An Ontology-based Intelligent Authoring Tool*

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Abstract: This paper describes an ontology-based intelligent authoring tool. We focus on how task ontology helps the construction of learner modeling and teaching strategy modeling. Our goal is to provide the intelligent training system authors with a friendly and helpful guideline using task ontology, which enables them to build more powerful and flexible intelligent training systems. In the learner model ontology, we describe the taxonomy of concepts and axioms used in building learner modeling system. In teaching strategy ontology, we present the two-level modeling for the construction of teaching strategies.

Key Words: Intelligent authoring tool, Learner model, Teaching strategy, Ontology, Task ontology

1. Introduction

Although intelligent training systems have been discussed for many years and there have been application systems in some domains, building an intelligent training system still presents some difficulties. First, building an intelligent training system always starts from scratch. It requires a lot of time and work. Second, knowledge embedded in most intelligent training systems does not accumulate well. Third, knowledge and functional components in intelligent training systems are seldom reusable and can not be shared by other intelligent training systems. Recently, researchers have designed and developed some authoring tools for building intelligent training systems. With the help of these tools, the efficiency of building an intelligent training system has been improved, but it still needs a lot of work. It is still not easy for the author to represent his knowledge in the form specified by the tool. In order to construct an intelligent training system, the author must have knowledge of the intelligent training system and the authoring tool as well as of the necessary functions and components for the goal of training. He/She must know how to represent domain knowledge, teaching strategies and learner models in the authoring tool. But until now few intelligent authoring tools could fulfill the requirements of building an intelligent training system efficiently and effectively. From the knowledge engineering point of view, this was because these authoring tools did not provide the author with a sophisticated vocabulary supported by computational mechanisms which enable him/her to represent his/her ideas about the training system at the right level of abstraction.

In recent years ontology engineering has been drawing much attention in the domain of intelligent training system [Mizoguchi,et al.1996b][Murray, 1998]. Ontology engineering is a research methodology that gives us design rationale. It enables accumulation of knowledge and supports knowledge reuse and sharing. It provides an explicit concept representation at different levels of abstraction. The ultimate purpose of ontology engineering is to "provide a basis for building models of all things in which information science is interested in the world"[Mizoguchi, et al., 1996a]. Our goal here is to provide the intelligent training system authors with a friendly and helpful guideline, which allows authors to build more powerful and flexible intelligent training systems.

In this paper, we first will introduce the concepts of ontology and task ontology, and their roles in intelligent authoring tools. Then we will describe what kind of guideline ontology can provide in intelligent training system authoring tools. Next we will give a concrete description on student model ontology and teaching strategy ontology in SmartTrainer Authoring Tool, which is under construction as a testbed. The last section is the conclusion of this paper and the future work.

* The aim of this authoring tool is to build an intelligent training system, but in this paper we focus on teaching strategies and learner model construction. For convenience we use "teacher" and "learner" instead of "trainer" and "trainee".

2. Ontologies in Intelligent Authoring Tools

As a philosophical term, ontology means "theory of existence". In Artificial Intelligence domains, an ontology is defined as "an explicit specification of conceptualization"[Gruber, 1992]. General ontology is task-independent and domain-independent. Task ontology can be regarded as a specialized version of general ontology. A task ontology is a system/theory of vocabulary for describing an inherent problem-solving structure for all existing tasks, domain-independently. The ultimate goal of task ontology research includes the attempt to provide a theory of all the vocabulary necessary for building a model of human problem solving processes.
Considering the shortcomings of current intelligent authoring tools and characteristics of ontology, an ontology can play the following important roles in intelligent training system authoring tools:

- helps to formalize the process of constructing an intelligent training system
- provides primitives facilitating the description of knowledge at the conceptual level
- helps to construct explicit model
- provides axioms directing the constructing of intelligent training system

3. Ontology-Based Intelligent Authoring Tool

In this section, we will present a brief overview of our ontology-based intelligent authoring tool--SmartTrainer Authoring Tool and ontologies in it.

