A Petri Nets-based Approach to Modeling SCORM Sequence

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Abstract

In order to adapt the teaching in accordance to individual students abilities in the distance learning environment, more research emphasis on constructing personali ed courseware. The new version of SCORM 1.3 attempts to add the sequence concept into this course standard. The sequencing describes how the sequencing process is invoked, what occurs during the sequencing process and the potential outputs of the sequencing process. As a result, we apply the valuable features of Petri net to decrease the complexity of the sequencing definition model in the SCORM 1.3 specification and construct framework within various instructional strategies by piecing subnets together.

1. Introduction

With the development of Computer Based Training and Web Based Training, the distance learning provides the novel learning way different from traditional education and has become one of the important styles of modern education. As far as course designers concerned, the rapid growth of Learning Management System (LMS) has created a significant problem that vendors organize their content databases in any fashion they choose. Various fashion results in time-consuming of moving a course from one LMS to another. Even complete reconstruction of the course materials requires. In order to get over the difficulties of portability, Advanced Distributed Learning (ADL) propose the SCORM (Shareable Content Object Reference Model) that aims to provide the specifications necessary to enable content developers with the ability to produce content that is sharable, accessible, reusable, and most importantly interoperable [1]. It defines a Web-based learning "Content Aggregation Model (CAM)", "Run-Time Environment", and "sequencing definition model" for learning objects. CAM provides a standard courseware of contents and structures representation format for content exchange and courseware reusable. The purpose of run-time environment is to establish a standard protocol for the courseware to talk to its underlying LMS, which is a machine and OS independent platform. Both of above specification enable courseware to be exchanged among different machines. The SCORM 1.3 draft specification was published in late 2002. One significant change compared to SCORM 1.2 is the adaptation of the IMS Simple Sequence Specification on interactivity and tracking learning status of individual users. A learning designer or content developer declares the relative order in which elements of content (SCOs) are to be presented to the learner and the conditions under which a piece of content is selected and delivered or skipped during presentation. It incorporates rules that describe the branching or flow of learning activities through content according to the outcomes of a learner's interactions with content. The components of an LMS used to execute the specified rules and behaviors are referred to as a 'sequencing engine'. As soon as the sequence engine receives a request from the courseware, the sequencing rules are fired at each step according to the definitions of different behavior. The outcomes of the sequencing process may update the status model of each individual student. The implementation of a LMS should provide a mechanism to keep the status of each user. Sequencing process also triggers the use of learning resources, which is sent to presentation in a common Web browser.

In the learner opinion, distance learning provides a flexible environment to learn anytime and anywhere. Moreover, the learner expect the distance learning should solve the problem of traditional education such as personalize learning. More and more learner with the different background, various learning needs and diverse learning styles take part in the same course. Relatively, they need the course "their own"- at their pace, in their demand. As a result, many research [7,11] focus on how to design the personalized distance learning course. Some literature [4,6,8] points out the educational technologies are process-oriented to integrated study process and demonstrate how workflow technology can provide a more flexible learning solution. The most well-founded process modeling technique is Petri net [9,10,12]. In this paper, there are three main causes why we adopt Petri net to mapping SCORM Sequence as below:

- **Graphic Characteristic:** It is too complex to trace any relative situation for content developer in the sequencing definition model. The graphic characteristic of Petri net will support the penetration to the learning designer and the communication with the learner.
- **Formal Analysis:** According to [3], there are many benefits that Workflow technology offers can potentially enhance

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e-Learning environment. Petri net is a famous process modeling technique with precise definition to support the dominant factor of workflow management.

- **Expansibility**: The Petri model can extend to satisfy each application domain including learning education.

After introduce the current situation and issues of distance learning, we will propose a framework in Section 2. Through analysis the routing constructs and possible constructs of the ADL released example, our framework adopts Petri-Nets technique to map onto SCORM Sequence. Finally, the last comes with the conclusions.

2. Map Petri net onto SCORM Sequence

As above description, the learning behaviors from different learners will lead to different learning paths which were stressed in the SCORM 1.3 sequencing definition model. In order to provide the proof of feasibility study of sequence and a preview of SCORM 1.3 Sequence features, ADL released the Photoshop sequence example [2]. It illustrates sequence several ways based on the same course content using various instructional strategies, such as linear, linear choice and knowledge paces, etc. To probe into the patterns of instructional strategies, we can get the categories of routing constructs and possible constructs as follows:

- **Routing Constructs:** Flow and Choice. The routing construct is the atomic structure being able to control the sequencing behavior for a cluster.
- **Possible Constructs:** Skip, Limit Condition, Suspend and Roll up. Skip is one of actions of set [*if condition set then action behavior*] in the sequence rule; Limit Condition is based on the Tracking Model, limited conditions override Sequencing Rules; Suspend means when the learner want to exit temporarily; Roll up is the process of evaluating the Objective and Attempt Progress data for a set of child activities for a parent activity.

