Standardized course generation process using Dynamic Fuzzy Petri Nets

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Abstract

Due to the explosion of e-Learning, there are too many useful learning materials to design a more efficient course. Therefore, to facilitate efficient course design and management for lecturers, automatic course generation is an important issue in e-Learning research and development. A complete standardized course, however, usually needs some auxiliary materials which are determined by the students’ behavior. This makes the course design process more complex and more challenging. In this investigation, a complete course generation platform was developed. The platform was made up of MEAT (Mobile E-learning Authoring Tool), LRMS (Learning Resource Management System), ANTS (Agent-based Navigational Training System), and a material arrangement agent. The material arrangement agent adopts DFPN (Dynamic Fuzzy Petri Nets) and the proposed extended model to introduce a process called SCGP (Standardized Course Generation Process). By means of this automatic process, standardized courses not only correspond to the SCORM standard but also arrange adaptive auxiliary materials dynamically. The generated multimedia course is interoperable, reusable, and standardized. Furthermore, the automatic process enables lecturers to efficiently generate courses.

Keywords: Dynamic Fuzzy Petri Nets; Standardized course generation process; SCORM; e-Learning

1. Introduction

In recent years, web-based learning environments have been regarded as suitable, interoperable, and effective in the field of e-Learning. For instance, the adaptive learning system, introduced by the advanced technology program of the National Institute of Standards and Technology, is a program that is able to share the costs of companies undertaking high-risk projects. Web-based learning systems are an essential part of the developed systems in the program. The advantages of a web-based learning system are as follows: (1) learners are not restricted to a particular content system (interoperability); (2) the material does not have to be rewritten if the course or an interactive training electronic manual is updated; (3) the development of a high-quality course avoids duplicating effort from the design process (reusability) (Valderrama, Ocaña, & Sheremetov, 2005).

Similarly, other studies in web-based education systems (Davis, Gamble, & Kimsen, 2004; Gunther, Muller, Schmidt, Bhargava, & Krishnan, 1997) also propose the concepts of interoperability and reusability of didactic materials and learning environments. In these kinds of systems, a special type of labeled materials is presented called Intelligent Components of Programmable Reusable Software (Valderrama et al., 2005). In Valderrama et al. (2005), the integration of the aforementioned approaches is discussed. IRLCOO (Intelligent Reusable Learning Components Object Oriented) was introduced and how it integrates with a multi-agent architecture was also discussed.

Moreover, quintessential textual learning in web-based learning systems or web-based education systems is already out of date. The state-of-the-art learning type in web-based systems should include multimedia content, such as audio, video, animation, and so on. Multibook (Saddik, Fischer, & Steinmetz, 2001), a project developed by the Technical University of Darmstadt and the University of Hagen, is...
a web-based adaptive hypermedia learning system providing a collection of multimedia courseware and communication technology. Akama, Osumi, and Makoshi (2002) presented two kinds of web-based learning system models which are the Patterned Frame Model and the Synchro-
nized Presentation Model. These two models both use multi-
media content to present learning patterns and achieve synchro-

Noteworthily, although a web-based approach is able to provide reusability, interoperability, and accessibility, the system cannot be regarded as an intact system without standardizing the learning contents. SCORM (Shareable Content Object Reference Model) (SCORM, 2004), a collection of standards that were developed by the White House OSTP (Office of Science and Technology Policy) and the Department of Defense’s ADL (Advanced Distributed Learning) initiatives, provides a comprehensive suite of e-Learning capabilities that enable interoperability, accessibility, and reusability of web-based learning content adapted from multiple sources.

Therefore, this study contributes towards planning an adaptive learning map of a course with dynamic auxiliary materials by providing a series of SCGP (Standardized Course Generation Process) automatically. With an automatic generation process, the design of a course would cost less and be more efficient. In addition, in order to lower the usage complexity of SCORM, the DFPN (Dynamic Fuzzy Petri Net) model (Chen, Huang, & Chu, 2005) was applied to dynamically organize a course. The model originates from typical Fuzzy Petri Nets proposed in Looney (1988). Furthermore, an extended DFPN model is also proposed, which defines the formation procedure of auxiliary material, and the details of the process are described in Section 3.

