ADDES: AIRCRAFT DRAWING–PART DIE DESIGN CAD EXPERT SYSTEM *

Xiangyang Fu
CAD / CAM Research Center
Northwestern Polytechnical University
Xi'an, Shaanxi, 710072, P.R. China

Abstract

In this paper, the structure of engineering CAD expert system (ECADES) is presented. And based on this, the paper instructs the structure of ADDES system. In order to reduce the information etc. from the part graph, the feature–based code method and key–element description method is used.The solving of the problems such as low knowledge search efficiency etc. caused by building big knowledge base for solving complex problems has been payed much attention with each expert system, so the knowledge organization, problem solving control strategy etc. are much more important. By the building of ADDES, it present that the system should be constructed as a hierarchically distributed system and adopt procedural control strategy which synthetically utilize the control strategy of schedule list, blackboard system, meta reasoning and so on. Through the loose combination of agents in different levels, the cooperation of many experts can be reached. From the practical use of ADDES system, we can see that studies in this paper are successful and are useful to general engineering design.

I. Development of CAD Technique

According to the rapid development of computer–aided design(CAD), computer has participated in engineering design widely. Recently, many disadventages exist in engineering systems which use CAD technnique. For an instance, the disadventages about the die CAD system are as the following:

* CAD technique can only participate in the design process partially and steply. About die planning design or parameter design or die structure selecting or the building of die graph bases etc. to one kind of part, For example, design work is only part of the whole die design process.

* The design scope of recent die design CAD system is narrow. The design capacity can only involve in one or some kinds of parts and the system has no expanding ability.

* The level of design results is very low. Engineering design is a complex synthetic design process and it needs much expertise and powerful synthesizing ability. Much of these knowledge and ability is the accumulations of experts' experience. General CAD systems don't do very good in synthesizing, accumulating and using these knowledge and capacity, so it is difficult to assure the level and quality when solving the problems.

The applications of artificial intelligence(AI) and expert system(ES) techniques to CAD to build intelligent CAD system is one of the developing directions of CAD. Inference mechanism, knowledge base, search methods etc. realized in AI technology have made computers more intelligent in solving problems and cut down the gap between requirements and computer capability. Many people have introduced AI into CAD system design[1-2]. CAD expert system combines strict and complex computation with the reasoning design. Those mentioned above make the ability of the system exceed far from the processing level of individual human expert.

The next section discusses the structure of ECADES and Section III builds the structure of ADDES system based on the discussion in Section II. Section IV discusses the method of building user model. It presents that the feature–based coding is practical useful for reducing the input information.

With the gradually wide application of AI and ES techniques, it is unavoidable to build bigger knowledge base for solving complex problems. How to solve the difficult knowledge processing and low reasoning efficiency and related problems caused above has been payed much attention by every system. The discussion of knowledge representation and organization discussing in Section V tends to solve this question.

Relative control strategy is discussed in Section VI and an instance is presented.In Section VII, the explanation and knowledge compilation method is instructed.

II. Structure of Engineering CAD Expert System

Compared with the controlling and diagnostic expert systems, the ECADES has the following features:

* The system uses not only the AI and ES technique, but also the complex calculation and large numbers of CAD techniques. This requires that the building of system should combine the above two aspects.

* Engineering design is a procedure. The design process can be decomposited step by step. Generally, the design process is always beginnig with the user model building, then the planning design. Through the analyses and detail designs, the design results are output in the form of engineering graph.

* Many areas of knowledge are involved in an engineering design which needs not only the knowledge in books, but also the accumulating of experimental knowledge. This requires that the system should use different knowledge representation motheds to fit the demands of design. In ADDES system, the motheds such as assertion, heuristic rule, frame and table etc. are used.

* CAD softwares about graph play an important role in engineering design. They are used in user model building, graph certifying about the design conclusions and engineering graph generating etc..

Based on the connecting structure between ES and CAD

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softwares, ES in engineering can be classified in three types:

* Intelligent front–end type. In this type of system, ES is used as an interactive intelligent front–end. It controls the communication between user and CAD software. With the help of ES, user inputs the problem description information such as the engineering geometric information and technological information etc. into expert system. ES uses the information to reason and calls suitable commands to run CAD softwares. Then ES gets results from CAD software and comment on them.

