Knowledge Level Design Support for Adaptive Learning Contents

- Ontological Consideration on Knowledge Level Structure of SCORM2004 Contents -

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ABSTRACT
This paper discusses learning contents design from the viewpoint of knowledge level and symbol level. The purpose of study is to develop a foundation for share and reuse of IESs on a global platform. SCORM2004 is becoming de facto standard so we choice it as the basis of the platform. On the platform we aim to build an environment for authors to clarify pedagogical meaning of learning contents based an ontology for IESs. This approach will allow us to share and reuse academic and technical expertise in the field of AIED research on common platform.

Categories and Subject Descriptors
K.3.1 [**Computing Milieux**]: Computer Uses in Education – *Computer-assisted instruction (CAI)*

General Terms
Design, Standardization

Keywords
Learning content design, Intelligent educational system, ontology, SCORM2004.

1. INTRODUCTION
In the research area of designing instructional systems, we have been aiming at a paradigm shift from "Story board representations of instructional material to more powerful knowledge based representation"[Murray 98]. Major benefit of the knowledge based representation is the realization of highly adaptive instruction with the integrated knowledge bases of learning domain, teaching strategies and learner models. However, building the knowledge bases still requires a significant cost. In order to bring about a solution for these issues, many efforts have been carried out in our IES community.

The thought of *Knowledge Level* by Newell [Newell 82] is seen to be value of designing intelligent systems. The Knowledge Level is a level of description of the knowledge of intelligent systems and the symbol level is one produces the intelligent behaviour based on the knowledge level description. If an intelligent system is high quality, the system is designed in a harmonious balance between the knowledge level and the symbol level.

Issues discussed in this paper are that what is support for structuring well-organized knowledge for intelligent educational systems and that what is adequacy of mechanisms for emerging intelligent behaviour based on the knowledge.

The authors think the keys to the issues are ontological engineering in terms of the former and scalability and interoperability, which are flowing from standards for e-learning, in terms of later.

This paper shows an advanced stage of our research activities on ontology-aware authoring tool [Hayashi 04] but the results are only in early stage. Based on the study, this paper discusses analysis of SCORM2004[ADL 04], which is a standard have gotten a lot of attention recently as next generation of foundation for e-Learning, from viewpoint of AI (Chap. 2), a way to connect knowledge level and symbol level (Chap. 3), and an SCORM2004 conformed ontology-aware authoring tool (Chap. 4).

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2. SCORM2004 as a symbol level for learning contents

2.1 Current state of designing learning contents conformed to SCORM2004
Currently, a typical learning content conformed to SCORM2004 has a tree structure reflected textbook structure. In such a content adaptive control is available by rules put on nodes representing chapter, section and so on.

Figure 1 shows an example of typical structure of SCORM2004-conformed learning contents. This content starts from "Pretest of brief of AI". If a learner passes the pretest, he/she will learn "the detail of AI". If not he/she will learn "brief of AI" before learning "the detail of AI".

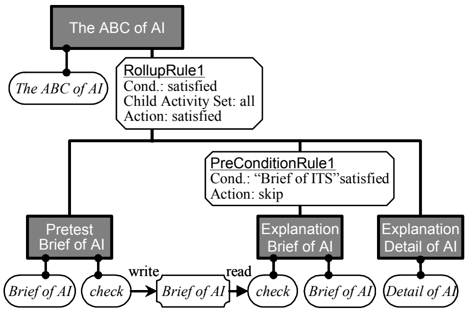

Figure 1. an example of typical structure of SCORM2004-conformed learning contents

This control is implemented by the sequencing rule (preConditionRule1).

When an activity is finished, tracking data in the activity is aggregated to its parent activity. For instance, "The ABC of AI" aggregates tracked data from all of "Pretest Brief of AI", "Explanation Brief of AI" and "Explanation Detail of AI" (That is because a parameter of RollupRule1 Child Activity Set is set "all"). So learning result of the entire content in recorded in "The ABC of AI".

These rules in SCORM2004 realize adaptive preorder page-turner structure easily. However, the focus of IES is not control that shows all of the contents or a part of them according the preordered structure but decision making of the next activity according to a learner's status.

2.2 Lessons learned from IES studies

IESs are educational support systems based on Artificial Intelligence technology [Wenger 87]. Typical thought of IESs is seen in the study of MENO-Tutor by Woolf [Woolf 84]. In MENO-Tutor knowledge of instructional control is described in an Augmented Transition Network (ATN). A node in the network indicates a teaching strategy or an action and is connected with other nodes that can be transit from itself. Depending on control rules referring to a learner model, instructional control is carried out by transition of the nodes. In this manner IESs have representation of its own structure of instructional knowledge. IES studies aim to generate learning sequences matching flexibility to each learner by sophisticating representation of knowledge and its learner model.

However there are some problems listing below.

I. Sharability and reusability are seriously low because a research oriented special purpose platforms are developed independently in each study. That has caused low productivity in practical aspect and few hoard of knowledge in research aspect.

II. Building an IES remains a costly work because of the complex knowledge representation and necessity of too much description of knowledge for a small learning content.