The rest of this paper is organized as follows. Section 2 describes the system framework of SCGP. Section 3 specifies the original DFPN model, the extended DFPN model, and these models were applied to design a standardized course. In Section 4, we present the development process of a course with a simple example. Section 5 presents a system demonstration with system manipulation diagrams. Section 6 shows the numerical evaluation of the proposed system and learning sequence. Finally, conclusions are discussed in Section 7.

2. SCGP (standardized course generation process)

There are many different methods to create a learning resource, but there is no minimized cost operation process for lecturers. This paper proposes a novel process, SCGP, to model the whole procedure of creating learning resources. SCGP is an operation process that contains several functions of an e-Learning framework. It also obeys the SCORM standard so that the learning resources created by SCGP can be shared in different e-Learning systems. The framework of SCGP contains the authoring module, the learning resource management system, and the learning portal and agents. Fig. 1 shows the components of this framework, with the details of these components described in the following sections.

SCGP is an automatic process which helps lecturers maintain the upload and feedback steps. Fig. 2 illustrates the relationships of each component in SCGP. MEAT (Mobile E-learning Authoring Tool) helps lecturers with the authoring of a learning resource. After the authoring step, the upload agent delivers the learning resource to ANTS (Agent-based Navigational Training System) which is an LMS (Learning Management System), and registers

![Fig. 1. The system framework of SCGP (Standardized Course Generation Process).](image-url)
the learning resource with LRMS (Learning Resource Management System) which is responsible for the management of learning resources. Then, a particular agent, called the material arrangement agent, is proposed to receive the information from LRMS and ANTS and recommend auxiliary learning materials to MEAT.

2.1. LRMS (Learning resource management system)

With the improvement of network technology, network applications are getting more popular in many research fields. Therefore, the online learning environment has grown rapidly and online learning resources are more and more complex. Besides, online learning resources typically contain many different elements which are difficult to identify without special keyword searching. As a result of the overabundance of learning resources, establishing a management system for online resources is necessary. LRMS provides an online registry and searching function for users, and automatically indexes the learning resources which are registered in the system.

LRMS is a learning resources integration center and allows registry by different learning resources or elements. LRMS also provides a searching interface for lecturers or students to publish learning materials and search learning resources in the system. During the publishing process, lecturers give the information relative to a learning material, and then LRMS can receive the description of the resources. If the learning material is a standardized SCORM resource, LRMS can receive the metadata of the resource from its manifest file, which contains the metadata of a SCORM-based learning resource. Whenever the information of learning resources is built in LRMS, LRMS automatically indexes the learning resources so that it can make the searching process more effective. The main concept of LRMS is as follows. LRMS only keeps the metadata and the file location address of learning resources instead of storing these files. If a user requests a learning resource, LRMS only returns the file location address of this learning resource. Then, the user can follow the instructions to get the learning resource. LRMS provides services for lecturers to publish or share their learning resources and knowledge. Accordingly, LRMS contains two main functions which are the LRMS registry function and search engine, and the functional modules shown in Fig. 3.

- **LRMS registry function**: The LRMS registry function allows lecturers to register their learning resources and automatically establishes the indexes of those learning resources by keywords. The function requires lecturers to provide learning resource registry information, such as the resource address, the resource identification mark, the resource restriction and the resource description mark. Actually, if a learning resource conforms to the SCORM standard, the resource description represents the metadata of this learning resource. Otherwise, lecturers need to manually provide the relative resource description information to LRMS.

- **LRMS search engine**: The LRMS search engine provides learners with a convenient searching environment and stores many different resources online. Learners can request certain courses by inputting keywords. The function also provides an online download of tests which could be regarded as a learning resource. With the help of the online download of tests, lecturers can reuse tests or refer to these tests whenever it is convenient.

