Modelling Interaction with Experts: The Role of a Shared Task Model

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Abstract. The role of an agreed, shared task model as an intermediate representation of a design/decision task upon which (1) negotiation between an expert user and a knowledge engineer, and (2) interaction between an expert user and an intelligent design/decision support system are based, is the focus of the research presented. A declarative compositional approach to user-centered system design (within the DESIRE framework) is presented and illustrated on the basis of a shared task model for the design of environmental policy.

1. INTRODUCTION

The role of the interface between an intelligent design/decision support system as such and the human user is to support the understanding of the task at hand (see also [1,2]) of the roles of the participating parties and of the results. User centered task analysis and task modelling are essential elements in the design of such systems [3,4]. To design a user interface for a design decision support system the interaction between system and (one or more) expert users can be based on a shared model of the task. In other situations, for example, for multi-user information retrieval support systems, collective interests may be of importance [5] and influence the design of the user interface.

2. INTERACTING WITH EXPERTS

To structure the exchange of knowledge between a knowledge engineer and one or more expert users often mediating representations are used (e.g., [6]). From our perspective, one of the results of knowledge acquisition (task analysis) is a shared task model: a model which both the knowledge engineer and the expert user(s) agree to be an acceptable representation of the task structure for which support is to be provided.

2.1 Knowledge acquisition

During knowledge acquisition and task analysis the mediating representations upon which a more extensive understanding of a task is acquired, is initially abstract. Subsequently the different types of knowledge involved are made explicit: the tasks and subtasks, task sequencing, knowledge structures, information exchange and delegation of tasks. These types of knowledge are also distinguished in task analysis approaches such as KAT/TKS [7,8].

The tasks involved in design/decision support systems, however, are often reasoning tasks: tasks which involve different types of reasoning at different meta levels. The task model (of a complex, multi-level reasoning task) which evolves during the phase of knowledge acquisition should be fully supported by the expert: the expert should agree that the (reasoning) tasks distinguished are, in some way, related to the way he/she views as the task at hand.

2.2 Shared task model

As a shared task model is the result of direct interaction between a knowledge engineer and one or more experts with the purpose of identifying a common understanding of the task at hand, the model defines the user's view of the required functionality of the system and possible delegation of tasks to participating agents, e.g. a system and a user. This model provides a basis for the design of the interface between the design/decision support system and the expert user. Within this model different types of subtasks will have been distinguished: some of which may require interaction between the user and the system, and others which may not. Different types of information may be exchanged, depending on the subtask. These different types of information can be seen to define different levels of interaction.

2.3 Levels of interaction

Within the context of a given task often specific subtasks may be assigned to either the expert user or the system. For example, the system may discover that certain information, required to be able to provide an answer to a specific user's request on a related issue, is unknown to the system. This is the case when, for example, the user has not yet made specific facts about a current problem known to the system. This type of interaction, *object level interaction*, in which one of the parties (often the user) is requested to provide facts of this type, is not uncommon to knowledge-based systems.

Interaction between the expert user and the system is, however, often of a slightly different nature. In design and decision making processes expert users frequently wish to influence the factors on which designs/decisions are based: the goals, the heuristics employed, preferences, assumptions, using the system to explore the results of different strategies. Interaction at this level, *the level of strategic preferences*, is not uncommon within the tasks examined, but is not often included in knowledge-based system design.

Although a shared task model is the result of interaction with an expert user, it is not necessarily "the" correct model of a task for all problems in all domains. The expert user may want to be able to influence, for example, the sequencing or choice of subtasks in a particular situation. The design/decision support system with which the user interacts should make this possible. This is not only of importance for the individual expert for which a system may have been designed, but also for other expert users (often the expert involved in the design of a system

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ECAI 96. *12th European Conference on Artificial Intelligence*
Edited by W. Wahlster
Published in 1996 by John Wiley & Sons, Ltd.

represents a class of experts for which the system is designed) for which the model can be seen as a model of consensus. This model may need to be adapted for individual experts. This level of interaction has been termed *the level of task model modification*.

To model the knowledge required at these three levels of interaction within the task model, a task based framework for the design and development of compositional systems is required.

3. MODELLING INTERACTION

Declarative compositional frameworks for the design of complex (knowledge-based) reasoning systems provide a means to specify shared task models. The framework developed and employed within our current research is discussed below, as is the process of model acquisition and model employment as a basis for the design of interactions with an expert user.

