Combining Rule-Based Knowledge Acquisition with Task-Oriented User Analysis for Dispersed, Embedded Expert Systems

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Abstract. *Production rules are a popular representation for capturing heuristic knowledge in expert systems. Rule representation is a simple and powerful tool for modelling a wide range of problems. However, rules have limitations in providing an overall problem solving strategy, particularly for dispersed and embedded expert systems. In contrast, a task-based approach can provide a high-level structure for problem-solving processes, but is less beneficial for specific aspects of decision making. In this paper, an approach is presented that combines a rule-based approach with a task-based modelling methodology to provide a method of cross validation for both rules and task models, and to facilitate the acquisition of both. Task models are used as specifications of overall system requirements, and map onto methods in the implementation of the system; expert system functions are then implemented as rule modules called by methods. This combined approach provides a richer representation, makes the maintenance process much easier, and facilitates the design of a system that integrates expert system functions with database access and general business activities performed by users.*

1. Introduction

The current generation of knowledge-based systems is typically intended to perform in a framework of collective work. Early expert systems typically had a simple control structure and uniform representation of knowledge, in the form of associational production rules; however, a pure rule representation is no longer considered to be sufficient, either for the purpose of system construction or for knowledge acquisition [1]. A task-oriented approach can provide a high-level structure for problem-solving processes [2, 3]. However, it is not always convenient for focussing on specific aspects of a problem.

Combining multiple models and methods, and adopting a knowledge-level approach [4] for designing knowledge-based systems, are complementary ways to overcome drawbacks of first generation expert systems [5]. This requires both stronger modelling facilities and simple if-then rules. In this paper, we have combined a task-based modelling methodology [6, 7, 15] with rule-based knowledge representation and processing to facilitate the expert system design. The task analysis approach enhances knowledge elicitation and guides the knowledge acquisition process [8], as well as providing an overall framework for user interaction and software system design. The rule-based structure records the detailed rules capturing expertise in the system and supports decision making by providing context-sensitive guidance to users. Task models are used as specifications of system requirements in terms of business processes, and also map onto methods in the design and implementation of the system. Expert system functions are then implemented as rule modules called by methods that are dispersed throughout the application. The combined approach provides a richer representation and simplifies system maintenance.

In this paper we firstly describe the problem domain, then we describe the system. The approach has been applied to build a successful industrial expert system in Australia.

2. The Problem

Spare assessing and provisioning are currently carried out by personnel with a wide variety of knowledge and experience in Royal Australian Navy. Due to the high staff turnover and the timeframe required to gain expertise for performing the task, the methods and effectiveness of problem-solving and decision-making by assessors varies. This results in less than optimal spares allowance determinations for expensive equipment investments. The Spare Assessing Expert System (SAES) aims to provide a standard approach to the assessment task, to improve the consistency of assessments, and to guide users in the assessment process.

3. Overview Of The Proposed System

A combined task-based and rule-based approach has been used to design the SAES system. The task-based description is based on MAD (Methode Analytique de Description) - an analytical method for describing the task [6, 7]. The rule-based structure includes decision trees and decision tables.

3.1 Task-based approach

MAD offers an extension of the key-concept of abstraction levels from the most general (root) to the most specific task. The main concepts that we apply from the MAD are: task and task descriptions. We have slightly modified the MAD to suit the specific needs of our purpose.

The concept of a task can be defined as:

- an *elementary task* - a task that cannot be further decomposed.
- a *composite task* - a task whose operational level can be decomposed into subtasks.

Each sub-task can be described as:

- name of the task: is given in natural language and is the clearest description of the task. For an elementary task, the name of the task is the content of the body; for a composite task, the name is a summary of the goal.
- automatic task: the task is automatically executed by the expert system.
- SEQ (sequential task); sub-tasks are carried out in sequence, i.e. one after the other in a given order.
- ALT (alternative task): indicates that a task can be carried out in various ways, but only one of its sub-tasks is carried out.
- PAR (parallel task): the order of sub-tasks is not constrained a priori.
- @ (iterative task): the task may be executed several times.

Figure 1 shows a sample task with subsequent sub-tasks. Due to the use of the SEQ operator in the figure, each sub-task executes in a sequential order from the left-hand side of the diagram to the right-hand side of the diagram.