2.2. ANTS (Agent-based navigational training system)

ANTS, proposed by Jeng, Huang, Kuo, Chen, and Chu (2005), presents a system framework to provide lecturers and learners with a convenient environment to publish
learning resources or to attain information. There are several intelligent e-Learning agents used in the ANTS system, such as the expert agent and the user agent. The expert agent, supported by the DFPN algorithm (Chen et al., 2005), navigates learners to learn courses in the proper learning sequence. The user agent collects each learner’s learning history and provides suitable learning paths based on data mining algorithms. With the help of these agents, lecturers and learners acquire assistance from ANTS and save lots of effort in finding relevant learning resources. The architecture is depicted in Fig. 4.

There are five roles in ANTS: the system agent, the system administrator, the teacher, the student and the anonymous user. The system agent collects a user’s learning history and gives learning suggestions. The system administrator manages the performance of the system and the learner’s account. Teachers supervise each student’s learning performance by using a friendly user interface in ANTS. ANTS provides many functions for teachers, such as an online review of homework, online tests which support multimedia files, course management, news management, and learning analysis. For example, a listening test requires playing a fraction of an audio file and asks the student what the content is. Therefore, with the help of multimedia in testing, the type of testing presentation could be more varied. The role of the student is to learn the online course and to record the learning history in ANTS. The student is also able to keep track of his or her learning progress. In addition, agents could follow the learning history and suggest the next learning course for students with the performance of learning algorithm. Finally, the role of the anonymous user is as a guest role of a learning portal. An anonymous user can view the announcements in the system and register as a new learner in the system. For a learning portal, ANTS gives each role different functions based on their needs.

2.3. MEAT (Mobile E-learning Authoring Tool)

MEAT is an authoring tool to develop a multimedia course, which supports the synchronization of learning resources, and makes the designed course conform to SCORM. In addition, MEAT not only produces a course that can be learned on a PC but also retrieves the necessary information from the original course to produce a mobile course that can be learned on mobile device. Through a friendly user interface, MEAT makes the synchronization process easier and more convenient. MEAT consists of four main functional modules depicted in Fig. 5. Each module is described below.

- **Material Transformation Module**: This module processes the imported learning resources, which include video, audio, images, web pages, PowerPoint files, and even Flash files. MEAT detects the imported resource type automatically and integrates these resources into the learning material. Using a number of designed learning materials, an author could develop a course with less difficulty.

- **Material Synchronization Module**: The learning resource synchronization could be separated into two processes which are: real-time synchronization and post synchronization. Real-time synchronization offers real-time video and audio recording and screen capture. These resources can be acquired easily and become useful resources. The post synchronization function of MEAT supports the same functions except if offers a real-time recording function.
• **SCORM Course Packaging Module:** This module makes the designed learning material conform to the SCORM standard. In essence, SCORM defines too much metadata to develop standardized learning material. Hence, this module provides a friendly user interface to authors, and makes them fill in the necessary metadata. The module is convenient for authors to develop standardized material more efficiently as a result of spending less time setting up all metadata defined in SCORM.

• **Mobile Content Packaging Module:** Due to mobile learning demand becoming more and more popular (Chu, Lin, Chen, & Lin, 2005; Heath et al., 2005; Mifsud, 2002), MEAT also supports the production of mobile learning material. Also, the general material and mobile version could be produced simultaneously. Because of limited resources in mobile devices, we only extract the necessary part of the original resource to be the mobile content. For example, after detecting a mobile device which has basic presentation ability, this module can offer audio and frame format instead of video resources.

2.4. Material arrangement agent

With the variety of online learning resources, choosing a suitable online course becomes difficult for learners. DFPN helps lecturers arrange the sequence of an online course; unfortunately, this sequence depends on the learners. Therefore, the material arrangement agent collects the relevant information of learning history or the learning resources, and then analyzes the relationship between online resources and the learners. The material arrangement agent executes the DFPN model and generates the auxiliary material for certain static learning material. With the help of the DFPN model, the material arrangement agent can generate new auxiliary material that may never be considered by lecturers.

There are four functional modules in the material arrangement agent, which receiving module, the operation module, the transmitting module, and the mining module (shown in Fig. 6). The receiving module receives the information from ANTS and LRMS in the XML file format.

