Resource Organization and Learning State Control For Adaptive Learning System

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Abstract
Adaptive learning system aims to provide adaptive learning materials with learners according to their aptitudes. The approach to organizing resource plays a major role in adaptive learning system.

This paper proposes a wide-area six-hierarchy resource organization model (ROM6 for short), which has been applied to the construction of self-adaptive learning system to dynamically adapt to the needs of a particular user in accordance with his aptitude. And in this paper, as an application example in ROM6, we introduce the self-adaption of how to control learning state of a user in ROM6.

1. Introduction
Presently the study of adaptive learning system has been an important subject in web-based learning and the approach to resource organization plays a major role. Adaptive learning system aims to provide adaptive learning materials with learners according to their aptitudes.

Different types of application systems web-based demand different approaches to resource organization [1], which directly works on information server supported. By analyzing existing learning systems, we fond the deficiency in resource organization as follows.

The resource is organized based on course (architecture and content). On the one hand, the approach gets little supports for organization tuneup or integration. On the other hand, it cannot represent compete knowledge structure clearly.

Furthermore, the organization published-oriented brings about problems for information exchange [2] because of inborn deficiency of html document in description of data model. 

Goals of a learner’s joining to Web-based learning are to finish learning task and achieve aim expected, and get learning skills. So the organization should be task-oriented. In this paper, we propose a wide-area six-hierarchy resource organization model (ROM6 for short), which has been applied to the construction of self-adaptive learning system to dynamically tailor learning materials for a particular user [3].

2. Resource organization for adaptive learning system
Following Advanced Distance Education Resource Construction Technology Schema [4] (China) and IEEE LTSC Schema [5, 6, 7, 8], we propose a general model called ROM6.

The figure 1 presents the structure of ROM6. Following Educational Architecture, ROM6 is structured in a wide-area hierarchical way, namely, Web learning resource, Field Knowledge layer, Major layer, Course layer, Knowledge-Cell class layer and Knowledge-Cell layer.

Using Knowledge-Learn Relation to describe the relations between layers and learning objects in the same layer and complete knowledge architecture can be built to support self-adaptive mechanism.

Many characteristics come from ROM6:
1. ROM6 gives powerful supports on the construction of self-adaptive mechanism to adapt to learner’s personalized needs;
2. The wide-area hierarchical model decides the down-top learning relations between lays;
3. ROM6 breaks the bulwark between courses and also solves the interdisciplinary problems;
4. ROM6 helps to generate user model for adaptive learning materials.

Also ROM6 gives an idea to make exiting systems be an adaptive one.
3. ROM6

First we introduce definitions related, and then present the formal definition of ROM6 in Definition 7.

**Definition 1:** Learning Object, Learning Object Entity

The element, which constructs the administrative levels of learning organization, should be named Learning Object. It can be called \( v_{ij} (i, j \in N, 1 \leq j \leq 6) \).

\( v_{ij} \) presents the \( j \)-th learning object on layer \( i \), just like knowledge is on 6-th layer and course on 4-th.

\[ v_{ij} ::= < \text{flag}, X_\text{bkt} > \]

Where:
- **Flag:** An attribute records whether the node has been finished. ‘–1’ show the node ongoing, otherwise flag for grade or level of a particular user in learning \( v_{ij} \).
- **\( X_\text{bkt} \):** A bucket for adding name-value pairs that provides limited extension capabilities to learning object.

\[ X = \{ \text{name: value} | \text{name is for the attribute name and value for result} \}; \]

The bucket promises the flexibility for the definition of the learning object.

If \( v_{ij} \) is in knowledge unit layer, there are 4 attributes extra (see Definition 4).

A set of Learning objects in ROM6 should be called learning object entity, LOT for memory.

**Definition 2:** Test Bank

A set is for exercises and test based on the knowledge unit.

**Definition 3:** Media Format

A set of media formats that shows the knowledge cell, \( MDF \) for memory.

\[ MDF = \{ \text{Text, Audio, Video, Animation, Slid, Image, Virtual Reality, \ldots} \} \]

**Definition 4:** Knowledge-Cell

A knowledge cell \( v_y (j \in N) \) is the smallest and most basic knowledge unit the learner learns in the learning process to obtain knowledge and attain his desired goal. It has nodes of the following properties:

\[ v_y ::= < c, y, t, S > \]

Where:
- **\( c \):** Cognitive type of the concept or knowledge cell; \( c \in \{ \text{know, understand, master,\ldots} \} \)
- **\( y \):** Flag of milestone. –1 for milestone of the knowledge cell, otherwise pointer to milestone (See the following Definition 5).
- **\( t \):** URL of test materials. The test materials consist of three components: materials related to \( v_y \), materials related milestone and the corresponding evaluation of the materials;
- **\( S \):** Set of media formats available of \( v_y \). \( S = \{ u_{is} | u_{is} \in MDF, u_{is} \text{ is the URI of } s, i \in N \} \);

**Definition 5:** Milestone

Milestone means the key node in knowledge cell layer. The definition provides opportunities for learner to jump in learning processing. Milestone can be selected by teacher or knowledge worker.

**Definition 6:** Knowledge-Learn Relation

Knowledge-Learn Relation is about the relation of knowledge learning, named \( R \).

