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EXPERT MODEL for Knowledge Acquisition

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Abstract

This paper describes an expert task representation model (EXPERT MODEL) and a knowledge acquisition method (Pre/Post Method) based on the EXPERT MODEL. There are two major phases in the knowledge acquisition process. The first phase is the modeling phase which builds an expert task representation model. The second phase is the EXPERT MODEL instantiation and refinement phase. The EXPERT MODEL is a task-oriented representation to extract the expert knowledge. The Pre/Post Method stimulates the human expert to remember his expert tasks and associative knowledge.

1. Introduction

Knowledge acquisition is the most important process in building a knowledge-based system. It is important to find primitive tasks and methods in the knowledge acquisition tasks of the knowledge engineer. According to the ICOT "Knowledge Acquisition and Learning in Case Studies of Expert System Development Report" [Iwashita 86], there are many phases in knowledge system building. The four major phases are:

1. **Problem Analysis Phase:** This phase is separated into three sub-tasks.
(a) Selecting problems: The possibility and value of building a system is evaluated, and problems are selected.
(b) Evaluating current software technology: For selected problems, current AI software technology is evaluated, and the necessity of introducing current AI software is investigated.
(c) Identifying knowledge sources: The necessary knowledge for solving selected problems is evaluated, and is therefore the possibility of solving them. The quality and quantity of knowledge per knowledge source are analyzed.

2. **Expert Model Building Phase:** This phase is a pre-knowledge acquisition phase, and contains four sub-tasks.
(a) Extracting conceptual structures: Knowledge which represents conceptual structures is extracted from the knowledge sources.
(b) Identifying expert models: If the main knowledge sources are humans, the ways how the experts use their knowledge (their problem-solving techniques and inference methods) are identified.
(c) Identifying user models: The users' expectation and use of the system are identified.
(d) Building an expert model: An appropriate knowledge representation form is selected and a conceptual structure is defined.

3. **Expert Model Instantiation Phase:** This phase is one of major stages of knowledge acquisition. (Generally, this phase is called the knowledge acquisition phase.) There are four sub-tasks in this phase, which are evaluated circularly rather than sequentially.
(a) Extracting knowledge: According to the expert model, knowledge is extracted from the knowledge sources.
(b) Arranging and refining knowledge: Extracted knowledge is arranged and mapped on the expert model. Knowledge is refined to find and correct insufficiency and inconsistency of extracted knowledge.
(c) Transforming knowledge: The obtained knowledge is transformed to a format that can be used by the computer and stored in the knowledge base.
(d) Evaluating knowledge base: The knowledge base is evaluated to check whether it is sufficient for the expert tasks.

4. **Knowledge Base Management Phase:** In this phase, the consistency of knowledge added to the knowledge base is checked, and knowledge explaining added knowledge is automatically generated in the knowledge base.

We are researching knowledge acquisition methods of the expert model building phase and the expert model instantiation phase. The knowledge representation of the human expert tasks has conceptual structures [Sowa 83][Bennett 85]. Recently, some successful knowledge acquisition tools have been developed, which have their own conceptual structures. ETS [Boose 84] has a simple conceptual structure for classification tasks. It includes result items and constructs which represent the specification for classifying items. MORE [Kahn 85] has a diagnosis domain conceptual structure which is more complex than ETS. It has hypothesis, symptom, test, hypothesis condition, symptom condition, symptom attribute, test condition, link and path for diagnosis task representation. The conceptual structures of ROGET

[Bennett 85] are derived from real diagnostic expert systems. Conceptual structures of ETS and MORE are simple but consist of basic common concepts for diagnosis tasks. The conceptual structure of ROGET is a task-oriented representation. Generally, there are two types of knowledge in expert tasks: basic knowledge and meta-knowledge. Meta-knowledge is a strategic knowledge which contains information on how to use basic knowledge to solve the problems of the expert tasks. However, those conceptual structures do not include their meta-level knowledge. A unique expert system building approach is the idea of generic tasks [Chandrasekaran 85]. Generic tasks support some expert task primitives. Its primitive tasks are useful to define expert knowledge in the knowledge acquisition stage. Six generic tasks have been found, and the ongoing research is searching for other generic tasks. There are not enough generic tasks to cover all the expert tasks and they include several levels of knowledge representation which are not systematized completely. Effective knowledge acquisition needs arranged knowledge structures, which are separated into basic knowledge and meta-knowledge. The generic operations of heuristic classification [Clancey 85] is also useful to model expert tasks. However, they are not small operation primitives to be used for knowledge acquisition.