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![Fig. 4. The functional module of ANTS.](image-url)
After receiving the necessary information, the operation module generates auxiliary learning suggestions, which is aided by DFPN. Following that, the transmitting module transfers the auxiliary learning suggestions to MEAT in the XML file format.

Noteworthily, an auxiliary place is created as soon as a learning material file is registered, and this kind of file has a fixed format filename that is determined by the authoring tool. According to the keyword in the filename, the proposed material arrangement agent uses the mining module to find out the association rules between this auxiliary place and a particular place. In other words, this auxiliary place might be an auxiliary material which belongs to a certain place. There is a detail description of the extended DFPN modeling design in the next section.

3. Model design by using DFPN

In this paper, we assume the procedure of developing a course is formed by dynamic fuzzy production rules and the modeling is realized by mapping these rules into a DFPN (Chen et al., 2005). In this section, we first introduce the parameters defined in DFPN, and then model the procedure of developing a course by using the DFPN reasoning algorithm.

3.1. The definition of parameters in DFPN

The DFPN structure is defined as follows:

\[ DFPN = (P, T, D, I, O, f, \alpha, \beta, \delta) \]  \hspace{1cm} (1)

where

- \( P = \{p_1, p_2, \ldots, p_n\} \) is a finite set of places;
- \( T = \{t_1, t_2, \ldots, t_m\} \) is a finite set of transitions;
- \( D = \{d_1, d_2, \ldots, d_n\} \) is a finite set of propositions;
- \( P \cap T \cap D = \emptyset, |P| = |D| \);
- \( I: T \rightarrow P^\infty \) is the input function, a mapping from transitions to sets of places;
- \( O: T \rightarrow P^\infty \) is the output function, a mapping from transitions to sets of places;
- \( f: T \rightarrow [0, 1] \) is an association function, a mapping from transitions to fuzzy numbers defined in the universe of discourse \([0, 1]\).
• \( x : P \rightarrow [0, 1] \) is an association function, a mapping from places to fuzzy numbers defined in the universe of discourse \([0, 1]\);
• \( \beta : P \rightarrow D \) is an association function, a bijective mapping from places to propositions;
• \( y : a \) a token value in a certain place \( p, y = \alpha(p) \), where \( y \in [0, 1] \);
• \( \delta \) a threshold value defined in the universe of discourse \([0, 1] \), stands for the minimum requirement of the rule;
• \( \lambda \) the value of the certainty factor (CF), \( \lambda \in [0, 1] \). A larger \( \lambda \) corresponds to stronger confidence in the applicability of the rule;
• \( \text{SPR} \) is the static production rule represented by a solid line;
• \( \text{DPR} \) is the dynamic production rule represented by a dotted line;
• \( \tau \) the browsing time that a learner persists in a certain learning material;
• \( \phi \) the browsing count is the frequency that a particular learning material is addressed.

Fig. 7 depicts a Dynamic Fuzzy Petri Net. In DFPN, \( \text{PR} \) is defined a set of dynamic fuzzy production rules, and written as \( \text{PR} = \{ \text{PR}_1, \text{PR}_2, \ldots, \text{PR}_n \} \).

The following formula shows how to generate a dynamic fuzzy production rule:

\[
\text{PR}_i : \begin{cases} 
\text{IF } y_j \geq \delta_i & \text{THEN } \text{PR}_i = \text{SPR}_i \ (\text{Threshold Value } = \delta_i) \\
\text{ELSE } \text{PR}_i = \text{DPR}_i \\
\end{cases}
\]  

ELSE \( \text{PR}_i = \text{DPR}_i \)

\[
\begin{align*}
\text{SPR}_i : & \text{IF } d_j \text{ THEN } d_x(\text{CF } = \lambda_i) \\
\text{DPR}_i : & \text{IF } d_j \text{ AND } d_x \text{ THEN } d_x(\text{CF } = \lambda_i)
\end{align*}
\]