* Tutorial type. In this system, ES is used as a system assisting tutor. It answers the user's various questions faced in the running of CAD softwares and helps user solve the problem when user uses the CAD software.

* Inserting type. In this system, ES and CAD technique are combined directly to compose a united system. ES controls and records the process of running CAD softwares and give tutoring and direction for user.

Based on the analyses above, we present an ES structure for ECADES. The construction structure should be inserting type and partially the intelligent front–end type is combined with it. The structure is shown in fig.1.

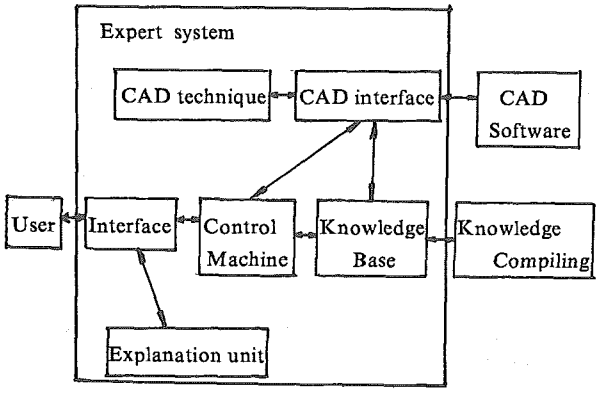

Fig.1 The structure of ECADES

In fig.1, we can see that, through the CAD interface, ES can be intelligent front–end to call CAD software and also combine with the CAD technique.

Ⅲ. Structure of ADDES System

Besides the components of knowledge base and control machine, man–machine interface, explanation unit and knowledge maintaining unit should also be payed the same attention. Shown in Fig.2, ADDES system consists of two main components: expert system core component and graph component.

The first component is the core part of the system and the language used is LISP. FORTRAN language is used in graph component. It operates to the design results such as data files, result frame etc. from the expert system component by graph processing part, and makes them have the forms which can be accepted by the graph display software. Then the results can be displayed on screen and the whole die engineering graphes can be drawn out and directly used in practice (Appendix is an assembling die graph).

Control machine consists of control unit and a blackboard system. Blackboard is practically a dynamical information registering area. It registers user model, the common information needed for the agents and immediate result information produced by agents in the design process.Control unit makes decisions in the design process. It starts the system, produces and changes the design environments, and decides the the next activity of the system. The control unit of ADDES system plans out the whole design process combining with the reasoning ability of the high layer agents in the system knowledge base.

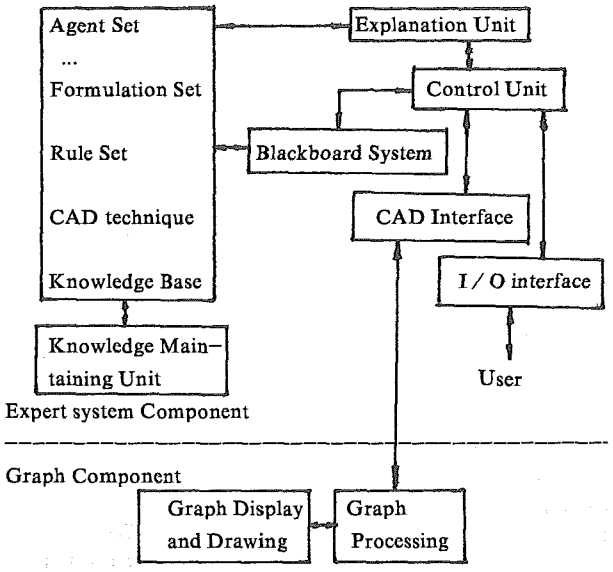

Fig.2 Structure of ADDES System

The running enviroments of ADDES are PC computer and CDC CYBER180 / 830 computer now.Graghic software is DI–3000 of CDC computer. Now ADDES system is beginning to use, and the graphic results can be used directly for manufacturing; the efficiency is notable. This made CAD enter its new period.

Ⅳ. User Model Building

The building of user model is the first and also very important problem which needs to be solved in any expert system. Every system should have its own 'knowledge representation language'. For example, 'predicate logic + data structure' is used in KAUS[5]Like the CAPP system, die design should traslate the information of part graph into the system internal representation. The part in different areas has different feature, so the feature–based code method is used to describe the part geometric feature and technological information. The ADDES system built DIE coding system with the the cooperation of a factory. Based on coding, ADDES system uses graphic key–element description method and frame method to describe graphic information precisely.