The EXPERT MODEL is designed to represent conceptual structures and meta-knowledge for the knowledge acquisition stage. It has three levels of knowledge representation. The core concepts of the EXPERT MODEL are syntactic generic operations. These syntactic generic operations are SELECTION, CLASSIFICATION, SORT, COMBINATION, TRANSFER, INPUT and OUTPUT. These primitive operations have been derived from diagnosis expert systems written in production rule form [Iwashita 86][ICOT 87]. In the EXPERT MODEL instantiation stage, these syntactic generic operations obtain semantics. The generic operations with semantics are called semantic generic operations. For example, one SELECTION with semantics is a test-devices selection operation. One generic operation consists of operation attributes, evaluators and element groups. An evaluator is the action description of a generic operation. The evaluator of SELECTION evaluates criteria of the selection. The evaluator of SORT compares attributes of elements in the element group and arranges them in order of the comparison result. The generic operations are constructed to be part of a knowledge base through modeling and instantiation. There is meta-knowledge to manage generic operations. Object-oriented architecture is adopted as this knowledge representation, because the message passing model as object-oriented architecture is suitable for top level human knowledge representation. In the EXPERT MODEL, the generic operation is an object. The following sections explain the EXPERT MODEL, an effective knowledge acquisition method and an implementation of the knowledge acquisition method on the personal sequential inference machine (PSI) [Taki 84].

2. EXPERT MODEL

This section explains the original idea of the EXPERT MODEL, and gives details of EXPERT MODEL structures.

2. 1 Basic Idea of EXPERT MODEL

The EXPERT MODEL is based on two ideas: the simplified expert task model and analysis and grouping of diagnosis expert knowledge written in production rule form.

(1) Simplified Expert Task Model

Expert systems can be distinguished as different task types. According to "Building Expert Systems" [Hayes-Roth 83], there are 10 generic categories of knowledge engineering applications: interpretation, prediction, diagnosis, design, planning, monitoring, debugging, repair, instruction and control. We tried to define these categories as simple models, because simple expert task models provide the expert task images for the human expert to represent his knowledge. Two samples are introduced later.

Simple Diagnosis Task Model

Fig.1 shows a diagnosis task. Diagnosis tasks are represented in tree structures and their search algorithm in general AI architectures. However, the tree structure is too general to represent individual expert tasks. A simpler model is a filter model. In Fig.1, G1 denotes the possible results of trouble positions, F1 is a filter to select real results, and G2 denotes the results of a diagnosis task. Fig.2 also shows a diagnosis task, but this model has some sub-tasks which are the same as these of Fig.1.

Simple Design Task Model

Fig.3 shows a very simple design task. Design tasks are very complex; therefore, this model is actually a sub-task of a design task. It consists of a part modification phase, a part assembly phase and a good selection result phase. G4 and G5 are design-part groups, F4 is a modifier, G10 is a group of modified G4 parts, F5 is an assembly or combination operation, G11 is an interim result group, F6 is a selector, and G12 is a group of design task results. (G5 should not be modified.) We have considered simplified expert task models and created a model (operation) which is constructed with a source element-group, evaluators (e.g. select filter) and a destination element-group.

(2) Study from Production Rules of Diagnosis Expert Systems

A production rule is a general knowledge representation for expert systems. Therefore, knowledge engineers must have techniques of rule writing to represent many kinds of knowledge. We assumed that those techniques may appear in the form of rules. Seven operations have been discovered in production rule sets: SELECTION, CLASSIFICATION, SORT, COMBINATION, TRANSFER, INPUT and OUTPUT. The combined result of both ideas is the syntactic generic operation.

2. 2 Expert Model Structure

The EXPERT MODEL is a specialized knowledge representation to collect expert task smoothly from human experts. It is not necessary for the knowledge acquisition process to provide a general knowledge representation, i.e. , production rule form. This section explains the components of the EXPERT MODEL.