3.2. Extended DFPN model

In the proposed extended DFPN model, we define a new type node and parameter first, and explain how to integrate them with the original DFPN model. The new type nodes are auxiliary places which are defined as \( P' = \{ p_1, p_2, \ldots, p_n \} \). Each auxiliary place \( (p') \) is involved with a validation value \( \mu \) which stands for the average download count per unit time. The validation value is modeled by applying a membership function and a sigmoid-type function, and its range is restricted in the open interval \((0, 1)\). Formula (3) shows how to calculate the validation value \( \mu \).

\[
\mu = \frac{h(x)}{t(x)} 
\]

where

- \( h(x) \) is a membership function, which is mapping a download count \( x \) into a degree. The degree is defined in the open interval \((0, 1)\). In Fig. 8, the \( X \) axis represents the total download count for the \( t \) time unit, while \( a \) and \( b \) are the lower and upper bounds respectively, which are defined by lecturers to determine how to evaluate the download count of auxiliary content. If the download count is less than \( a \), the auxiliary content is considered not popular or useful; while \( b \) is the upper bound of an auxiliary content, and when the download count is greater than or equal to it, this auxiliary content could be taken as what the learners usually need.

\[
h(x) = \begin{cases} 
0, & x < a \\
\frac{x-a}{b-a}, & a \leq x \leq b \\
1, & x > b 
\end{cases}
\]

- \( t(x) \) is a time-dependence function and has sigmoid-form, which is defined as \( \frac{2}{1+e^{-x}} \) and shown in Fig. 9. In this function, \( x \) is defined as the time unit and its value is assumed to be greater than or equal to zero so that the function is in the open interval \((1,2)\). \( v \) is a control parameter, which controls the growth proportion of the function. The value of \( x \) and \( v \) can be set by the lecturer who can use the life time of the course to evaluate them.

Each static place \( p_i \) has an authentic threshold \( w_i \) which is defined to determine whether or not \( p_i \) could transfer into an auxiliary material or a place \( p_{i+n} \), where \( n \) is the number of static places. The authentic threshold \( w_i \) represents the maximum downloading qualification defined in each static place and is also a heuristic parameter since it can be modified according to different materials and learners’ behavior.

The validation value of an auxiliary place \( p_i \) for a given time \( t \) is defined as \( \mu_{i,t} \). Firstly, initialization conditions are
set up for each static place and auxiliary place. According to the validation value $l_i$ calculated by formula (3), we check whether it is greater than the authentic threshold $w_i$. If the value is greater than $w_i$, the auxiliary place could transfer into an auxiliary material $p_i + n$ where $n$ is the number of static places; otherwise, it still remains an auxiliary place $p_i$. The transformation process of an auxiliary place $p_i$ is shown in Fig. 10(a) and (b), where $n$ is the number of static places. In Fig. 10, we use dotted circles to represent the auxiliary places with validation values.

3.3. Course design by using DFPN reasoning algorithm and the extended model

In this section, we introduce the course design process which consists of five steps.

**Step 1.** Creation of static production rules.
The lecturer first creates a few static propositions $d_1, d_2, \ldots, d_n$ and static places $p_1, p_2, \ldots, p_n$. Then, the relationships between propositions should be determined by the lecturer. These static production rules are a fixed part of a course, which can not be changed with the learning process.

**Step 2.** Parameters reasoning process.
Using the course intensity function defined in (Chen et al., 2005), the token values of the original propositions can be calculated. Then, the token values of other propositions are predicted by using Fuzzy Petri Nets (Chen, Ke, & Chang, 1990).

**Step 3.** Auxiliary places forming process.
In this step, the material arrangement agent retrieves information from LRMS, and determines whether an auxiliary material can be formed. According to the association rules found by the material arrangement agent between the learning resources and the existed learning contents, the learning resources might become auxiliary places associated with certain places. Meanwhile, the validation value $\mu_i$ of each auxiliary place is recorded by the material arrangement agent. The calculation method of $\mu_i$ is shown in formula (3). Then, the auxiliary places can be determined whether they transfer into auxiliary materials or not.

**Step 4.** Create auxiliary materials as dynamic propositions.
As long as auxiliary places transfer into auxiliary materials, these auxiliary materials are set to

$$\frac{2}{1+e^{-x}}$$

Fig. 9. The time-dependence function ($v = 1$).