DIE coding system adopts mixture code structure which is near to Opitz code. DIE code has 11 bits and it includes two parts: geometric feature code and assisting code. The bits from the 1st to 6th is about assisting code which is used to describe part's technological information and complementing information of geometric shape. The bits left is geometric shape code which is used to acertain the key shape features through the coding of part's bottom and wall and flange and cross section

shape etc..

V. Knowledge Representation and Organization

Expert system is a kind of systems which takes the knowledge information processing and utilizing as its center. From the view of the building knowledge base of expert system, the building of knowledge base and the knowledge organization method will affect the executing efficiency of the system.

The knowledge base(KB) of ADDES system includes the following parts:

* Data Base is used as the form of data file, table etc..

* Assertion set is used to register the facts which are known from the user and produced while the process of running.

* Rule Base(RB) is the representing of heuristic information. The KB has many subsets and the subsets are at the different levels in order to connect the different agents at different levels. The form of the rule can be understood in Section 6.

* Formulation Base is the collection of the formulations which are important to the design. The formulations from the human expert's experience should be collected to the formulation base in order that the formulation can be modified and managed easily. This is benifit to develop and expand the ability of the system. The formulation base has its own manage system. Through the interface function FORMU–USE, the system calls the formulations in procedure or rules etc..

* Procedure set is the collection of functions which are programmed by knowledge engineer.

* Standard component base consists of standard die installation structures and the standard die components.

So far, the knowledge organization ways used in expert systems have two: "single" and "distributed"[3]. In distributed system, under one KMS, knowledge is distributed registered to form many knowledge sources. It solves the problem of low knowledge processing efficiency when the knowledge number is great, and make the sharing propositions and results of many expert systems loosely cooperate. But the knowledge source organizing way of such system is dull, and its verbality is big and sharing ability is not so good.

There are some notable distributed artificial intelligence systems: Smith and Davis's Contract Net, Lenat's PUP6 system , MACE (Multi–Agent Computing environment) developed in the University of Southern Carolina and AF (activation Framework)[8–9]. and so on systems. Here we do not discuss about them.

In engineering design, a design process can be generally devided into several steps and the problem–solving task can be divided into subtasks. In the paper the hierarchically distributed knowledge organization way for ECADES design is shown in Fig.3. In the figure, one AGT represents one agent. Each agent provides either expertise in a particular way or the capability to effect a particular function[4]. The system can finish design task by the union of agents.

Each agent is composed of a processing unit and the knowledge about it. The higher layer agents can not only execute the basic problem solving task but also decide the executing or cooperating agents needed to finish its task. The agents will be permitted to communicate only with its immediate ancestor and descendants and agents at the same level in their particular

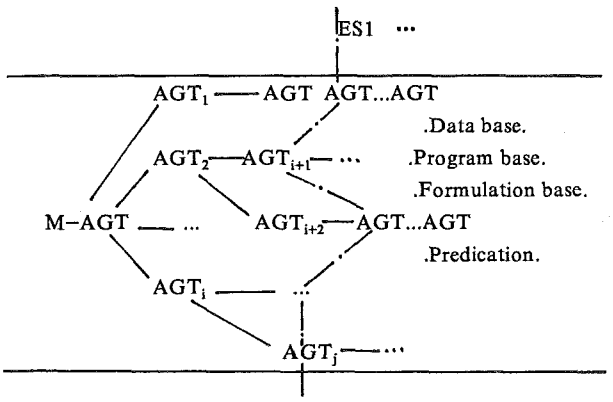

Fig.3 Hierarchical distributed knowledge organization

subtree. In order to reach the information sharing between agents, the information communication is transmited through the system's " blackboard system ".

The agents can be organized hierarchically and distributedly by the task decomposition. Then the agents compose an and / or tree. This knowledge organization way makes system have many advantages:

* Task solving step is planned explicitly and the problem–solving space is divided into several layers. This makes problem solving always develop to the correct direction. Because each layer space is small, the search speed is faster and the the running efficiency of the system is speeded up.