2. 2. 1 Generic Operations

Generic operations are kernel knowledge representations in the EXPERT MODEL. The generic operations have been derived from simple expert task models and by analyzing production rules of diagnosis expert systems. There are two types of generic operations: syntactic generic operations provide primitive expert operation structures, and semantic generic operations provide details for the operations. Both are useful frameworks for knowledge acquisition. The benefits of these frameworks are explained as knowledge acquisition methodology in section 3.

(1) Syntactic Generic Operations

There are seven syntactic generic operations: SELECTION, CLASSIFICATION, SORT, COMBINATION, TRANSFER, INPUT and OUTPUT. Each operation has one or more source groups, destination groups and evaluator groups. Combinations of the source and the evaluator group are dynamically changeable.

SELECTION Operation

The SELECTION operation picks up elements from the source group according to the selection conditions of the evaluators. Fig.4 shows an example of the SELECTION operation.

CLASSIFICATION Operation

The CLASSIFICATION operation separates source elements into groups. The upper SELECTION operation is an example which is a special case of CLASSIFICATION. Fig.5 shows an example of the CLASSIFICATION operation.

SORT Operation

Elements of groups take turns to evaluate. The SORT operation sorts elements of the source group and makes a destination group, in which elements take their turns in order of the sorting condition.

COMBINATION Operation

The COMBINATION operation assembles source elements into new elements. Generally, there are multiple sources, as shown in Fig.6.

TRANSFER Operation

The TRANSFER operation is used for data abstraction and data interpretation. In this operation, elements of the source group are translated and the destination group is generated. New elements must be generated, or attributes of elements must be added or changed.

INPUT Operation and OUTPUT Operation

These are interaction operations between expert systems and a user (or a measuring device). The INPUT operation makes a new group without source groups. The OUTPUT operation does not make a destination group. It gives source group information to the user according to the output process.

(2) Semantic Generic Operation

The semantic generic operation is the syntactic generic operation with semantics and control. It has the following additional attributes for semantics and control.

Semantic Generic Operation:
Operation_Name: XXXX
Operation_Class_Name: YYYY
Pre_Operation_Class_List: [O1,O2, . . . /On]
Post_Operation_Class_List:[Po1,Po2, . . . /Pom]
Syntactic_Operation_Class:[Select/.../Output]
Source_Group_Type: ZZZZ
Destination_Group_Type: AAAA
Evaluation_Group_Type: BBBB
Control_Type_Default:[Sequential/Parallel etc.]
**Operation_Instance_Name: xxxx*
**Pre_Operation_List:[o1,o2, . . . /on]*
**Post_Operation_List:[po1,po2, . . . /pon]*
**Source_Group_Name: zzzz*
**Destination_Group_Name: aaaa (or auto_generate)*
**Evaluation_Group_Name: xxxx*
**Control_Type:[Sequential/Parallel etc.]*
**Starting_Condition:[. . .]*
**Send_Message:[. . .]*

Attributes prefixed by an asterisk are used for instantiating the generic operation. These attributes are called instantiation attributes. Other attributes are used for checking values of instantiation attributes in the instantiation process. These attributes are called acquisition type checkers. If an acquisition type checker does not have any types, that check is not performed at the instantiation process. Semantic generic operations have information for an inference engine. They are defined in Control_Type_Default and *Control_Type. The search control type by which all solutions are searched is the all solution search type. The search control type by which the ordered number of solutions are searched is the partial solution search type. The contents of the control are shown in Fig.7. There are no notably different effects between sequential and parallel inference control. The EXPERT MODEL supports parallel control, because the inference of parallel inference control is more efficient than that of sequential inference control, and there is some parallel representation in expert tasks by nature. The normal inference algorithm in expert systems is the all solution search type or the one solution search type, whereas human experts solve some solutions and select a better result from those solutions. This is one reason why partial solution search type control is supported in The EXPERT MODEL. When human experts do not know their solution mechanisms, then the *Control_Type attribute is empty and the Control_Type_Default attribute is used for the search type.

2. 2. 2 Elements

Elements consist of items and their attributes. Elements are frame-based knowledge representations which have attribute-slots and an inheritance, but they do not have the attached procedures as demons. Each element must belong to one or more element groups. An element is accessed by one or more semantic generic operations.

2. 2. 3 Evaluators

Evaluators consist of conditions and actions, and may include the procedural process. Their form is a production rule. Sometimes, the evaluator group is a source group of a generic operation. For example, in a constraint relaxation problem of a planning task, a big evaluator group which has many conditions as constraints must be modified to a small evaluator group which has fewer conditions. This small evaluator group is used to solve the planning task.

