applications. For example, symbolic integration may be carried out by the forward approach, from a certain integral formula to a final integrated result. The forward approach is also used in design work in gerneral. In contrast, the backward approach is more effective in the proof of a theorem, that is, the approach from theorem to axiom is better than the reverse order, because the former needs fewer branchings. MYCIN uses backward chaining to simulate the reasoning performed by a doctor. A tool consisting of several inference techniques currently used will be considered so that users can select any combination they desire.

Both forward and backard inferences are to be incorporated into the inference mechanism. The selection will depend on the problem to be solved. The combination of these inference mechanisms and the dynamic switching of inference processes will be determined from the meta-level knowledge on strategy.

Reinforcement of the inference mechanism such as inference with an uncertain knowledge will be examined.

(3) User Interface

User interfaces can be classified into two types, the interface used to build expert systems, and the interface supplied to the users of expert systems.

- Expert system builder interface

  Menu-oriented and syntax-oriented editors are provided in the form appropriate for each knowledge representation.
- Expert system user interface

  Facilities for explaining the reasoning process and asking various information from the user in the process of reasoning are provided. As a tool, it is important to prepare a support facility that helps easy incorporation of those interfaces into an expert system when the system is built

5.2 PSI AS THE DEVELOPMENT ENVIRONMENT

PSI (Personal Sequential Inference Machine) is the major product from the initial stage of the project. PSI and its operating system SIMPOS (Sequential Inference Machine Programming and Operating System) provide a comfortable logic programming environment for the programming experiments in the current stage of the project. ESP (Extended Self-contained Prolog) is the system description language for SIMPOS. ESP is designed for writing SIMPOS itself, but is found to be very powerful and useful for describing various application programs, especially those requiring hierarchical knowledge representation.

(1) SIMPOS

The basic design philosophy of SIMPOS is to build a super personal computer within a uniform framework, i.e. logic programming. The development of SIMPOS has achieved:

- System programs in logic programming
- A programming environment for logic program

SIMPOS consists of a programming system (PS) and an operating system (OS). The OS consists of three layers: kernel, supervisor, and I/O media subsystem. The PS consists of subsystems such as Coordinator, Debugger/Interpreter for ESP, Editor/Transducer, and Library.

(2) ESP

ESP is based on the Prolog-like machine language of PSI called KL0 (Kernel Language 0). Thus, ESP has essential features of logic programming, e.g., unification mechanism for parameter passing and depth first tree search by backtracking. ESP is, at the same time, an object-oriented language with the notions of objects with states, object classes and their hierarchical structure organized by the inheritance mechanism.

5.3 IMPLEMENTATION CONSIDERATION

We are implementing the prototype on the Prolog-based and object-oriented environment of the PSI machine. As shown in Fig.2., the tool is basically a rule-based system with the following characteristics:

(1) Hierarchical Represenration of the Problem Domain

Frame representation, such as is-a and part-of hierarchies, and attached procedures, are realized by utilizing ESP's object mechanism. Definitions of relations among elements could be represented as frame elements enabling users to describe easily not only relations of two elements, but also relations of more than two elements. Working memory serves as a playground for instance elements instantiated from the element templates. WMMS (Working memory management system) accepts access requests from rules. WMMS carries out manipulation on instance elements like creation, deletion, modification, and various searches, such as a search for an instance element having a certain slot's value. The relation mechanism incorporated here is completely user-defined and manipulable by rules.

(2) Rule Base

Rules could be organized into groups, and the selection of a certain group or the transition from one group to another could be described using the knowledge on meta-level strategies. Thus, the tool provides the multiple Knowledge Source (KS) mechanism as the rule base. Using this mechanism, problem solving knowledge could be well modularized, and from the implementation point view, rules could be executed efficiently because of the restricted search of rules at a time. Each KS has its user-specified inference and conflict resolution strategy, such as forward/backward chaining and priority of rules. To provide an easy incorporation of expert system user interface typical for consultation or diagnosis systems, explanation (e.g.Why,How) and ask-user facilities, are embedded in the rule base. The user-defined functions in ESP could be included in the system and fragments of ESP code including these function calls could be mixed in rules achieving high expressive flexibility. Rules are compiled into ESP codes when they are executed.

(3) Meta-level Knowledge

Meta-level knowledge is the knowledge about rules or KS. It specifies the direction of rule chaining (forward/backward) transition condition from one KS to another KS, and goals to be achieved in a KS especially when it is a backward-chaining KS. Meta-level knowledge is currently included in each KS description, though this knowledge could be separated from the rule description and form a higher level module supervising the activities of knowledge sources in the system.