3.1 Background of SmartTrainer

SmartTrainer is a computer-based training system for substation operators in the electric power network. Its goal is to train operators how to recover from accidents of substations. When an accident happens, the electric power transmission will be interrupted, and the operator should recover from it as quickly as possible. He should first find the spot of the accident, continue to supply the electric power to some special places such as hospitals and police stations at once by borrowing some power from other substations, and find the cause of the accident and recover from it within a limited time.
SmartTrainer first asks the operator to practice. According to the mistakes the operator makes, it selects an appropriate teaching strategy to teach the operator the knowledge behind the practice. To the operator, this is a kind of "learning-by-doing" procedure.

3.2 Ontologies in SmartTrainer authoring tool

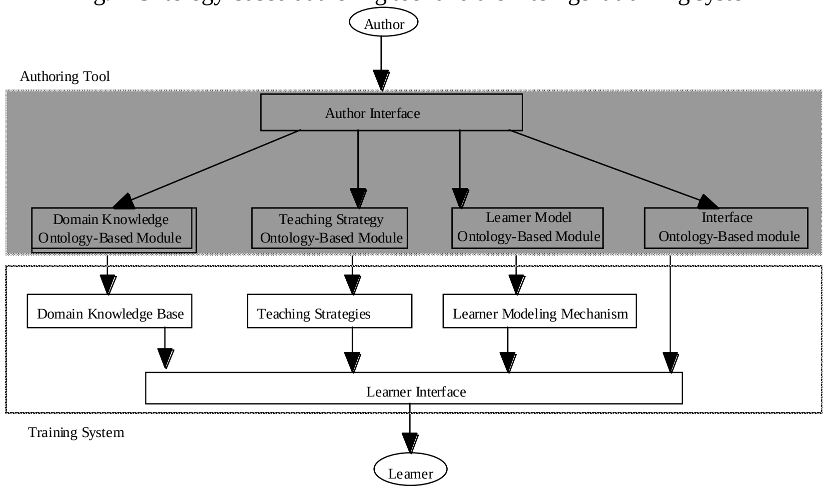
In SmartTrainer authoring tool, we can have the following four kinds of ontologies:

- Domain Ontology--The goal of a domain ontology is to specify the conceptual vocabulary and representational framework for classes of domain. In intelligent authoring tools, authors can represent their domain knowledge in term of a domain ontology. In this paper we do not emphasize this point. For details readers can refer to [Ikeda et al., 1997][Seta et al., 1996].
- Teaching Strategy Ontology--The goal of teaching strategy ontology is to provide the author with a facility to model the author's teaching experiences. According to each learner's specific error, the author can represent an appropriate teaching strategy with the use of such an ontology.
- Learner Model Ontology--It helps the author to represent a suitable learner model mechanism so that the intelligent training system can behave adaptively to the learner's understanding state. Learner model ontology facilitates to build learner models in intelligent training systems.
- Interface Ontology--Its aim is to help the author define intelligent training system interface in his own style and to make the intelligent training system interface adaptive to different learners.

Fig. 1 shows the ontology-based authoring tool and how it works. In the training system, there are four modules: domain knowledge base, teaching strategies, learner modeling mechanism and learner interface. In the authoring tool, we have four corresponding ontology-based modules--domain knowledge module, teaching strategy module, learner model module and interface module, and these four modules can be used in any order.

This paper will focus on learner model ontology and teaching strategy ontology. We will show how learner model ontology helps authors to build learner modeling mechanism and how teaching strategy ontology helps authors to construct teaching strategies. Research on Interface Ontology is in process.

Fig. 1 Ontology-based authoring tool and the intelligent training system



4. Representation of Training Task Ontology

At present in the training task ontology we have five kinds of relations between concepts:

• *is-a* is used to describe the relations between general and specific concepts.

• *part-of* is used to describe the relations between whole and part.

• *seq-part-of* means that the parts should be in a certain order.