These problems stand in the way of research promotion and practical application of IESs. We suggest that the two following issues are important to solve the problems.

A. Organizing constructive concept of instructional control knowledge in IESs that allows IES designers to share their knowledge, that is, understanding others' description of knowledge easily and describing their own knowledge that the others can read easily.

B. Sharing IES platform to execute instructional control knowledge based on the constructive concept (ontology) in communities of researchers and practitioners.

2.3 Overlooking SCORM2004 from the viewpoint of AIED research

The Authors have developed an ontology-aware authoring tool called *i*Designer[Ikeda 97][Hayashi 04]. The study addresses the problems about making non-IES learning contents mentioned as I and II in the previous section with an approach A. Following up the previous study, this study aims to develop a high scalable user-friendly IES development environment with Sequence and Navigation specification in SCORM2004 as the basis of approach B. This section shows the authors' basic idea of SCORM2004 as a foundation of IES platforms.

An activity node in SCORM2004 is basically thought to represent learning experience learners have. An activity, that is to say, is "What to teach" from the view point of educational systems, and is "What to learn" from the viewpoint of learners. Each node represents "A material used in learning" (e.g. contents in described in a chapter, a section and a page). An activity tree represents "Structure of materials". On the other hand, in many cases, decision-making structures of IESs are "Which teaching action is better" from the system's view and "Which learning action is better" from learners'. A node represents an action and a structure represents decision-making of teaching actions, for example,. in ATN of MENO-TUTOR, "introduce", "tutor", "hack" and "complete" (Of course, if you embed "action" within "what to teach" in SCORM, it might looks like "Teaching action" in IES. But such an embedding must not be valid because it hides knowledge to select actions. This issue will be mentioned in chapter 3.)

If one wants to make a learning content to be highly adaptive to an individual learner, one must organize learning experiences with a central focus on knowledge-based decision-making structure of learning action. In this case, it is not so easy to reflect the structure to on an activity tree but not impossible. The solution is to find a way to convert selection of learning action into selection of activities in SCORM2004 and a way to convert selection structure of actions into activity tree.

This is matched with "Knowledge level and symbol level" that Newell proposed as the principle of artificial intelligent systems. Framework of description of IES knowledge is the source of intelligent behaviour of IESs and is equivalent to knowledge level. A platform that behaves intelligently based on the knowledge is equivalent to the symbol level.

The authors consider that studies of intelligent educational systems will be developed and turned into actual utilization if it is possible to build framework of knowledge level description of educational control knowledge based on SCORM2004 platform as high-scalable symbol level.

3. Building a bridge between a knowledge level and a symbol level

3.1 An activity tree as a decision-making tree for delivering learning object

Figure 2 indicates an example of decision-making model in knowledge level. The learning process described in the model is composed of a flow of learning. “Review”, the last part of the flow, will be done if a learner does not pass the exercise. The tree structure of “Review” represent that it is achieved either two types of alternative strategy.

As stated above, decision-making model describes a structure strategic decision-making of teaching action. Fig. 1 indicates a structure to select contents but fig. 2 indicates structure to select what to do. Clarifying knowledge to select action is the basis of IES and significant in the following two point.

A) The system can construct teaching sequences that fit for each learner’s understanding status, and
B) The system can assume a learner’s learning property through analysis of teaching action accepted by the learner.