2. 2. 4 Meta-Operation-Control: Meta-Script

The expert tasks have their scenario for solving problems, therefore, this meta-operation control is called Meta-Script in the EXPERT MODEL. It is a representation language to describe meta-level knowledge. Fig.8 shows its location in the knowledge base. The EXPERT MODEL is recognized as an object-oriented model, and a generic operation is an object. The communication between a semantic generic operation and other operations is a message passing process, which has two types in the EXPERT MODEL: the inheritance and the post operation call. The inheritance is supported as the Operation__Class__Name attribute. The post operation call is supported as the Post__Operation__List attribute. The control of the message passing for the post operation is shown in Fig.9. In the parallel process, all post-operations for which the condition of *Starting__Condition is satisfied run concurrently after their pre-operation is executed.

3. Knowledge Acquisition based on EXPERT MODEL

This section describes the Pre/Post Method, which is a method of knowledge acquisition based on the EXPERT MODEL. There are two processes for acquiring expert knowledge from a human expert: the model building phase and the model instantiation phase. In the knowledge engineering process, the knowledge base is built cumulatively. The first knowledge base is called the initial knowledge base. It is useful to study the problem of the expert tasks and how the human expert solves it with his knowledge, for a knowledge engineer, a human expert and a user. Generally, the initial knowledge base has only major items and relations of solving the problem, and it rarely has meta-level knowledge for effective problem solving. Almost knowledge acquisition tools support only the initial knowledge base building. We analyzed these ways of building knowledge bases as shown in Fig.10 and designed the Pre/Post Method to acquire not only basic knowledge but also meta-level knowledge.

3. 1 Model Building Method: Pre/Post Method

The Pre/Post Method is a horizontal knowledge acquisition method (*Model Building -> Model -> Model Instantiation -> Knowledge Base*), shown in Fig.10. This method has a few model building strategies. The main strategy of this method stimulates a human expert to remember pre/post operations which are associated with a focal operation. The human expert can easily answer what operations are necessary before or after the operation. For example, when the car does not move, the human is asked *"What do you do before checking the engine ?"*. He can easily answer, *"I have to check the remaining gas"* or *"I have to check the battery"*. The following steps are knowledge acquisition steps based on the Pre/Post Method.

Step 1: Collecting several human expert operations at random. It is not necessary for each operation to have any relation to the others. These operations are used as the starting points of knowledge acquisition.

Step 2: Making questions to obtain pre and post operations for each collected operation. This step continues until no new operations are extracted from the human expert. The same process is repeated for new operations.

Step 3: Many operations have been gathered and they have pre/post information which operations have to execute before or after operations. This step is the pre/post relation check step. One way of checking is to display pre/post relations graphically for the human expert. Fig.11 shows pre/post relations. Relation1 shows only that Pre1 to Pre3 are pre-operations of a point operation and Post1 to Post3 are its post-operations. In relation2, there are new orders among pre/post operations defined by the expert. Pre1 is a pre-operation of Pre3. Pre2 is a post-operation of Pre3. Post1 is a post-operation of Post2. The more pre/post information collected, the clearer pre/post relations. The sequence of some operations may be unclear. We treat the group of these operations as a weak sequence strategy group. When an operation of this group is finished, sometimes the result of the operation affects the other operations of this group. It is important for this group to obtain constraint information.

Step 4: This step is the instantiation step of each operation. The human expert must select a syntactic generic operation to define the role of each operation. Sometimes, operations defined by the human expert are big tasks which contain several sub-operations. To distribute these big tasks, it is important to ask *"What sub-operations exist in XX (an operation name)? Please answer at random"*. After this question, pre/post operations must be extracted for sub-operations. Then, the Step 3 process is executed again.

Step 5: This step merges operations. According to pre/post information and generic operation types, some operations are merged to one generic operation.

Step 6: Each operation has evaluators. This step defines these evaluators. It is not difficult to do this process, because the role of the operation is clear and its function has been identified by its generic operation type.

Step 7: The elements of the source group are defined in this step. Sometimes, it is difficult to decide the elements and group of a focal operation, because they are decided dynamically after its pre-operation has been executed. Therefore, the human expert must search for the candidates of the source group from the result (destination group) of its pre-operations.