6 CONCLUSION

We outlined the research and development program of expert systems and expert system tools at ICOT. We discussed the importance of doing research on expert systemms in the FGCS Project as one of the applications where the new generation computer technologies are expected to contribute. Experimental expert systems in various domains are being developed in the logic programming environment. And an expert system tool is being designed and developed on the PSI machine.

We have to establish the technology of evaluating expert system tools and then, the underlying AI technologies. We are also working on researches for basic technologies, such as knowledge representation and knowledge aquisition which are the most important issues in the current expert systems research.

7 ACKNOWLEDGMENTS

The authors thank to H. Kubono and Y. Nagai, members of the fifth research laboratory, ICOT, for their contribution in designig and implementing the prototype tool on the PSI machine. Thanks are also due to researchers from collaborating companies who have engaged in implementing various expert systems and had very stimulative discussions with us about various aspects of the expert system development.

REFERENCES

[1] F. Hayes-Roth, D.A. Waterman, and D.B. Lenat, 'Building Expert Systems,' Addison-Wesley Publishing, 1983.

[2] B.G. Buchanan, 'Research on Expert Systems,' HPP-81-1, Department of Computer Science, Stanford, March 1981.

[3] T. Chikayama, 'Unique Features of ESP,' International Conference on Fifth Generation Computer Systems, November 1984.

[4] K. Furukawa, T. Yokoi, 'Basic Software Systems,' International Conference on Fifth Generation Computer Systems, November 1984.

Table.1. Expert Systems at ICOT

THEME	GOAL	TECHNICAL ISSUES	Implemented /Designed On	Target Machine
Diagnosis System for Electronic Switching System	· Diagnose undetectable faults by internal test program	· Hypothetical reasoning (dependency directed backtracking) · Deep Knowledge	SUN-II / PSI	CHI
Intelligent Office Secretary System	· Schedule business trips · Schedule meetings	· Verification of CIL · Verification of GALOP	OA-90	PSI
CAD for Computer Room Facility Layout	· Layout of computer room facility	· Verification of object oriented features in ESP	PSI	PSI / Multi-PSI
VLSI Logic Design System	· Supports algorithm design · Designs CMOS circuits from algorithm · Acquires knowledge from designer	· Structured knowledge base · Deep knowledge · Knowledge acquisition · Stimulating designers	PSI	PSI
CAD for Analog LSI Layout	· Layout design of functional blocks of Bipolar Analog LSI	· Knowledge representation of design concept · Knowledge utilization of existing data base	SUN-II	CHI
Project Planning & Management System	· Research and development of intelligent support system for project planning & management tasks	· Knowledge representation of project environment · Support for activity plan · Activity scheduling · Monitoring progress	PSI	PSI