After analysis the base components of our framework, our Petri net model is defined as a directed graph PN = (P, T, F, W, M_0); where

1. $P = \{p_1, p_2, \ldots, p_m\}$ U $\{cp_1, cp_2, \ldots, cp_n\}$ is a finite set of places that consist of two subset, ordinary place subset (circle) and control place subset (double circle), respectively.
2. $T = \{t_1, t_2, \ldots, t\ \}$ is a finite set of transitions that draw by bars.
3. $F : \{P \quad T\}$ U $\{T \quad P\} \rightarrow I$, $\{P \quad T\}$ is an input function that defines directed arcs from places to transitions, and $\{T \quad P\}$ is an output function which defines directed arcs form transitions to places, $I \quad 1, 2, \ldots$ representing set of nonnegative integers.
4. W: $F \rightarrow I$ is a weight function, $I \quad 1, 2, \ldots$ representing set of nonnegative integers. a k weight arc can be interpreted there are k parallel arcs.
5. M_0: $P \rightarrow \{ I_{C1}, I_{C2}, I_{C3},$ is the initial marking (dot) which assigns color tokens to each place in the net, I_C *is the* nonnegative integers *set* representing the number of color tokens.

General speaking, there are some typical interpretations of place such as preconditions, input data, conditions, resource needed. As the above, the ordinary places represent learning material including lessons, assessments or courses; the other type of place is control place that give assistance of model management. T is a finite set of transition which is event, computation step or state changing operator. To deserve to be mention, according to [5], arc directs the information flow outgoing form input place either a point of departure or temporary pause. The dynamic behavior of model simulate by the firing rules. A transition will be fired if the token number of its input place is greater than the weight of its input arc. If the transition is fired, the token of input place will be moved to the output place according with the weight of output arc.

Two patterns of Photoshop Sequence example, routing constructs: Flow, Choice and possible constructs: Skip, Limit Condition, Suspend, Roll up, have been identified as follows:

Flow displays the straight linear learning path. It ensures the learner progresses through the content aggregation in a pre-determined order. The Figure 1 shows the Flow construct.

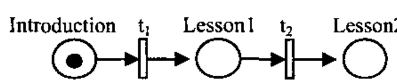

Figure1. Flow Construct

Choice represents the learner can 'jump' to select other lessons in any order. As Figure 2, the learner can choose "Lesson1" or "Lesson 2" by firing the transition 1 or transition 2 after he has completed "Introduction".

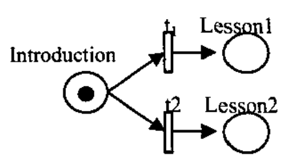

Figure2. Choice Construct

Skip is the action when the learner wants to ignore some learning material temporarily in the linear manner. We adding the control place with an initial token and collocating with the choice structure to allow learner either directed through the content in a linear manner, or skip one of the learning materials. In the Figure 3, the double circle represents the control place. If the t_4 be fired then the learner will skip "Lesson2" and learn the "Lesson3" immediately. The reason why the input arc of t_4 is two-way is to preserve the learning opportunity of skipped learning material (Lesson2).

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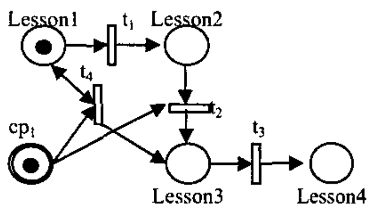

Figure3. Skip Construct

imit Condition describes condition under which an activity is not allowed to be delivered. Because the SCORM 1.3 does not requires the evaluation of any time-based limit conditions, our model focus on the maximum number of attempts for the activity. By the number of token in the control place, we limit the times that the learning material can be read. As Figure 4, if the number of cp_1 equals two then the learner can enter into the "Lesson2" twice.

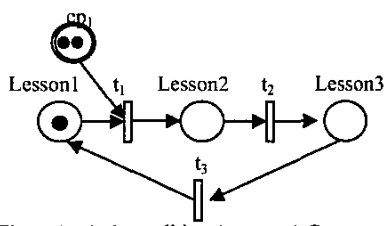

Figure4. Limit condition (tempt=1) Construct

Suspend means when the learner need to terminate learning activities temporarily, the LMS should record the break point in order to restart learning. In our model, one type of the arc can represent the suspend drawing with "s" above the arc. It can distinguish whether the source place of an outgoing arc terminates or is temporarily paused when the mark leaves that place.