3.1 Declarative compositional approach

DESIRE [9,10,11], provides support for the specification (and implementation) of task models including knowledge of:

1. the task structure (task (de)composition) as, for example, hierarchies;
2. sequencing of (sub)tasks and goals (control (de)composition) specifying, for example, which (sub)tasks can be done when (and under which conditions);
3. knowledge structures (knowledge (de)composition), such as, for example, taxonomies;
4. information exchange, such as the types of information transferred between components; and
5. which (sub)tasks may be assigned to which party (task delegation).

All this knowledge is declaratively specified with semantics based on temporal logic [10].

3.2 Task models

A shared task model, as a mediating representation, is the result of negotiation between a knowledge engineer and one or more experts. An expert has extensive (often implicit) knowledge of a domain and of his/her task and strategies. A knowledge engineer has knowledge of existing models of related tasks which may or may not be applicable. Abstract task models are often used to structure the knowledge acquisition process.

Within the DESIRE framework [9,11], a number of such abstract task models, generic task models, exist which are used for this purpose. These models have been defined on the basis of experience and logical analysis. The concept of a generic task, introduced by Chandrasekaran [12,13] and Brown and Chandrasekaran [14], is comparable to the notion of *generic task model* in that they are both generic with respect to domains. Generic task models within the DESIRE framework, however, are generic with respect to both tasks and domain: generic task models can be refined with respect to the task by *specialisation* (e.g., further decomposition of a subtask) and refined with respect to the domain by *instantiation* (e.g., addition of domain-specific knowledge). Moreover, the way a generic task model is specified in DESIRE is more declarative (with semantics based on temporal logic) than the way generic tasks are described in Chandrasekaran [12,13] and Brown and Chandrasekaran [14].

Existing task models have been analysed and generic elements distinguished. The generic task model for design in DESIRE, for example, is a result of this type of process. Task models for the design of financial routing specification [15] and the design of office assignment formed the basis for this model. This model has since been used for the design of a lift [16], but also for the design of an emission inventory support system [17].

The integral approach to levels of abstraction within the DESIRE framework supports the use of generic task models during knowledge acquisition. Different levels of abstraction and composition play a role during the negotiation phase. Once, however, a shared model has been found, this model is used to structure interaction with the user (see also [18]). A system designed, developed and implemented for RIVM [19] (the Dutch Research Institute for Environmental Studies) within SKBS (Foundation of Knowledge Based Systems) for environmental decision support will be used to illustrate the knowledge included in a shared task model but also how the model was used to structure interaction with the user.

4. A SHARED TASK MODEL FOR ENVIRONMENTAL DECISION MAKING

The task of constructing combinations of possible political environmental measures which can be taken to reduce specific types of pollution, is a task with which most governments are faced. In general, this task is done “by hand” using models with which the result of a particular measure on emission factors can be calculated. These systems most often do not support the process of choosing and combining (sets of) measures which together should reach a given goal.

Within the SKBS project (supported by RIVM and the Dutch Ministry of Economic Affairs) the decision making/design process entailed in this particular task has been analysed and modelled. In interaction with policy makers a shared task model has been developed for the task of designing, for a given set of goals (with respect to the reduction of future emissions of polluting matters; e.g., NO_2), a set of environmental measures for processes in, e.g., metal industry, oil refineries, traffic, agriculture; these processes form a taxonomy. This shared task model and its role in the design of interaction with the expert user will be discussed below. Based on the knowledge contained in this shared task model and further analysis the interactive decision support system SENSE has been developed.

4.1 The shared task model: task decomposition and delegation

based on the generic task model for design tasks, presented in [20] a shared task model was developed and used in communication with experts in this field. The main tasks for environmental policy making, are:

1 *Acquire problem statement* To acquire the user's goals, in terms of overall emissions for specific polluting matters.
2 *Manipulate requirements qualification sets* To determine requirements (and their qualifications) at different levels of abstraction on future emissions for the various processes.
3 *Manipulate design object descriptions* To determine sets of measures for different processes.
4 *Design process coordination* To coordinate the overall design strategy.

The shared task model includes more detailed knowledge of each of these main tasks and the delegation of subtasks. A pictorial representation of decomposition and information exchange, as shown in Figure 1, provides the basis for the user interface of the SENSE system.