**Fig. 10.** (a) Two auxiliary places are created. (b) Auxiliary place $p_i'$ transfers into an auxiliary material ($\mu_1 \geq w_2, \mu_2 < w_2$).
dynamic propositions. Furthermore, since the usage of these auxiliary materials mainly depends on the learning quality of the main materials, some constraints like the token value, browsing time, and browsing count are not considered on the auxiliary materials.

**Step 5. Establish the Dynamic Fuzzy Petri Nets.**

According to the DFPN reasoning algorithm and formula (2), we can determine which dynamic propositions need to be used in the learning process. In other words, we successfully generate the learning map for the learner. Of course, learning materials which are not needed should not appear in the learning map.

### 3.4. Implementation issue

The material arrangement agent receives information from LRMS and ANTS and performs the algorithm to recommend auxiliary learning material. The communication information is a standard XML format document which contains the necessary data for the material arrangement agent. The XML data sent between ANTS and the material arrangement agent are shown in Fig. 11. It contains the browsing time of certain learners. Fig. 12 shows the communication data between LRMS and the material arrangement agent containing the download counts and registered time. After receiving the data, the material arrangement agent performs the algorithm and transmits the information to MEAT. Fig. 13 illustrates the format of such information.

![Fig. 11. XML data sent between ANTS and the material arrangement agent.](image)

![Fig. 12. XML data sent between LRMS and the material arrangement agent.](image)

![Fig. 13. XML data sent between MEAT and the material arrangement agent.](image)

### 4. An example

In this section, by using a simple example, a process of forming a learning sequence is demonstrated. Firstly, we suppose that the system has recorded the learners’ behavior for three months continuously. Hence, the value of \( n(x) \) is 1.9051 (i.e. \( n(3) = 1.9051 \), the time unit is set to one month).

In step 1, the lecturer should arrange some static materials for a course and set up the related parameter values involved with places and transitions as shown in Fig. 14. Places and transitions can be considered as the materials and tests of a course, respectively. Table 1 presents the maximum download qualification \( w \) for each static place.

In Step 2, according to the course intensity function introduced in (Chen et al., 2005), let the token value of propositions \( d_1 \) and \( d_2 \) be obtained as 0.59 and 0.85, respectively. Meanwhile, the browsing time and the browsing count are also acquired from the users’ learning behavior. Then, the related values of propositions \( d_3, d_4 \) and \( d_5 \) can be predicted by using the DFPN model. The prediction result and values of each token are depicted in Fig. 15.

In step 3, the material arrangement agent retrieves information from LRMS, and determines whether an auxiliary material can be formed. According to association rules found by the material arrangement agent, some auxiliary places are associated with some certain static places. The download count of each auxiliary content can be presumed as 58, 988, 913, 890, 319, and 1512 for auxiliary places \( p_0^1 \) to \( p_0^6 \) respectively. In this example, the upper and lower bounds in \( h(x) \) are 40 and 1000 respectively. Hence, the download degree of each place can be calculated by formula (4), and the results are 0.1875, 0.9875, 0.90937,

![Fig. 14. Static places and transitions of the example course.](image)

<table>
<thead>
<tr>
<th>Static place</th>
<th>( p_1 )</th>
<th>( p_2 )</th>
<th>( p_3 )</th>
<th>( p_4 )</th>
<th>( p_5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum downloading qualification ( w )</td>
<td>0.40</td>
<td>0.45</td>
<td>0.35</td>
<td>0.52</td>
<td>0.60</td>
</tr>
</tbody>
</table>
0.88541, 0.2906, and 1.0. Subsequently, with the above-mentioned \( t(3) = 1.9051 \), we can calculate \( \mu \) within each auxiliary place by formula (3), and the results are 0.01, 0.52, 0.48, 0.46, 0.15, and 0.52 for \( \mu_1 \) to \( \mu_6 \), as shown in Fig. 16.

Using the extended DFPN model presented in Section 3.2, the auxiliary places which can transfer into auxiliary materials are determined in step 4. Then, we are able to successfully establish the token prediction involved with a few auxiliary materials of an example course as shown in Fig. 17.