Step 8: Attributes and attribute values of the elements are defined in this step. Each element must have the attribute evaluated by the evaluators. Generally, elements flow through a lot of operations, and need the attribute which is evaluated by the evaluators in the flow.

3. 2 Example of the Pre/Post Method

This is a diagnosis knowledge acquisition example about part of a controller of a steel rolling mill.

Q1 (System): *What operations are there in your task? Give one.*
A1 (Human Expert): *Control amp check.*
Q2: *What are the pre-operations of the control amp check?*
A2: *Electric current hunching check.*
Q3: *What are the post-operations of the control amp check?*
A3: *Pre-circuit of speed control loop check, pre and post stand AGC check, speed control loop check and current control loop check.*
:
Q4: *What are the post-operations of the electric current hunching check?*
A4: *Other control circuit effect check, machine vibration check, pre and post mill effect check.* (Fig.12 shows the operations extracted after A4.)
Q5: *Is the function of the control amp check included in syntactic generic operations?*
A5: *No.*
Q6: *What are the sub-operations in the control amp check?* A6: *Condition input, sort next check sequence and select next check.*
Q7: *Please select the syntactic generic operation type for A6 operations.*

The operations shown in Fig.13 are sub-operations of the control amp check, which have their syntactic generic operation types and own rough contents. (They also have pre/post information, which is not described here.) All operations are distributed into small sub-operations which can be described with syntactic generic operations. Each operation is given semantics and refined. Operation 11 is a SELECTION operation, therefore, the knowledge acquisition system knows what is necessary to perform the SELECTION operation, i.e. , selection criteria and selection objects. The system easily makes questions for instantiation of the operation attributes.

Q8: *What do you call Operation 11 ?*
A8: *Control amp detail check selection.*
:
Operation 11:

Operation__Name: "Control amp detail check selection"
Operation__Class__Name: "Controller Circuit"
Pre__Operation__Class__List:[Input,Output,Sorting]
Post__Operation__Class__List:[Any]
Syntactic__Operation__Class:[Select]
Source__Group__Type: Operations
Destination__Group__Type: Operations
Evaluation__Group__Type: No condition
Control__Type__Default:[Sequential/Backtrack/1]
**Operation__Instance__Name:*
"Control amp detail check selection"
**Pre__Operation__List:[Operation 1 . . . 10]*
**Post__Operation__List:[Operation 12 . . . 16]*
**Source__Group__Name: Group20*
**Destination__Group__Name: Group21*
**Evaluation__Group__Name:*
First__candidate__pick__up
**Control__Type:[Sequential/Backtrack/1]*
**Starting__Condition:[None]*
**Send__Message:[Group21]*

After all operations are instantiated, element groups and evaluator groups are instantiated and refined.

Q9: *Group 20 has four elements: current control, speed control, AGC and pre-circuit of speed control. Are there any other elements in Group 20?*
A9: *No.*
Q10: *What are the criteria to sort in Operation 10 ?*
A10: *Count up the attributes which are equal to values of attributes of Control__Amp element and sort elements of Group 20 in order of the count number.* (This answer must be changed into rule form.)

This example is part of the knowledge acquisition process based on the Pre/Post Method with the EXPERT MODEL (generic operations).

3. 3 Implementation of Pre/Post Method

To implement the Pre/Post Method, pre/post relations must be displayed clearly for the human expert. Therefore, a workstation with a multi-window display is a useful display tool. A knowledge base after the knowledge acquisition must be evaluated dynamically to check whether it satisfies the expert tasks or not. The structure of the EXPERT MODEL has rules for evaluators, frames for elements and object-oriented mechanisms for meta-level control. Therefore, the workstation should have a logic programming language with object-oriented architecture. A knowledge acquisition support system using the Pre/Post Method, called EPSILON/EM, is being developed on the personal sequential inference machine (PSI) which has an object-oriented logic programming language (ESP: Extended Self-contained Prolog) [Chikayama 84]. Fig.14 shows the windows of the contents of an operation on the PSI.

4. Conclusion

This paper introduced the EXPERT MODEL which is derived by analyzing production rules in diagnosis expert and simple expert task models, and explained a knowledge acquisition method, the Pre/Post Method.