* Because of the hierarchical decomposition of task, the system can comment on results of every design steps and can redesign it. When the system defeats to execute some agents, it may go on running by the methods of interfacing with user and so on. So the reliability and user believability increase much.

* The hierarchical and distributed organization of the agents makes the building of the system obey the rules of Software Engineering. This make it easier to design, run and maintain the system.

* Such knowledge organization makes the cooperation of many expert system be reached easily.

VI. Control Strategy

Problem–Solving Strategy – Being related to hierarchical agents in Fig.3, the system synthetically utilizes the control strategy of schedule list, blackboard system and meta reasoning etc. to control problem solving. The knowledge used in the system to make higher level decisions is called meta knowledge, and the rule which is composed of meta knowledge is called meta rule. Generally, we call the operating activity to select relative rules from big knowledge base the meta reasoning[6]. the agents at the system's higher layer assign task through the processing unit, and select recent and low layer executing units. Then through the cooperation of control unit and reasoning ability of higher layer agents, the system does meta–reasoning to work on the schedule list by the blackboard. So the system can define the executing agents and their executing sequence in problem solving, and combined with the next layer agents the system decides whether needs the lower layer agents to finish solving task of recent agent. Shown as Fig.3, the highest agent of the system is called meta agent.

Meta agent is composed of knowledge base, inference engine and schedule list. Meta knowledge base is mainly composed of meta rules.

Schedule list is a grade arranging list of agent executing and is composed of operating functions. Each operating function calls and executes a function. It may call a procedure or may operate forward or backward reasoning to a rule set, or it does the combination of the above two aspects. The executing of agents in high layer is generally the operation to schedule list, but about simple task the agents can finish the task directly and need not the finishment of next layer agents. Schedule list may be changed in the problem solving.

Cooperation of Many Expert Systems – To solve complex problem, the cooperation of expert systems in different areas is needed(shown as the following instance). ADDES system finishes the cooperation of many expert systems by means of building overall dynamic data base through blackboard system. Every expert systems are logically independent. They have their own expertise and relative agents for problem solving. The revising to an expert system does not influence other expert systems. Through the producing and revising of schedule list, the cooperation of many expert systems is easily reached.

An Expert System(ES) can be defined by the agents it uses:

$$ES = \bigcup_{i=1}^{m} AGT_i$$

Then Many Expert Systems(MES) can be defined as:

$$MES = (BLACKBOARD + SCHEDULE - LIST) + \bigcup_{i=1}^{n} ES_i$$

Instance – To the square box–shaped part as shown in Fig.5, when running the expert system component, the system reasons about the control rules in strategic rule base by control unit to decide tantively the schedule list about agents for finishing the problem solving.

(Strategic–Rule–005
(IF ((equal part–num 11101)))
(THEN ((deduce "strategy.lsp" equ–square))))

The meaning of the rule is: if the part is square box–shaped, then operate forword reasoning to the equ–square rule set in rule base.

Then the system reasons about the rule set of square box–shaped part. It uses the following meta rule in meta agent.

(Meta–Rule–023
(IF (("PREDICATE" not to produce local material stacking)
("PREDICATE" not to produce too big stress))
(THEN ((ADD–LIST (times–11101–2))(EXECUTE schedule–list))))

The meaning of the rule is: if the user need not produce partly material stacking and bigger stress, then append the drawing times calculating agent of square box–shaped part to schedule list. Then execute the schedule list.

(Meta–Rule–024
(IF ((> (fget result pro–parameter times) 1))
(THEN ((ADD–LIST (cal–11101–3))
(ADD–LIST (deduce "strategy.lsp" cup–no))
(ADD–LIST (init–2–cup))
(EXECUTE schedule–list))))

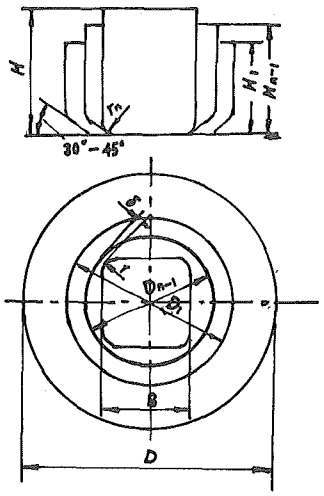

Fig.4 Deformation of square box–shaped part

The meaning of the rule is: if the drawing times is bigger than 1, then append the following agents to schedule list: the part's information calculating agent of the n–1 time (drawing times is n), design agent of cup–shaped part with on flange, design agent of square box–shaped part with one drawing time. Then execute the schedule list.