• *division-of* means that in the slot are the divisions of the class. Compared with the part-of relation, the contents in the slot of division-of relation have to be mutually exclusive, and they collectively cover the class.

• *attribute-of* means that in the slot is the value of the attribute of the concept.

part-of is represented as p+, which means there is only one part, or p*@n which means there are two or more parts, while *seq-part-of* is represented as seq-part+ or seq*@n.

division-of is represented as d+, which means there is only one division, or d*@n which means there are two or more divisions.

attribute-of is represented as a+, which means there is only one attribute value, or a*@(n which means there are two or more attribute values.

Other relations are represented as r+ or r*@n.

In SmartTrainer Authoring Tool, there are two ways to represent the ontology. One is text form, the other is graphic form. We have implemented the text form representation, while the graphic form is still under construction. Fig. 2 is a portion of training task ontology.

Fig. 2. Training task ontology (A portion)

Text

d@n backbone stream: backbone stream*
d@n rib stream: rib stream*

backbone stream

p+intention: A
p+teaching content: A
p+question list: series of questions
(+ corresponding path[?P2]: path)
p+corresponding path[?P1]: path
p+object accident: accident

rib stream

p+object scope: teaching material
p+correspoding label: learner's label
p@n teaching behaviors: teaching strategy*

questions

p+question: question
p+question intention: question intention
p+object scope: workflow
p@n treatment: treatment*

series of questions

p+corresponding path[?P]: path
p+questions: questions
(+object scope[?P-n]: workflow)

question intention

p+learning content: A
p+thinking procedure: thinking

question

p+question content: A
p+correct answer: A
p+learner's answer:
p+incorrect answer:
p@n error pattern: error pattern*

-fill-in question

-multiple-choice question

p@n multiple-choice option [?ASI-i]: multiple choice option*
p+correct answer[?ASI]: multiple choice option

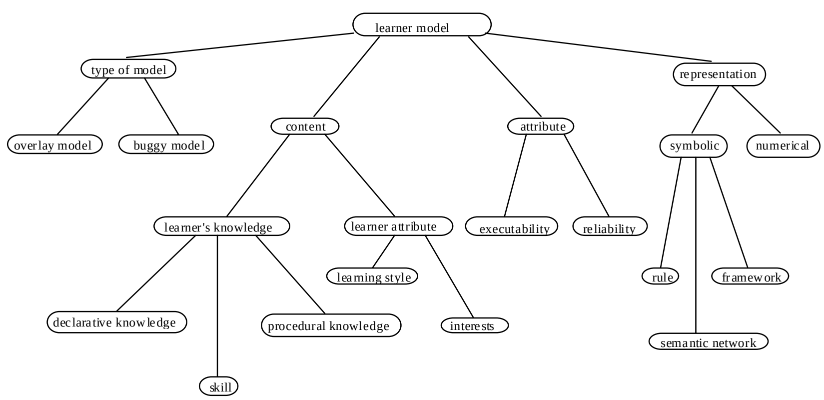
5. Learner Model Ontology

Learner model ontology, like other ontologies, consists of taxonomy of concepts and axioms. Fig. 3 shows part of the taxonomy of concepts in student model ontology. It is a general ontology for learner model. Each of the terms in Fig. 3 has its definition. For example, the “overlay model” is defined as “a learner model, which represents state of learner’s knowledge as a subset of an expert’s knowledge”.

For the task of constructing a modeling system, we also need some general verbs in addition to the concepts shown in Fig. 3. In task ontology, we have defined general verbs, such as “select”, “predict” and “infer”. The vocabulary in learner model ontology has two roles:

- as primitives in terms of which authors can describe their own student modeling systems
- as primitives for the communication between training system and modeling system

Fig. 3. Learner model ontology (A portion)



Moreover, learner model ontology includes some axioms, which are used as guidelines for the construction of learner modeling systems. To give a flavor in the details, we show some examples:

- According to the target knowledge of teaching, axioms help authors to decide suitable content of learner model.