In step 5, according to the DFPN reasoning algorithm, the lecturer should define the constraint value of each transition such as \( \delta, \tau, \phi \), and determine if auxiliary materials should be transferred into a part of the learning map for the learner. At this time, all production rules, SPRs and DPRs, are listed as follows.

**Static Production Rules:**
- SPR1: IF \( d_1 \) THEN \( d_2 (\lambda_1 = 0.8, \delta_1 = 0.6) \),
- SPR2: IF \( d_3 \) THEN \( d_4 (\lambda_3 = 0.75, \delta_3 = 0.8) \),
- SPR3: IF \( d_5 \) THEN \( d_6 (\lambda_3 = 0.65, \delta_3 = 0.7) \).

**Dynamic Production Rules:**
- DPR1: IF \( d_1 \) THEN \( d_2 (\lambda_1 = 0.8, \delta_1 = 0.6) \).
- DPR2: IF \( d_3 \) AND \( d_6 \) THEN \( d_7 (\lambda_3 = 0.75, \delta_3 = 0.8) \).
- DPR3: IF \( d_2 \) AND \( d_4 \) AND \( d_8 \) AND \( d_9 \) THEN \( d_5 (\lambda_3 = 0.65, \delta_3 = 0.7) \).

Figs. 18 and 19 describe abovementioned processes. Therefore, an adaptive learning map of a course is produced automatically so that it makes the designed courses more correct, efficient, and adaptive.

5. System demonstration

Following the previous description, LRMS records the download action of learners and the relevant information such as the download date and searching keywords. Then, LRMS provides the necessary information to the material arrangement agent and the agent performs the algorithm to generate the auxiliary material. After that, the material arrangement agent delivers the auxiliary material to MEAT and changes the original learning path designed by the lecturer. This section displays the system presentation...
and the implementation result. A prototype of LRMS was published on the web-site http://www.easylearn.org/lrms/ to provide search and registration services. Fig. 20(a) shows the searching service of LRMS. After inputting the query term into the search function, the system returns the appropriate resources and ranks them by degree of popularity. Fig. 20(b) shows the search results for the user. After the user presses the download button, the system considers this resource as potentially popular. The system does not actually store the resource but redirects the user’s request to the host of the resource.

Fig. 21(a) shows the registration interface of LRMS. The lecturer registers the learning resources by filling out the resource description. The description helps to establish index information for the search function. Fig. 21(b) shows the record of a learner’s request in LRMS. The material arrangement agent receives the necessary information from LRMS and performs the algorithm to suggest auxiliary material.
Fig. 22 is the implementation of the DFPN module in MEAT. Fig. 22(a) shows the learning path designed by the lecturer. The left frame displays the available material or test in a course. Lecturers can drag and drop the material or test to the right frame and arrange them in sequence. If the material arrangement agent recommends new auxiliary material, the new auxiliary material appears in the corresponding position of the original learning path map. Fig. 22(b) displays the auxiliary material in the original learning path map. The straight line represents the static learning path, and the dashed line represents the dynamic learning path. Each circle presents the available material and the square stands for a test. There is a threshold value set by the lecturer in a test. When a learner finishes a static learning path, there is a test. If the learner cannot get the score value over the threshold value, the dashed line will transform into straight line. Then, the learner is guided to the auxiliary material which would probably be an assisted course or a low level course.

Fig. 23 illustrates the layout presentation of a course. The left frame displays the lecturer’s video file and a list of course index slides. The learner can read each course index slide by clicking the slide’s title, and then the selected learning content is shown in the right-hand frame, while the lecturer’s video jumps to the corresponding time slot. This presentation interface is made up of XML and XSLT documents; the XML document provides the learning content information and the XSLT provides the course layout definition. Therefore, the course layout is easily and conveniently changed by replacing an XSLT document.
Fig. 23 (a) and (b) display different layouts of a course with the same learning content.

