ICOT Technical Memorandum: TM-0456

TM-0456

Towards an Expart System Architecture for Routine Design-Focusing on Constraint Representation and an Application Mechanism for Mechanical Design

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August, 1988

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Towards an Expert System Architecture for Routine Design

- Focusing on Constraint Representation and an Application Mechanism for Mechanical Design

(Extended abstract)

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Keywords

CAD system, DA system, expert system, routine design, design process, modeling, constraint representation, constraint-based problem solving, mechanical design

Summary

The object of this research is to clarify the architecture of the expert system for various designs such as LSI (circuit) design, mechanical design, and configuration, by regarding constraint-based problem solving as a suitable new paradigm different from the rule-based and frame-based paradigms, and to propose primitive tasks for the constraint-based problem solving required to realize the architecture. As the first step, this paper reports on the framework of the expert system architectures for design problems and necessary functions for them, while considering the relation between the expert system and the design systems or tools and defining the routine design. Especially, it focuses on and specifies constraint-based problem solving, consisting of constraint representation and the application mechanism to it for mechanical design, in order to consider expert system architecture including the modelling facility for mechanical routine design.

1. Introduction

Recently, knowledge-based systems, such as expert systems, and design systems or tools, such as design automation (DA) systems and computer aided design (CAD) systems, have been developed and utilized in various design fields.

In expert systems, there are two major application domains, diagnosis problems and design problems. For example, expert systems for design problems are being developed and evaluated for various application fields, such as VLSI design [Kowalski 83], [Subrahmanyam 86], mechanical design [Brown 86], [Dixon 84], [Mittal 86], configuration [McDermott 82], process planning [Descotte 85], [Eliyahu 87]. The architecture of expert systems for design problems are not yet as explicit as those for diagnosis problems. This is why design problems can be regarded as complicated problems that contain a synthesis task in addition to analysis and simulation tasks [Medland 86]. The descriptions of artifacts to be designed are changed and determined dynamically because of the trial and error nature of the synthesis task and the results from the synthesis task, are analyzed and evaluated in the analysis task. In other words, after the models for artifacts are selected, modified and determined such that the design specification can be satisfied, the synthesis and analysis tasks are performed repeatedly according to the model for detailed description of artifacts.

However, this modeling facility is not provided explicitly in existing expert systems for design problems, and the relation between the expert system architecture and this modeling function has not been considered. Most expert systems for design problems are formalized as systems that generate detailed descriptions of the artifacts as the solution by combining known components, assemblies or parts, and by refining them so that the design specification to be required can be satisfied. However, it seems that they lack recognition of the modeling concept from the viewpoint of design. Therefore, expert systems for design problems require a sophisticated architecture that considers the design process model, including planning and modeling facilities.

Design systems or tools such as the DA system and CAD system can be classified as automated design systems or interactive design systems by considering whether interaction exists or not during design [Eastman 81]. Automated design systems require the determination of formalization or definition of the design process and the decision-making sequences. Usually, they are not interactive with the designer, and demand vast data and computation time. Interactive systems are very flexible and open-ended to the designer, and multiple descriptions as input specification from the designer. They have a decentralized control structure for the design process, while the structure of the non-predetermined decision-making sequence and its control depend on the designer. Most CAD systems are interactive and are applied only to parts of the design process. Furthermore, the structure of the process model and decision-making sequence for design systems or tools depend on the design area.

This paper reports on the frameworks of expert system architectures for design problems and the functions required to realize a system, while considering the relation abetween the expert system and the design systems or tools. This paper focuses on consideration of the constraint representation and application mechanism for mechanical design.

2. Overview

First, this paper overviews the design systems or tools in relation to the design process model and clarifies the position of the expert system's role to the design system or tool.

Second, the design process models of the expert system applied to the design systems or tools for automated and interactive design are described to formalize the design problem as the expert system. Here, we regard a design problem as a well-defined and well-structured problem, and this specialized design is defined as routine design. This routine design is classified more details, and design process model for each detailed design, the fundamental design task and the relation between the classified designs and practical design fields are specified.

Third, the architecture and necessary problem solving mechanism of the expert system for routine design are described. Researches has been conducted on architectures consisting of primitive tasks for routine design, called design generic tasks [Chandrasekaran 86], [Brown 86], [Mittal 86]. These architectures provide the ability to structure knowledge for the various design descriptions and problem solving for the design to reduce the gaps between the necessary functions for the task in the design process and the functions supported by expert system building tools. However, they do not support the modeling facility and it seems that they are insufficient for this generic task approach to handle the constraint representation. Therefore, the architecture including the constraint representation and the application mechanism to it, and the modeling facility, are investigated. This constraint representation is proposed as a new paradigm for knowledge representation and the application mechanism as a new paradigm for the architecture of routine design expert systems.

Fourth, the application mechanisms for constraint represenatation in routine design expert systems are defined as constraint-based problem solving, and are described in detail. Furthermore, constraint-based problem solving focuses on the failure recovery handling mechanism. Failure recovery handling consists of constraint satisfaction problem handling and the redesign problem of partial design, and can be formalized as a generate & test + failure recovery (analysis + modification) loop. For this object, constraint representation is classified as general constraints necessary for routine design or domain-specific constraints, and application mechanism are considered according to these kinds of constraint [Nagai 87]. Modeling corresponds to the formalization of various descriptions for design knowledge and the method of handling design knowledge by trial and error. The knowledge derived based on this modeling can also be regarded as deep knowledges. The following constraints are generated, derived, modified, or deleted from modeling during the design process. For example, a general constraint for routine design may contain static and dynamic constraints, obligatory and requisite constraints, local and global constraints, or value and interval constraints. A domain-specific constraint may contain performance and cost constraints derived from the input specification, constraints for mapping from the function description to the physical or geometrical world based on the chosen model, or constraints on the structural descriptions for artifacts and relationships among components, assemblies or parts. The constraint-based problem solving mechanism is described according to the above constraint classification through matching the design process model for a routine design to the design system or tool.

Finally, the paper gives a detailed explanation of the architecture of expert systems and the constraint-based problem solving mechanism for routine design by focusing on mechanical design, specifically the design of a power transmission unit for a lathe, as an example.

3. Conclusion

In conclusion, the relation of the routine design to the design system or tool is specified, and the architecture of expert systems, including the modeling facility for routine design, is proposed by focusing on constraint-based problem solving composed of constraint representation and the application mechanism. Machining tools, specifically, a power transmission unit for a lathe, are selected as the design target.

Our future research is to clarify the architecture of expert system for various routine designs, such as LSI (circuit) design, mechanical design, and configuration, by regarding constraint-based problem solving as a new paradigm different from rule-based and frame-based paradigms, and to propose primitive tasks for the constraint-based problem solving required to realize the architecture of expert systems for various routine designs. This paper can be considered as the first proposal in this research.

Acknowledgements

I would like to thank to Mr. Yuuichi Fujii, Chief of the Fifth Research laboratory for the encouragements of my research and thank to other members of the Fifth Research laboratory for helpful comments. Finally, I would like to express special thanks to Dr. Kazuhiro Fuchi, Director of ICOT Research Center, who gives me the oppornunity to research in the Fifth Generation Computer Systems Project.

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