If the target knowledge is declarative knowledge, the learner model had better be a conceptual model. If the target knowledge is procedural knowledge, then the learner model had better be a process model. If the target knowledge is skill, it is better to choose skill model.

- According to the content of learner model, axioms help authors to decide how to represent the model.

If the model is conceptual, it is better to choose frame or semantic network, while if it is process or skill model, it is better to choose rules

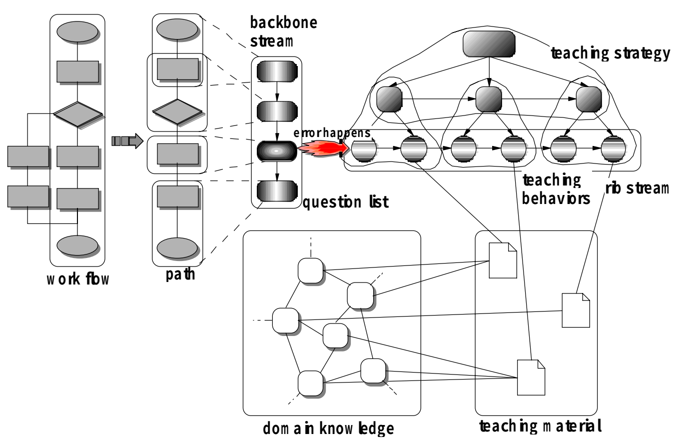
- According to the content of learner model, axioms help authors to decide how to acquire the model.

If the model is conceptual, constraint-based diagnosis or misconception recognition is better. Bur for process and skill model, model-tracing or plan recognition is better.

6. Teaching Strategy Ontology

Fig. 4 shows the construction of a teaching strategy with the training task ontology in SmartTrainer. In order to help the author prepare teaching material efficiently, SmartTrainer Authoring Tool provides a task ontology for workflow. When the goal of training is to teach the operator how to recover from an accident, the training procedure is a sequence of recognition, judgment and actions. This sequence is called a workflow. The initial state expresses the situation where the accident happened and the goal state expresses the status where the accident has been recovered from. For the recovery procedure, there are sometimes different methods corresponding to different actions. That is to say, in a workflow there may be several paths. The author can choose one path from them and based-on the actions in that path, he can specify some questions. The questions corresponding to the path constitutes a backbone stream (task-oriented organization). In response to each question in the backbone stream, the operator may make some mistakes. Corresponding to each specific mistake, the author has a teaching strategy in his mind. With training task ontology, he models his strategy into a sequence of teaching behaviors which constitute a rib stream (topic-oriented organization).
The modeling process is made up of two levels: the first is to model the knowledge in his mind into a sequence of abstract steps (sub-tasks). The second is to model the subtasks to a sequence of concrete teaching actions on teaching materials, which will be shown to the operator. In the next subsections we will discuss these two levels in detail.