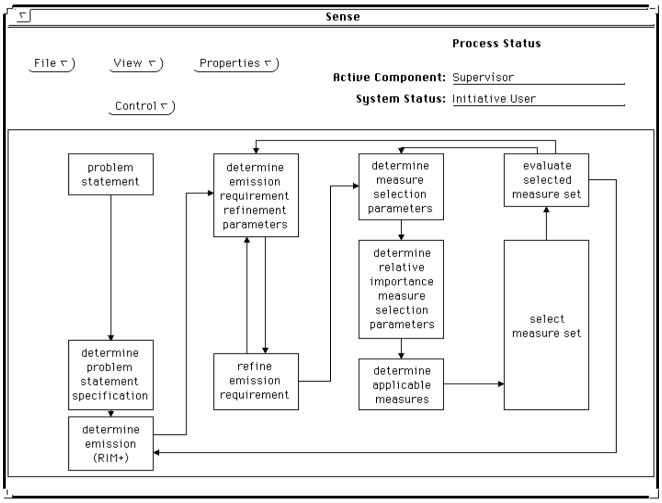

Figure 1. User interface including decomposition and information exchange of the shared task model (translated)

Acquire problem statement

To acquire the problem statement a user specifies a list of desired reductions for matters distributed over different regions (see Figure 2). The system completes this list (by adding desired reductions on processes that are logically implied by desired reductions specified by the user).

Manipulate requirement qualification sets

The task of defining priorities and relations between requirements (requirement qualifications) involves the user specifying the extent to which each of the processes involved should contribute to the required reduction. The system uses these parameters to determine a refinement (distribution) of the emission requirements to the lower levels of processes in the taxonomy. Furthermore, the user specifies parameters to be used for the measure set selection: costs, future expandability, social acceptability. The system calculates relative measure selection parameters from these user specified parameter (by normalisation).

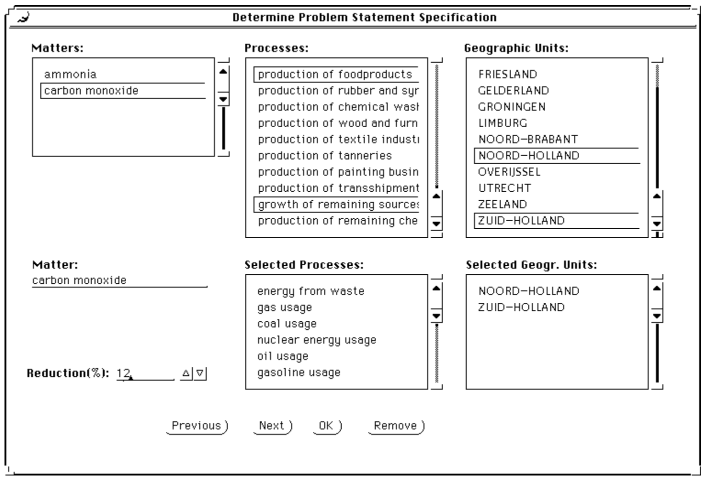

Figure 2. Specification of user goals

Manipulate design object descriptions

Given a set of requirements a set of measures needs to be found. The system determines which measures are applicable. Based on the applicability of the measures, and the measure selection parameters determined in the previous task, the system selects a set of measures. This set is presented to the user who can then indicate that he/she accepts or rejects the proposed set of measures. If the user accepts the proposed set of measures the system determines the emissions implied by the selected set. This is performed by a calculation-intensive system which predicts the effects of measures on future emissions on the basis of models designed for this purpose (the RIM+ system). If the set of measures has been rejected the emissions are not determined but the next task, (decide about continuation) described below, is performed.

Design process coordination

The coordination of the overall design strategy is a task in itself. In principle, the system has sufficient knowledge to be able to coordinate the design process according to a global design strategy. However, at some points in the process the user may wish to influence the strategy. For example, after the emissions for a selected set of measures (in fact for a number of them) have been determined, the results are presented to the user who can indicate whether this is a satisfactory solution or not.

4.2 Decomposition of knowledge and global control

Subtasks in the shared task model make use of (domain) specific knowledge. Different parts of the knowledge are used by different subtasks. For example, the knowledge expressing pollution caused by each of the processes, or which processes occur in which geographic regions, etc.

To guide task execution, global control knowledge related to the task model has been specified. In contrast to knowledge decomposition, *global control decomposition* is directly related to the task decomposition: for each decomposition of a (sub)task into sub(sub)tasks related control knowledge is specified for the sequencing of these sub(sub)tasks. A more detailed description of our approach to (formal) specification of hierarchical task decomposition can be found in [10,11].

4.3 Levels of interaction in the example shared task model

In Section 2 three levels of interaction were distinguished. In the current section the levels in the shared task model for environmental decision support are discussed below.

Object level interaction

Within the shared task model the only exchange of factual information is initiated by the system when the system presents the selected sets of measures. This is one-sided interaction: the user is not given the opportunity to change object-level information on the measures themselves. The user's influence on the combination of measures is limited to the specification of strategic preferences.