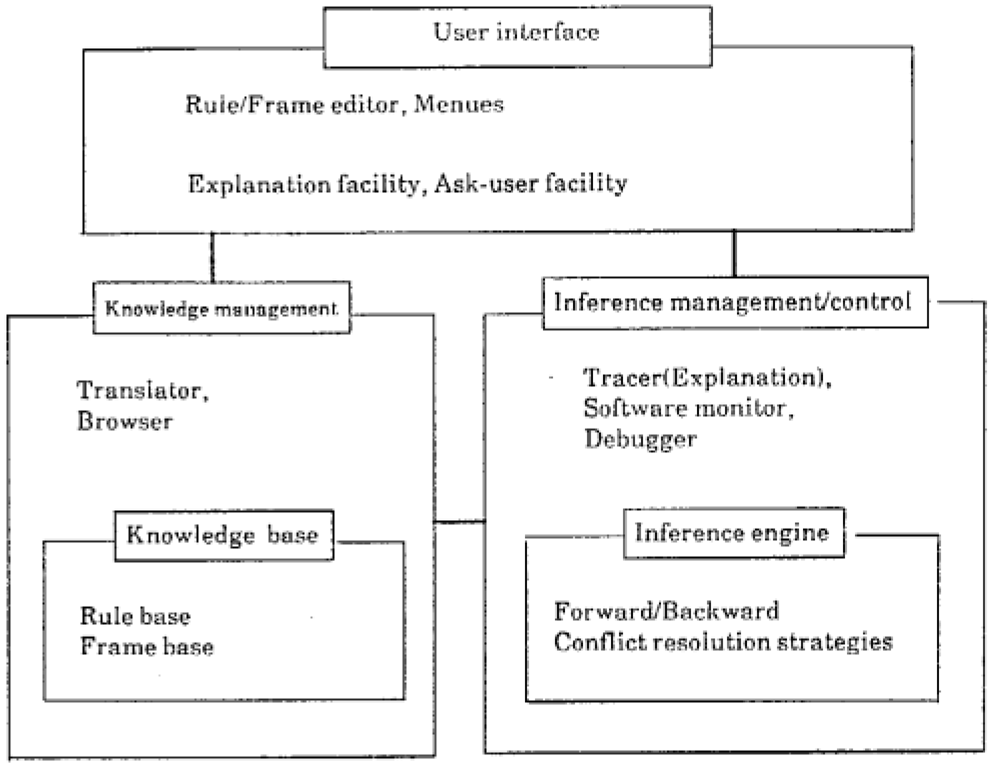

Fig.1. Expert System Tool Block Diagram

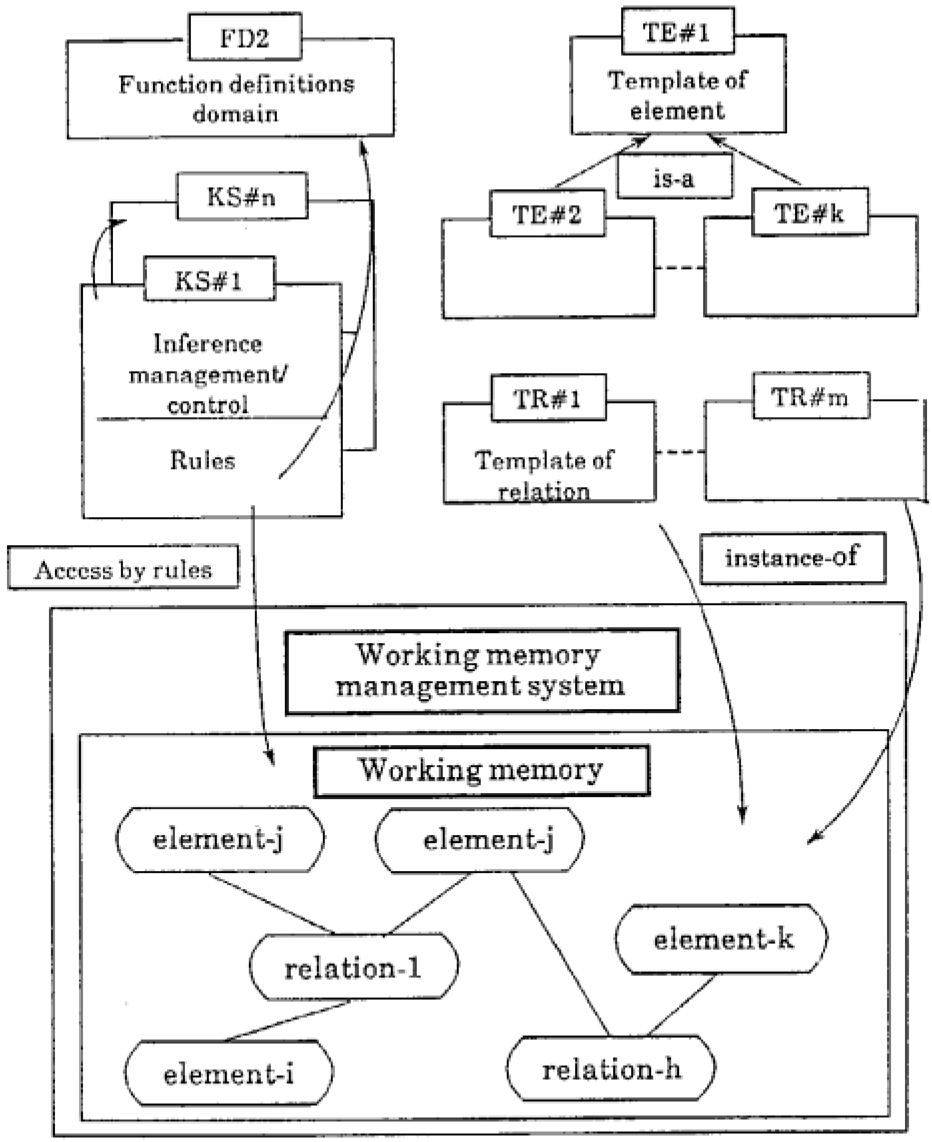

Fig.2. Structural Overview of Prototype Tool