Fig. 4 Construction of training task ontology

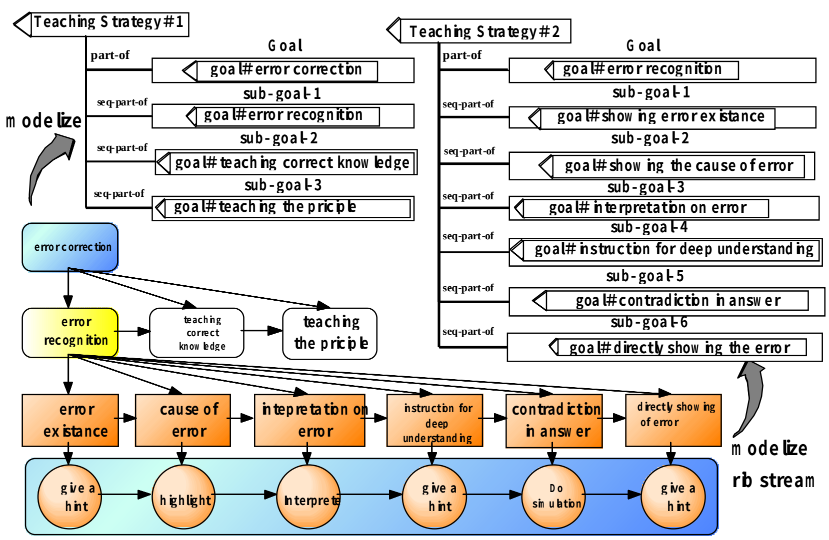


6.1 Ontology to model the teaching strategy in mind

End authors possess a wide variety of knowledge and principles underlying their pedagogical actions. It is suggested that they have a mental agenda of actions for each specific error of the operators. This mental agenda includes goals at different level of generality. For example, to correct an error of the operator, which is a general goal, in the author's mind there maybe a series of more specific sub-goals such as making the operator recognize the error, teaching the operator the right knowledge and teaching the operator the underlying knowledge.
In the author's mind this agenda is implicit. In authoring tools, however, the agenda should be represented explicitly. But the task of mapping out the author's pedagogical knowledge and systematizing it is fraught with difficulty. For this reason we incorporate the concept of task ontology which can describe the knowledge at different levels of abstraction. At a higher level of abstraction are the goals and sub-goals of a specific teaching strategy which indicate typical ways of explaining, communicating and representing particular topics or subject material. The hierarchical structure at different levels of generality provides a

basis for the teaching behaviors in a complex task involving integration of high-level goals and actions with lower level materials.
At a relatively higher level, for example, in order to correct an error, usually the procedure will include the following three steps:
1) making the operator recognize the error
2) teaching the operator the right knowledge
3) teaching the operator the underlying knowledge
In training task ontology, the teaching strategy is modeled into the framework of teaching strategy#1, which includes a general goal and three more specific sub-goals, as shown in Fig. 5. Furthermore, with the goal of making the operator recognize an error, the procedure usually includes the following six steps:
1) teaching the operator to recognize the existence of an error
2) teaching the operator the cause of the error
3) giving further explanation about the error
4) teaching underlying knowledge for deep understanding
5) giving explanations on the contradiction in the operator's answer
6) pointing out the error directly
In this case, the teaching strategy in the mind is modeled into a framework--teaching strategy#2 in Fig.5.

Fig. 5 The first level modeling



The procedure of modeling the teaching strategy in the teacher's mind is supported by the ontology construction environment in CLEPE with ontology editor and browser [Seta, et al., 96].

6.2 Ontology to model the teaching behavior

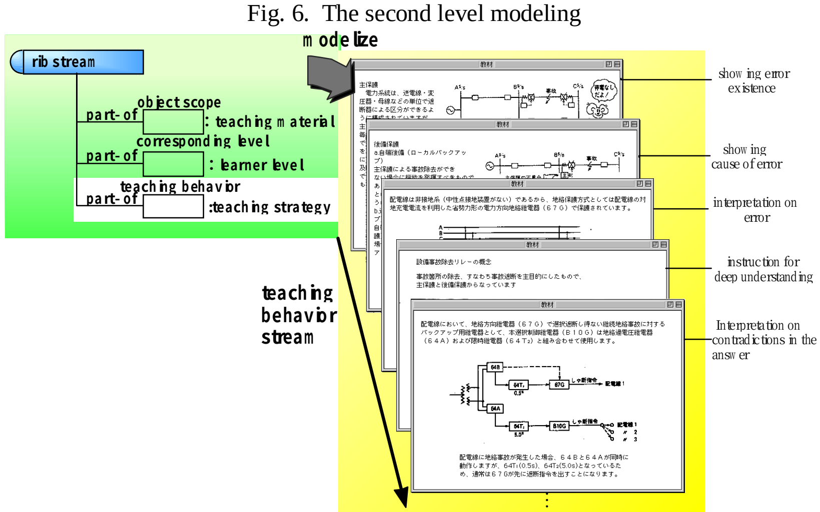
At a relatively higher level, teaching strategies are modeled into frameworks with goals and sub-goals. Along with the sub-goals in the author's mental agenda are teaching behaviors with materials such as concrete examples, hints, demonstrations and simulations to be used to attain the sub-goals. As the sub-goals become concrete, they finally can correspond to a sequence of teaching behaviors, which constitute a rib-stream. But how to help the author to represent the behaviors is still a difficult problem. We need a facility to model these behaviors, and that is the training task ontology we are developing.
In the training task ontology, we define vocabulary, which can be used by the author to represent his/her behaviors explicitly. The vocabulary includes verbs and nouns:
Verbs: give, show, explain, simulate, present
Nouns: hints, examples, results
With the help of the training task ontology, the author can model his/her teaching behaviors into a series of verb-object phrases.