Table 1 presents existing Knowledge-Learn Relation.

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part</td>
<td>is part of</td>
<td>s</td>
</tr>
<tr>
<td>Prerequisite</td>
<td>prerequisite</td>
<td>m</td>
</tr>
<tr>
<td>synchro</td>
<td>can be studied</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>without certain order</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1. Knowledge-Learn Relation \( R \).**

**Definition 7:** Formal Definition of ROM6:

\[ \text{ROM6} = (V, \{E\}) \]

Where:

\[ V = \{ v_y | v_y \in LOT, i, j \in N \text{ and } i \leq 6 \} \]

\[ E = \{ < v_y, v_{ij} > | (v_y, R v_{ij}) \wedge (v_{ij}, v_{y} \in LOT), i, j, k, l \in N, \text{ and } k \leq 6, R \text{ sees table 1} \} \]

1. There is a sole node \( v_{11} \) that the in-degree is zero. \( v_{11} \) is just the learning resource.
2. \( < v_y, v_{ij} > \in E \). To any node, there is no learning relation from itself to itself;
3. \( < v_y, v_{i+1, k} > \in E \), it shows there is a “part” relation. Namely \( v_{i+1, k} \) is part of \( v_y \). If a learner has finished the study of node \( v_y \), it means he has passed all nodes belonged to \( v_y \).
4. \( < v_y, v_{kl} > \in E \) but \( < v_{kl}, v_y > \in E \), it shows the “prerequisite” relation between them. Namely, if a
user plans to learn \( v_{ik} \), he must finished the study of node \( v_{ij} \) first.

5. \(<v_{ij}, v_{ik} \triangleright E \) and \(<v_{ik}, v_{ij} \triangleright E \), it shows the “no order” between \( v_{ij} \) and \( v_{ik} \). That is to say, \( v_{ij} \) and \( v_{ik} \) can be learned without certain order.

6. \(<v_{ij}, v_{i+1,k} \triangleright E \) and \(<v_{i+1,k}, v_{ij} \triangleright E \) ( \( k \neq l, i \neq 1,4,5,6 \), there is an interdisciplinary relation between \( v_{i+1,k} \) and \( v_{ij} \). But there is no same relation under course layer.

7. If assume, 
   \[ V_i := \{ v_{ij} | v_{ij} \text{ is for Web learning source} \} \]
   (Note: \( n(V_i) = 1 \))
   \[ V_2 := \{ v_{ij} | i \in N, v_{ij} \text{ is for field knowledge} \} \]
   \[ V_3 := \{ v_{ij} | j \in N, v_{ij} \text{ is for major} \} \]
   \[ V_4 := \{ v_{ik} | k \in N, v_{ik} \text{ is for course} \} \]
   \[ V_5 := \{ v_{ij} | i \in N, v_{ij} \text{ is for knowledge-cell class} \} \]
   \[ V_6 := \{ v_{lm} | m \in N, v_{lm} \text{ is for knowledge-cell} \} \]

   Then \( V_1, V_2, V_3, V_4, V_5 \) and \( V_6 \) actually show the learning layers in down-top level.

4. Controlling the Learning State

Before focusing on this topic, an useful definition should be introduced first.

Definition 8: Node-Related Partial Set

A node set starting from node \( v_{ij} \) through depth-first is called Node-Related Partial Set, \( V/pv_{ij} \) for memory.

In fact, each node presents a state of learning and there should demand specific conditions from current learning state to next. There are different ways to decide the change:

- Whether the node got a specific grade in test;
- Whether a learner had time enough or frequency in learning this node

Here “grade” a learner has got should be applied to evaluate the change.

Using a boolean function as judgement: If a learner has passed the testing of the node \( v_{ij} \), we record it “pass(\( v_{ij} \))”.

Following the formal definition of ROM6, there are two types of changes.

4.1 Controlling the learning state in the same layer

A learner can jump from state \( v_{ij} \) to state \( v_{i,j+1} \).

1. If \( v_{ij} \in V_2 \) and pass(\( v_{ij} \)), then the change should be successful;
2. If \( v_{ij} \in V_3 \), then the following should be alternative:
   i) If \( v_{ik} \) is the milestone related and \( v_{ik} \in V/pv_{ij} \), pass(\( v_{ik} \));
   ii) To any \( v_{ik} \in V/pv_{ij} \), pass(\( v_{ik} \))

   in which, \( i,j,k \in N \).

4.2 Controlling the learning state in different layers

A leaner can jump to the learning state \( v_{i+1,k} \) from state \( v_{ij} \), it must be a condition necessary.

Assuming \( V_l := \{ v_{ik} | R_S v_{ik} \} \), \( R_S \) shows the “part” relation of \( R \) , then to any \( v_{ik}, \) pass(\( v_{ik} \)).

   where \( i,j,k \in N \).

5. Conclusion

This paper suggests a wide-area six-hierarchy resource organization model (ROM6) for adaptive learning system to dynamically tailor learning materials for a particular user. And as an application example, we introduce the way on how to control learning state of a user in ROM6.

Based on ROM6, we can also solve the following two problems [3]:
1. self-adaption of a user’s learning process and learning navigations;
2. self-adaption of a user’s learning content and learning strategies.

Because a user model [3] should be involved, this paper fails to discuss them.

6. References