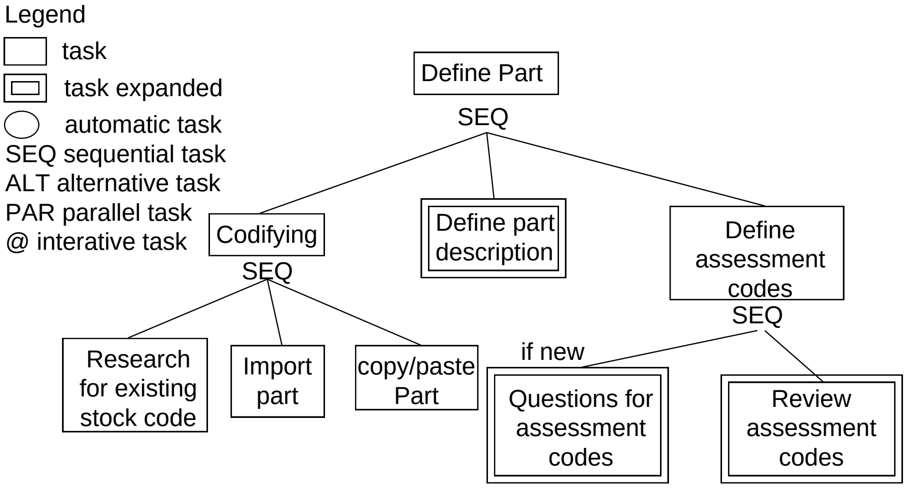

Figure 1. A sample task with subsequent sub-tasks.

Task descriptions are associated with each task. The elements of a task description include:

- Goal: the objective achieved by executing the task
- Pre-conditions: a set of conditions expressing constraints upon the objects of the initial state of the task
- Task component: the body of the task. It can either be an elementary action or a structure of subtasks.
- Post-conditions: a set of conditions expressing constraints upon the objects of the final state of the task
- Description: comments or explanations about the task

For example, below is the task description for the "define part" task,

Goal:	create or modify part information
Pre-condition:	define APL
Task component:	composite task
Post-condition:	Development report
Description:	an APL consists of many parts. The same part number may belong to different APLs.

We have restricted the MAD to suit the specific needs of this project. For example, to express a conditional task in the MAD, we add a constraint on the task model (see figure 1). We also do not use the simultaneous operator in the MAD.

An APL (Assembly Parts List) lists all components or parts of an assembly that comprises particular assembly. The assessment codes contain OBRP (Onboard Repair Part Code), MLC (Maintenance Level Code), PEC (Part Essential Code), MRU (Minimum Replacement Unit), T/O (Technical Override), and RF (Replacement Factor).

The MAD methodology provides an overall organisational framework for application development, based upon user task decomposition. The resulting task blocks then provide focus areas for detailed knowledge acquisition tasks. The association of task-specific rules with task-specific objects and data structures in the final application allow this modularisation of the knowledge base to be preserved in the final implementation of the system.

3.2 Rule-based approach

While the task-based approach is beneficial to capture the big picture of the tasks supported by the system, it does not provide detailed descriptions of the kinds and nature of specific automated decision support functions for specific tasks. In addition to providing data definition and interfaces, active expert system functions are provided to guide the user in the assessment process, eg. by presenting context-specific and adaptive sequences of multiple choices questions. Based on the answers provided by the user, decision tables or decision tree techniques are used to select sequential subtasks. For example, a decision tree shown in figure 2 represents the process and decision making for an OBRP task, corresponding to a detailed subtask block in the expanded tree under “Questions for assessment codes” in Figure 1. The OBRP of an item indicates the allowance calculation method to be used. The determinations of the OBRP are based on the size, weight and handling of the assembly.

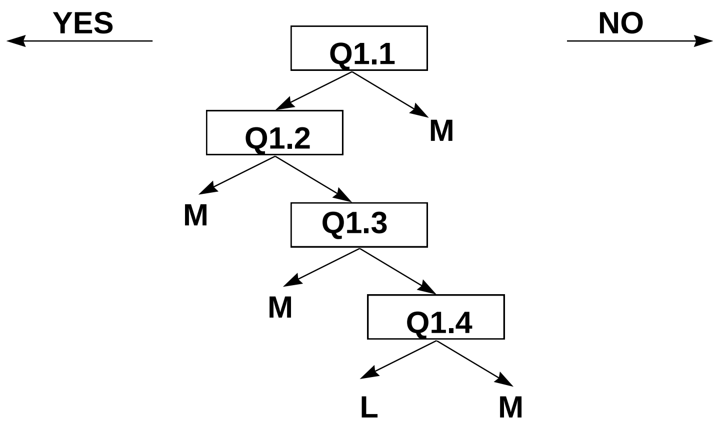

Figure 2. A decision tree for the OBRP assessment code.