Interaction at the level of strategic preferences

Most interaction within the shared task model is directly related to the user's preferences and requirements with respect to the choice of measures. This level of interaction, the level of strategic preferences, is modelled in:

- Establishing the initial goals of the design process.
- Providing strategic preferences on the manner in which requirements should be refined or distributed over the various processes
- Specifying strategic preferences in measure set selection They are in fact soft requirements; they guide the reasoning strategy for a (preferred, optimal) set of measures.

Interaction at the level of task model modification

This most global level of interaction is related to the global sequencing of tasks: under which conditions which subtask should be performed. Interaction at this level is for example: after having seen the selected set of measures, the user decides which subtask is to be performed: determine measure selection parameters, determine emission requirement refinement parameters, or determine emissions.

5. DISCUSSION

To model a design task in which an expert user and an intelligent decision support system collaborate, appropriate intermediate representations of the task at hand must be designed. The role of a shared task model as an intermediate representation of the task (within which different levels of specificity are modelled), has been addressed in this paper.

Not only the knowledge acquisition process (and task analysis) is structured on the basis of this shared model, but also the design of the interaction between the user and system. Three different levels of interaction between an expert user and an intelligent design/decision support system have been distinguished: object level interaction, strategic preference interaction and interaction required for task model modification, each requiring specific modelling techniques.

The knowledge involved in a collaborative design task, to the extent modelled in an agreed shared task model, includes the knowledge of different types of interaction involved within: (1) knowledge of the task structure, (2) knowledge of sequencing of (sub)tasks and goals, (3) knowledge of the knowledge structures, (4) knowledge of information exchange, and (5) knowledge of task delegation.

These five types of knowledge are explicitly modelled in the declarative compositional framework for the design of complex reasoning tasks, DESIRE. Within this framework agreed, shared task models have been designed for a number of design/decision support systems in different domains. In this paper the principles behind the DESIRE approach to user-centered system design are presented and illustrated on the basis of one of these systems, the SENSE system, a system for environmental decision support.

The role an agreed shared task model can play as the basis for modelling the necessary functionality of interaction between an expert user and the system, and thus as the basis for the design of an interface, has been discussed in this paper. The most global level of interaction distinguished, the level of task model modification, provides a means to allow expert users to adapt shared task models to their own specific situation (the result of domain characteristics, or individual preferences, for example). User models within which the user's "own" version of the task model is stored, could be used to initiate interaction with the design/decision support system, making the individual expert user's task model the agreed "shared" task model upon task commencement.

Within the DESIRE framework existing abstract models of generic tasks, provide a means to structure initial interaction with the expert user during knowledge acquisition, but also to declaratively specify the most abstract level of the shared task model. The declarative nature of knowledge specification itself, is of particular importance to modelling strategic preference interaction between the user and the design/decision support system. Explicit, declarative representation of strategic knowledge (for which modelling primitives exist within DESIRE) allows strategic knowledge itself to be subject of interaction, both from the user to the system (which preferences hold, which relations between preferences exist, etc. influencing the system's reasoning strategy), and from the system to the user (which preferences have been fulfilled, to which extent, etc.).

COMMONKADS [21] with its six models is less tuned to modelling interaction between users and a system. Within expertise models object level interaction can be defined (by transfer tasks between system and user(s)), but modelling interaction at the level of strategic preferences or task model modification is less clearly defined. It either has to be defined within the task layer of the expertise model, or within the domain and inference layer when the REFLECT [22] principle is included in the architecture. Using the task layer to model these levels of interaction is not really appropriate, as domain specific (strategic) knowledge is involved, which then would not be specified at the domain layer and inference layer of the expertise model. The REFLECT approach models an entire expertise-model in the domain layer of another expertise model.

The role of shared task models in situations in which more than two parties (agents) are involved, is a current focus of research. A shared task model is an agreed model: in some situations agreement may be reached between more than two parties (resulting in a situation comparable to the situation described above for two parties), but in other situations different models of a task may exist between parties, thus requiring "attunement" between parties. Such collaborative tasks are currently being analysed, providing insight in the extensions required to the DESIRE framework.

ACKNOWLEDGEMENTS

This research has been (partially) supported by the Dutch Foundation for Knowledge-based Systems (SKBS), within the A3 project "An environment for modular knowledge-based systems (based on meta-knowledge) for design tasks" and NWO-SION within project 612-322-316, "Evolutionary design in knowledge-based systems".

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