After the execution of one agent, the system does the operation of deleting the agent (DELETE–LIST). When executing the schedule list, the system operates with the agent in schedule list sequencely. The deformation of square box–shaped part shown as Fig.4 needs the cooperation of two sub expert systems: cup–shaped part with no flange and square box–shaped part with no flange.

Ⅶ. Explanation and Knowledge Compilation

Explanation is an important feature of expert system. To engineering design expert system, explanation makes expert system different from general CAD system in a very important aspect. Recently, expert systems adopt the explanation methods such as Canned Text, Execution Trace, strategy explanation and automatic programmer etc.. ADDES system synthsizes the front three methods to explain the system's treatment, problem–solving strategy and system processing process and so on questions. The system built a special explanation strategy rule set and the strategy rules are at high levels. From this, the high level explanation such as the system design thinking etc. can be received. An example of a explanation strategy rule is as:

(Strat–expla–rule–00n
(situation (goaln))
(condition (cond–n1)(cond–n2)...(cond–nn))
(action (subgoal–n1)(subgoal–n2)...(subgoal–nn)))

The system uses developing frame to record the reasoning type, the rule set or subset, the rules which are used in the running of the system, and the functions and its attributes(functions, variables, the subfunctions and formulations used etc.) are also recorded, so the tracing of the system executing process can be reached. The system using the module / keyword matching method to understand the user's natural language.

Knowledge compilation component is connected closely to explanation component. Through the understanding of user's

requirements, the system can make user use the displaying, modifying, expanding, updating and so on maniputation to the RB and DB and formulation base etc. in the knowledge base. Knowledge compilation component adopts the supervised learning mothed. The system display some words to the user's requirement and then the user can process every operation.

Ⅷ. Concluding Remarks

This paper suggests that the ECADES be the combination of intelligent front–end type and inserting type. The knowledge should be organized hierarchically and distributedly and the system should synthetically utilize the control strategy of schedule list, blackboard system, meta reasoning etc.. The researches made in the paper make the system also have the following advantages besides which is presented in section Ⅴ:

* The complex problems are solved through the cooperation of the knowledge in different areas.
* The system has potential expanding ability.
* The top–down technique is developed in the system.
* The system has high transparency and can be understood at different abstract levels.

The practical use of ADDES system in factory can explain that the researches in the paper is notable.

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References

【1】 Ohsuga, S 'Introducing knowleged processing to CAD / CAM' FiDnite Elements In Analysis and Design, Vol.1 (1985)

【2】 Gero, J. S(ed) Expert systems in computer aided design, North–Holland Amsterdan (1987)

【3】 Forgy, C "RETE: A Fast Algorithm for the Many Pattern / along Object Pattern atch Problem", AI. Vol.19, No.1, 1982

【4】 G. M. P. O'Hare "Designing Intelligent Manufacturing System: A Distributed Artificial Intelligence Approach", Computers inIndustry, 15 (1990) 17–25

【5】 Setsuo Ohsuga 'Toward intelligent CAD systems', Computer Aided Design Vol.21 June 1989

【6】 DAN I. Moldovan and Chung–I Wu, 'A Hierarchical Knowledge Based System for Airplane Classification', IEEE Trans. on Software Engineering, Vol.14 No.12 December 1988

【7】 M. N. Huhns, L. M. stephans and R. D. Bonnell, 'Control and co–operation in distributed expert system', Pro. IEEE Southeast Con., 1983

【8】 L. Gasser, C. Braganza, and N. Herman, "MACE: A flexible testbed for distributed AI research", in: M.N. Huhns(ed.), Distributed Artificial Intelligence, Morgan Kaufmann, Los Altos, CA, 1987

【9】 P. E. Green, "A framework for real–time distributed cooperative problem solving", in: M.N. Huhns(ed.), Distributed Artificial Intelligence, Morgan Kaufmann, Los Altos, CA, 1987

Appendix