“M” refers to an item if it physically too big or too heavy and “L” refers to the size of an item is small.

An example rule for representing the OBRP decision making process is:

```
If the answer of Q1.1 is No then
      OBRP = M
else
      ask Q1.2
end if
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Decision tables are also used to support decision processes [16]. For example, the decision table shown in table 1 represents the decision making for the PEC task. The PEC code decides if the part is vital or non-vital to the assembly.

Question 3.1	Question 3.2	Question 3.3	PEC decision
yes	yes	yes	vital
yes	yes	no	vital
yes	no	yes	vital
yes	no	no	vital
no	yes	yes	vital

no	yes	no	non-vital
no	no	yes	vital
no	no	no	vital

Table 1. A decision table for the PEC assessment code.

The rule for representing the PEC decision making process is:

If the answer of question 3.1 = no and
 the answer of question 3.2 = yes and
 the answer of question 3.3 = no then
 PEC = non-vital
else
 PEC = vital
end if

4. Discussions

One of the advantages of applying the MAD methodology, compared with a specific knowledge acquisition methodology like KADS [9] or generic task modelling [3] is that MAD can be used as a tool both for knowledge acquisition, for user interface design [10], and for the overall design of the application software. The MAD methodology provides ergonomic specifications based upon an analysis and description of the users' task. The task analysis and description carried out using MAD focuses on the identification and selection of interface design, providing a business model within which dispersed expert system functions can be embedded.

In traditional expert systems, all of the rules may need to be re-validated if a new rule is added or an old rules modified. Thus, it is very difficult to maintain expert systems and control the effects of additional knowledge [11]. The combined of task-based and rule-based approach makes the maintenance process much simpler by modularising collection of rules and thus allowing the user to manage the rules in each task separately.

5. Related Work

Many knowledge-base development methodologies and implementations are based upon an integration of rule processing with frames or object-based representations. Research in planning has heavily relied upon hierarchical task decomposition leading eventually to detailed situation-action rules [12].

The approach explored in this paper differs from these established methods by the introduction of a task analysis methodology specifically intended for HCI (Human Computer Interaction) analysis. This integrated methodology offers a significant enhancement to knowledge acquisition approaches. For example, a well established knowledge acquisition methodology for knowledge-based systems is KADS. KADS organises the design and development of knowledge systems into phases where each phase represents a separate portion of the whole development process. It develops layered modelling languages for conceptual models and design models. A library of interpretation models is available with the methodology, and conceptual model can be built by the knowledge engineer selecting interpretation models, combining them, and adding the domain layer.

However, we found that it was difficult to map our problem types into interpretation models in KADS. Also, KADS has not attempted to address the user interface design and the management of the resources and tasks required to complete the design and development of the knowledge-based systems in a limited time period.

6. Conclusions

The MAD methodology provides a method for modelling overall business processes and user tasks, as well as problem solving and decision tasks that can be automated by expert systems technology. This project has demonstrated that this provides a very effective method for designing an integrated, dispersed system for work flow support in which expert system functions can be invisibly integrated with extensive user interfaces for data definition and manipulation tasks. Supplementing MAD with rule representation and processing techniques provides a language for further elaboration and definition of business rules within a framework for holistic system development. Expertise is dispersed throughout the resulting system, seemlessly integrated with user work practices.

This integrated approach to knowledge systems development has resulted in a highly successful application, and promises to enhance the effectiveness of knowledge systems in general. A particular feature of the approach is its focus on the nature and role of formalised knowledge processing within the human task environment. Problems with knowledge systems have often been attributed to insufficient represented knowledge, and the need for common sense or contextual knowledge [13]. An alternative conception of knowledge bases as a formalised text structure suggest a different approach of leaving contextualisation to the user [14]. In this case, a strong focus upon user tasks and user-knowledge model interaction is critical in ensuring that knowledge contextualisation occurs in the most appropriate way. As this project has demonstrated, the use of HCI methodologies integrated with knowledge engineering methodologies facilitates this contextualisation, facilitating simple solutions to the contextualisation of knowledge systems.

Acknowledgement

The authors would like to thank the SAES project team members from MCCA and ISSC for their invaluable cooperation in building the expert system.

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