This knowledge acquisition method supports the model building stage and the instantiation and refinement stage. The Pre/Post Method stimulates the human expert to remember his expert tasks and associative knowledge. The EXPERT MODEL has strategic knowledge representations (generic operations), but does not have special basic knowledge representation primitives. In the future research, the EXPERT MODEL should have multi-level knowledge task primitives, which are elements, evaluators, local strategy, global strategy and more hierarchical strategy, and the knowledge acquisition method based on the EXPERT MODEL should have model building and instantiation methods for multi-level knowledge task primitives.

5. Acknowledgment

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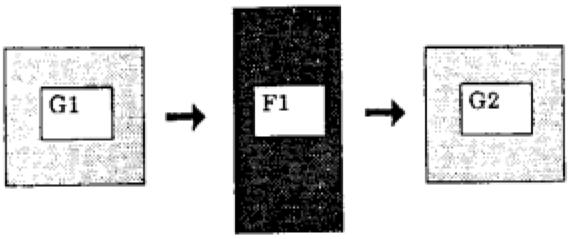


Fig.1 Simple Diagnosis Task Model.(No.1)

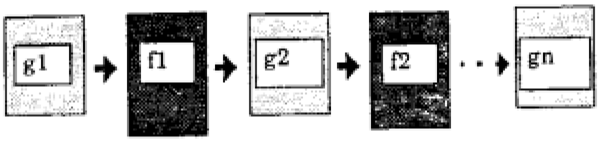


Fig.2 Simple Diagnosis Task Model (No.2)