Roll up is the process of evaluating the Objective and Attempt Progress data for a set of child activities for a parent activity. It involves in Objective Satisfaction, Objective Measure, and Activity Completion Status. In our model, we make use of the token number and the weight of arc to determine whether the roll up condition is satisfied. We take the Knowledge Paced example that is the most complex structure to demonstrate roll up construct.

In SCORM, activities are placed within an Activity tree that consists of clusters. A cluster includes a single parent activity and its immediate children activities. Sets of rules are associated with each activity and its cluster. The concept can be mapped on the valuable feature of Petri net to construct framework. An entire activity tree may be replaced by a single place or transition for modeling at a more abstract level or places and transitions may be replaced subnets to provide more detailed modeling.

As a result, we can illustrate the Exam sub-model, applying pretest and posttest, with Figure 5. When the t_1 is fired, the token is moved from Question1 to cp_1 to judge the answer is correct or not, if correct then firing t_5 and move the token from cp_1 to $cp_{correct}$ else firing t_4 and move the token from cp_1 to cp_{error}. After all questions are finished, the number of tokens in $cp_{correct}$ and cp_{error} represents the total number of correct and error answer respectively. And go on, we use the weight of arc connecting to t_{10} to set the filter whether the Minimized Objective is satisfied. If the number of correct answer is equal or greater than 2 then the t_{10} will be fired to represent the learner satisfied the objectiveness of this Exam module.

To explain the application of subnet, we draw out the Abstract Module 1 in Figure 6. We can observe that the arc connect from $p_{pretest}$ to two transition t_1 and t_2 are the hierarchical relationship with Figure 5. $p_{pretest}$ is the abstract place can contain Question1, Question2, Question3 and its output is the result of this assessment t_1 and t_2. If the learner enter into Model1 and pass the pretest, he can ignore this immediate lessons and posttests to experience next Module. If the learner does not pass the pretset, he is directed to that module of instruction, and once completed, must take the posttest.

In Figure 7, subnet replacements on Module 1, Module 2 and Module 3 have each output transitions which represents whether each model satisfied or not satisfied respectively. The token number in cp_1 equals or greater than the weight of output arc stands for the satisfaction of roll up rule: complete if all complete, satisfied if all satisfied. As a result, we must satisfy and complete all Models and then roll up.

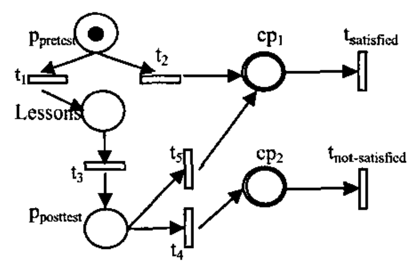

Figure 6. Module 1 subnet

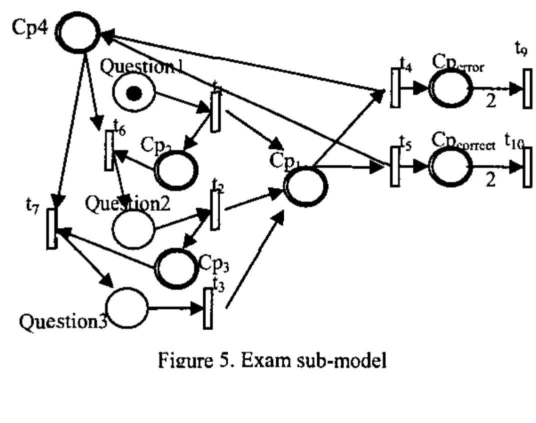

Figure 5. Exam sub-model

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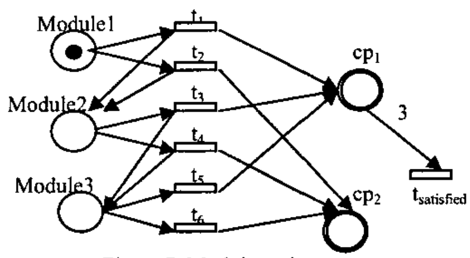

Figure 7. Modules subnet

3. Conclusion and Discussion

We construct the framework of SCORM Sequence using subnet oriented and firing rule of Petri net. The available advantage of mapping Petri net on SCORM sequence is making all of construction process traceable and trustworthy. Besides, it gives different thought what's the importance capabilities of distance learning have never been probed into in SCORM 1.3 but has expressed on Petri net. For example, using Petri net to model SCORM offers an important benefit that can potentially enhance e-Learning environment such as the subject of Collaboration between learners. As a result, our future work is developing more complete model which can suit for all learning behaviors in distance learning standard.

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