6. Evaluation

In this section, we perform the impact of SCGP to a whole learning process. Similar to (Chen et al., 2005), a questionnaire which includes a five-point scale and several questions was designed to evaluate the satisfaction among lecturers and learners. The investigation targeted 90 lecturers and 400 learners, 40 of the lecturers and the half of the learners experienced the platform for the first time, while others have used the platform before but without SCGP. The questionnaire answer degree has five levels: very useful, useful, moderate, useless, and very useless. Tables 2 and 3 show the compared satisfaction results of both lecturers and learners who have operated the platform before. The numbers in brackets are the satisfaction degree without SCGP (Chen et al., 2005). Figs. 24 and 25 depict the lecturers’ satisfaction degree percentage for the question 1 with and without SCGP, respectively. It can be observed that with SCGP assistance, the improvement of degree “very useful” is up 40% and negative responses have also been reduced. In addition, the response of question 2 in Table 2 suggests that the auxiliary materials generated by the extended DFPN model are really helpful to the lecturers. Accordingly, this means that the proposed platform with SCGP has made the lecturers more satisfied.

As to learners, we also evaluated the improvement percentage after applying SCGP. For question 1 in Table 3, Figs. 26 and 27 illustrate the difference of applying SCGP. Obviously, most learners responded positively than

![Fig. 22. The DFPN module. (a) The static learning path designed by a lecturer. (b) The auxiliary material recommended by the material arrangement agent.](image)

![Fig. 23. The two kinds of presentation interface of a course with the same learning content. (a) Style-1 interface. (b) Style-2 interface.](image)

**Table 2**
Lecturer’s opinions about usefulness of the authoring tool and auxiliary materials

<table>
<thead>
<tr>
<th>Question</th>
<th>Lecturer’s choices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very useful</td>
</tr>
<tr>
<td>(1) How do you rate the usefulness of the facility of the dynamic learning sequence scheme?</td>
<td>25(5)</td>
</tr>
<tr>
<td>(2) How do you rate the usefulness of the auxiliary materials generated from the system for the original materials?</td>
<td>10</td>
</tr>
</tbody>
</table>
negatively. The results are expected since the whole learning process has been reorganized according to the learners’ behavior when applying SCGP. A positive response for question 2 is also expected to appear in Table 3. However, it should be noted that the proportion of learners who rate the course materials as very useless increased slightly. We suppose that these learners might be opposed to changes on principle and insist on their own learning sequence.

Tables 4 and 5 present the other 40 lecturers and 200 learners who had never experienced the platform. The responses from lecturers in Table 4 imply that most of them are satisfied with the learning sequence and the auxiliary materials which are generated by the platform. Table 5 shows that more than 70% of learners perceive ANTS is beneficial to learning and more than 50% of learners think that the learning sequence is useful for the learning process.

7. Conclusions

This investigation proposes a framework, SCGP, which includes an e-Learning portal, an authoring tool technique and a material arrangement agent. Therefore, SCGP can provide learning suggestions to an individual learner. Moreover, SCGP is compatible with SCORM, which is...
most accepted e-Learning standard in the world. This study also illustrates the system architecture and intelligence of the material arrangement agent. Finally, a presentation example is also given to demonstrate the material arrangement agent. Even though many different methods to create a learning object can be found in other studies, efficiency and standardization are not emphasized. With the assistance of SCGP and the authoring tool, lecturers can simply arrange a learning object. Then, SCGP automatically guides this learning object to upload, register, and re-organize. Therefore, the automatic process decreases the effort for lecturers to maintain their learning resources. On the other hand, facing lots of learning resources in a learning portal, online learners are usually confused about which appropriate learning object is right for them. Accordingly, a learner who has auxiliary material assistance would find the learning process easier. Based on this idea, this paper extends the original DFPN model and provides potential auxiliary material to the DFPN model. A potential auxiliary course could become a real auxiliary course for learners when the restrictions are satisfied. As the results of the evaluation show, most lectures and learners response was positive, whether they have experienced the platform or not.

In the future, we would like to expand this model to apply to various domain applications. Furthermore, we intend to develop a new performance evaluation method which is appropriate for recommendations of auxiliary material by the material arrangement agent. In addition, in order to perform complete adaptive learning, the material arrangement agent should be developed to recommend specific materials to individual learners.

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