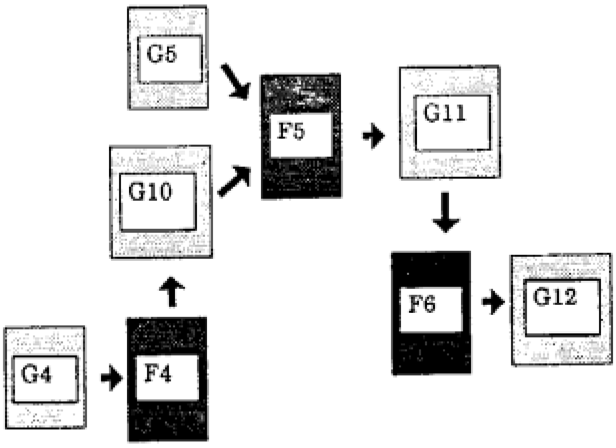


Fig.3 Simple Design Task Model

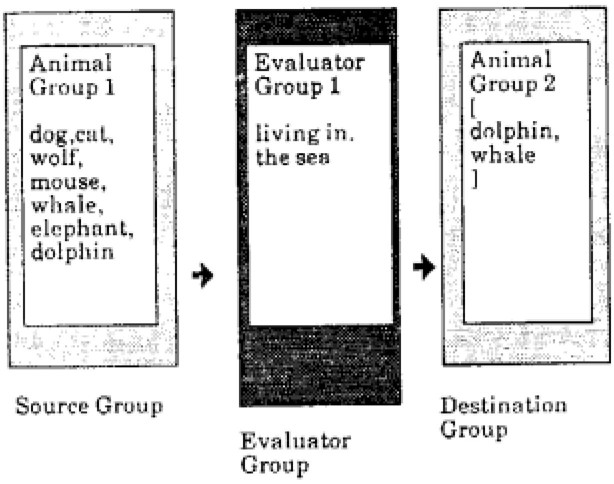


Fig.4 Example of SELECTION operation

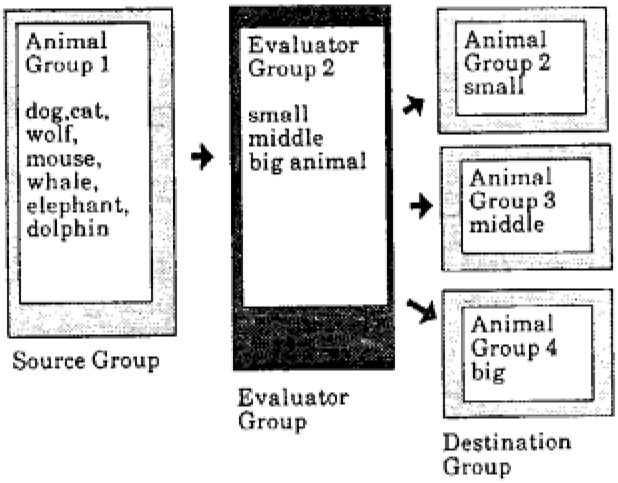


Fig.5.Example of CLASSIFICATION operation

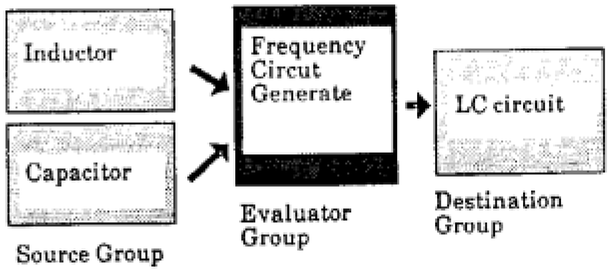


Fig.6.Example of COMBINATION operation

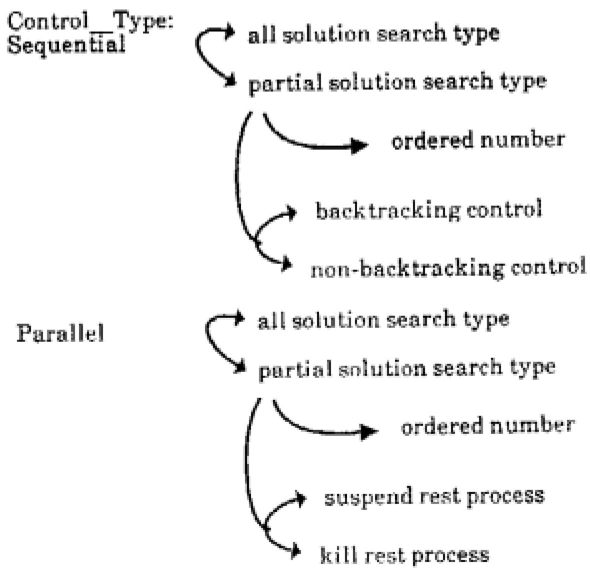


Fig.7.Generic operation control types

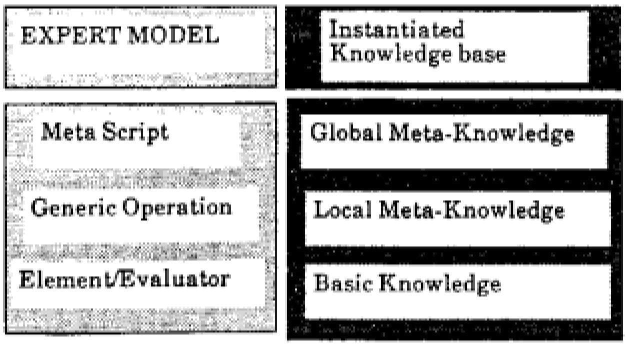


Fig.8 Hierarchy of the EXPERT MODEL