Furthermore, the author arranges the teaching materials according to such behaviors, in order to get a sequence of well-arranged material which will be shown to the operators.

In Fig. 6, the rib-stream consists of object scope, learner's level and the teaching behaviors. With the help of this ontology, the intelligent training system author can represent his behaviors such as "give a hint", "highlight 64 and B10G" and "interpret the accident" corresponding to a sequence of cards to be shown to the operator. This is another kind of modeling, which is supported by the ontology-based authoring tool.

Although we have applied training task ontology to the modeling of teaching strategies, we still need to provide some guidelines in order to support the author. As we all know, for a certain error of the operator, different teachers may adopt different strategies. But usually they will agree on a specific strategy, which they think most suitable for that specific error. In our training task ontology, we should provide facilities for the author to choose an appropriate strategy. For this reason, it is necessary for the task ontology to provide some axioms to describe prototypical expertise. For example, if the cause of the error is only because the operator can not remember a certain concept, giving a hint to remind the operator of the concept is more suitable than doing simulation. We need more of this kind of rationale to select a suitable teaching strategy corresponding to a specific error.

Fig. 6. The second level modeling



7. Conclusion and Future Work

In this paper we have described the roles of ontology in SmartTrainer Authoring Tool, especially two-level modeling for the construction of a teaching strategy. Ontology acts as a guideline for the design of an intelligent training system. It facilitates knowledge reusability and sharability. Ontology-based authoring tools make the construction of an intelligent training system more efficient.

Fig. 7. An Ontology-based CBT authoring Environment

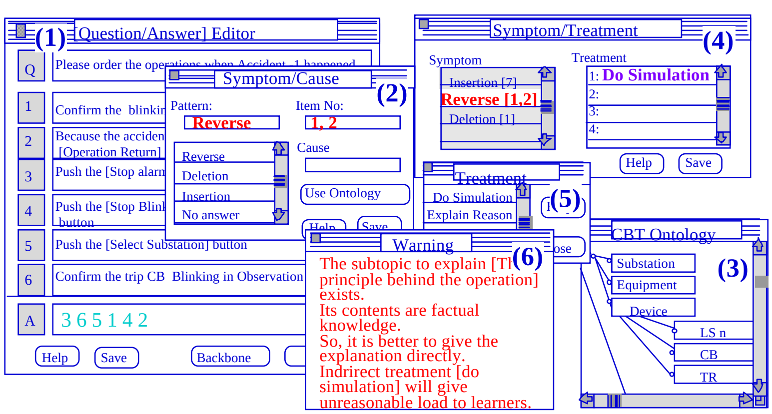


Fig. 7 is an implemented ontology-based CBT (Computer-Based Training) authoring environment [Jin, et al, 1997]. With the help of ontology, the intelligent training system author first decides a teaching strategy corresponding to a certain error. Then he can edit the teaching strategy if necessary. After that he selects actions according to the strategy, and edits the rib stream (teaching behaviors). Finally he chooses teaching materials which consist of cards to be shown to the operators.

At present we have about 500 terms of training task ontology in text form. Now we are trying to augment the training task ontology in order to model training knowledge more efficiently and effectively. Furthermore, we will work on implementing this authoring tool and making it practical.

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