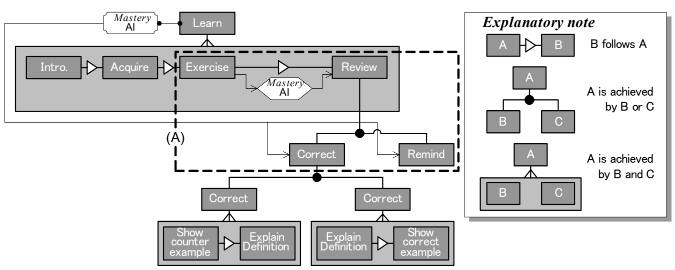

Figure2. an example of decision-making model in knowledge level

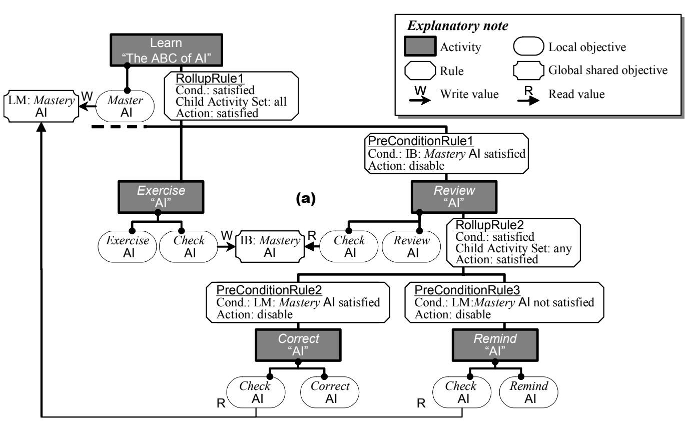

Figure 3 Symbol level model

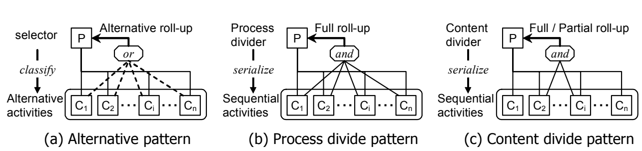

Figure 4. Patterns for designing an activity tree

Patterns of information collection represent connection upper objective and lower one in the decision-making structure. Two types of connection is defined; “And” and “Or”. In the structure shown in fig. 4 “Review AI” is achieved by any one of lower action; “*Correct* AI” and “*Remind* AI”. Hence result of “Review AI” is determined by the result of “*Correct* AI” or “*Remind* AI”. On the other hand, the entire content “Learn AI” consists of the flow of “*Introduction* AI”, “*Acquire* AI”, “*Exercise* AI” and “*Review* AI” so the result of “Learn AI” determined by all of the lower action. This aggregated result information is recorded in “LM: Mastery AI”. Therefore “LM: Mastery AI” represents not only the objective of the entire content but also the record of learner’s experience.

3.2 Symbol level model

Fig 3 shows the symbol level model converted from the knowledge level model shown in fig 2.

Decision-making structures are converted to structure of activity tree and sequencing rules. In fig 3 “*Exercise* AI” and “*Review* AI” are described as child activity of “Learn AI”. The condition that “*Review* AI” is made available is described as PreConditionRule1.

The information collection structures are converted to roll-up rules. “*Learn* AI” must aggregate information of all of child activity so the roll-up rule1 has value “all” in child activity set.

3.3 Patterns for designing an activity tree

In this section, we will organize decision-making structure and information collection structure and relate the patterns to SCORM2004 specification. This study proposes three kinds of basic decision-making and information collection patterns listing below.

(a) Alternative pattern: pattern for selecting only one activity,
(b) Process divide pattern: pattern for dividing a process, and
(c) Content divide pattern: pattern for dividing a contents

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■Activity
  ■Introduce
    ■Take interest
    ■Pay attention
    ■…
  ■Remind
    ■Remind concept
    ■Remind example
    ■Remind relation
    ■…
  ■Understand
    ■Remind concept
    ■Remind example
    ■Remind relation
    ■…
  ■Dismiss
  ■Correct
  ■Check
  ■Evaluate
  ■…
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Figure 5. Concept of activities (partial)

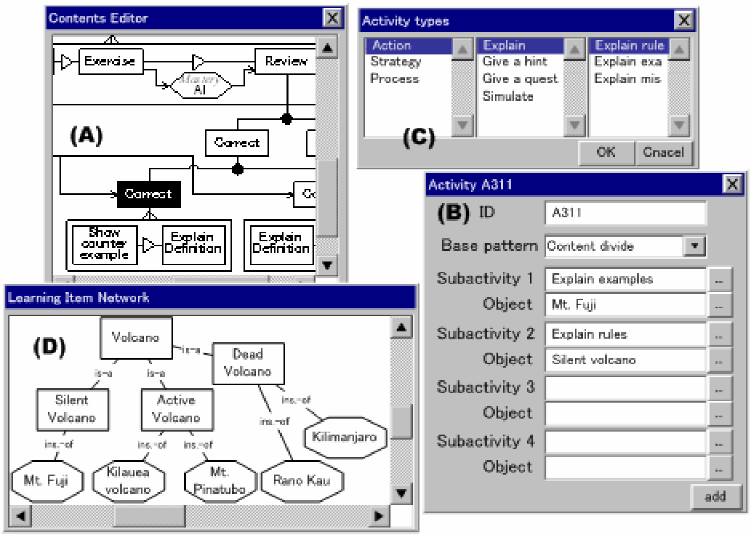

Figure 6. Interfaces of the authoring tool (imaginary)

These patterns are shown in fig.4. Each activity in the patterns are put into shape by the IES ontology (partially shown in fig. 5) which is developed our preliminary work in [Mizoguchi00][Hayashi 04]. Combination of these patterns allows designers to construct a flexible decision making model for variety of learning contents.

4. Toward a knowledge level authoring support

In this study we have been developing an IES authoring tool conformed SCORM2004 based on iDesigner [Hayashi 04]. Characteristics of the authoring tool are that it has not only ontology awareness [Ikeda 99] but also standard awareness for high scalability. The tool can convert author's design intention in knowledge level to the implementation in symbol level based on an ontology for learning contents, the patterns shown in fig. 4, and SCORM2004 specification.

Fig 6 indicates an image of the authoring tool. The main interface is the content editor (fig 6(A)). This shows a decision-making structure. Values of each node are set on window (B). While setting the values, authors can refer to items to be selected with windows (C) and (D).

5. Conclusion

This paper discussed learning content design with knowledge level representation on top of SCORM2004 platform as a symbol level architecture of IES decision-making structure. This approach will allow us to share and reuse academic and technical expertise in the field of AIED research on common platform. This will also contribute to develop SCORM into next generation standard specification for more adaptive and intelligent contents. Though many problems are left, for example organizing concepts related educational activities, accumulating principle or empirical knowledge of construction of activities, coordination between knowledge level and symbol level and so on, ontological engineering approach must be of assistance to do them.

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