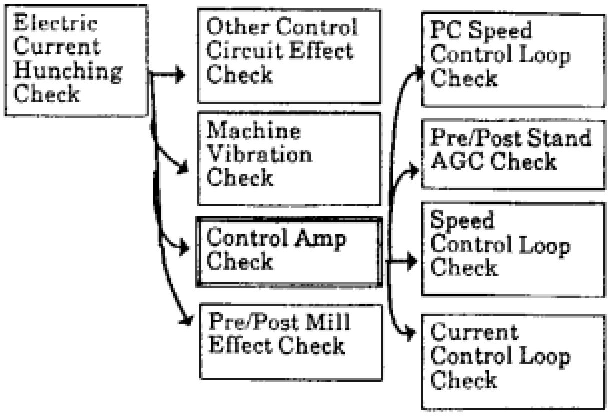


Fig.12 Example of pre/post operation relation

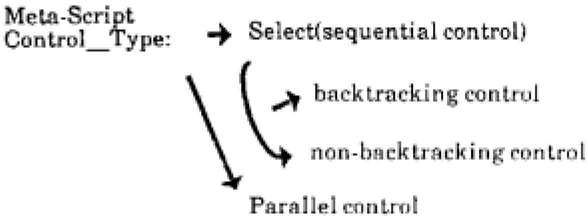


Fig.9 Meta-Script level operation control

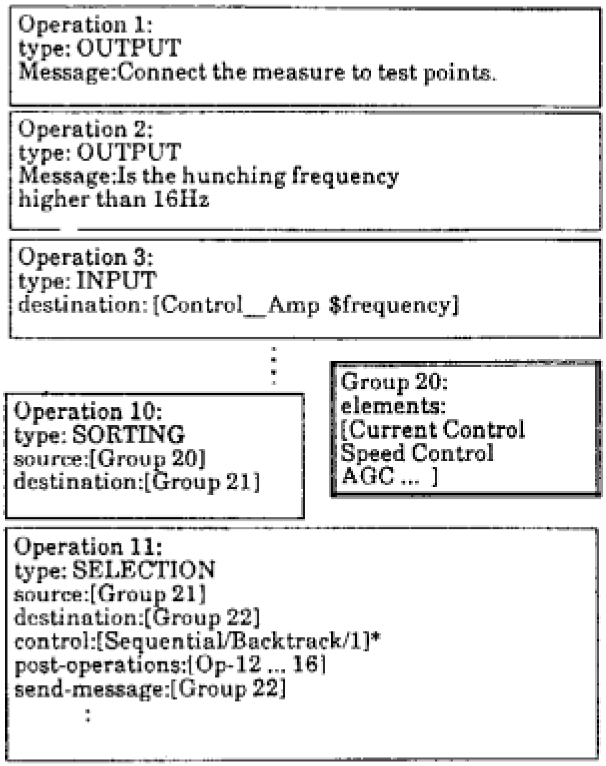


Fig.13 Operations of control amp check

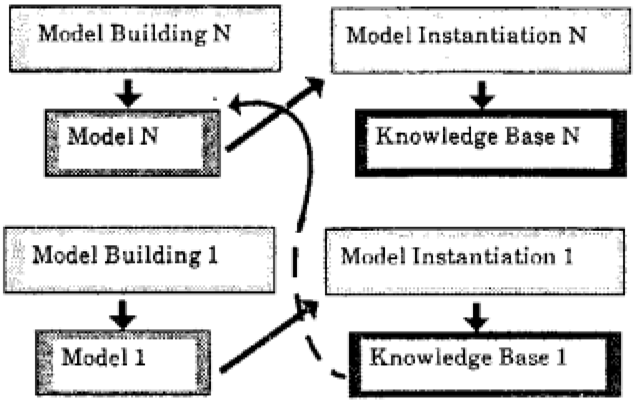
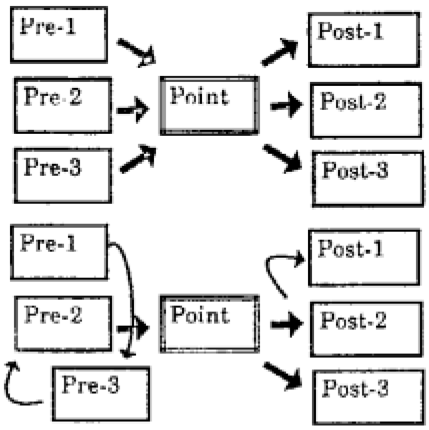


Fig.10 Knowledge Base Development Process



Relation-1

Relation-2

Fig.11 Pre/Post relation example

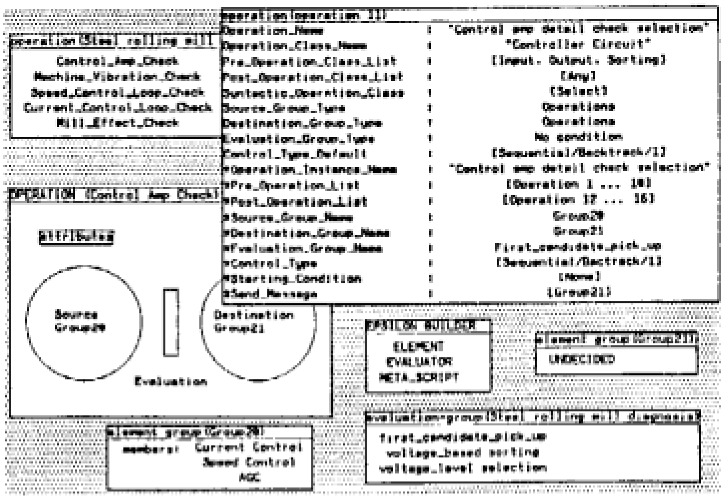


Fig.14 Sample Windows of EPSILON/EM