# Storyboard Design for Adaptive E-learning Based on Learning Styles

Dessislava Vassileva

Department of Software Engineering, Sofia University,
5 J. Bourchier blv., Sofia 1164, Bulgaria
ddessy@fmi.uni-sofia.bg

**Abstract.** The article discusses the methodology taken for instructional design of adaptive courses based on learner character such as learner goals and preferences, learner style and, as well, learner performance and satisfaction level. The adaptive course is presented by storyboard graph, whose nodes are pages with learning content, but paths in it represent different pedagogical strategies set by the instructor. This approach was used in ADOPTA - adaptive technology-enhanced platform for edutainment, in order to develop a course on XML. It is consistent with a new conceptual model for adaptive hypermedia and uses a family of Honey and Mumford learning styles.

**Keywords:** adaptive e-learning systems, instructional design, learning style, storyboard design

## 1 Introduction

In recent years, in the field of e-learning there was established a tendency to develop adaptive learning courses, which use various pedagogical approaches to different students. This is one of the main direction, which adaptive e-learning works to. Its aim is to develop models, standards and platforms enabling the creation, management and delivery of adaptive learning content [1].

The criteria for selection of specific pedagogical strategies are different depending on the purpose of the course author and the target group of learners. Some of them are such as different levels of knowledge of students, different way of adoption of information, different ways of understanding, different goals, preferences, etc. [2].

Approaches for creating adaptive courses can be mainly divided into three groups. The first one uses a network of concepts related in various ways with each other. Relationships between concepts most often define order in which they must be visited by a learner [3]. However, for the author created thereby course, can be hard to add additional conditions to a concepts sequence such as preferences or learning style. This approach is most suitable for the automatic creation of curriculum sequencing, where student sets herself/himself goals or more precisely concepts that she/he wants to know.

The simplest and easiest approach for creating adaptive course is to create a course with different content for each student or group of students. However, this course is difficult to be customized to the objectives, preferences, learning style and knowledge of each learner.

Other way to create adaptive course is by setting rules for the transition from

one concept or page to another one [4]. These rules can be implemented in two main ways – they can be programmed in the course itself or to be described in a particular format that is understandable to the system delivering adaptive content. The first approach requires programming skills by the author and intensive labor. The second one allows more freedom of the author and the ability to add transition rules and criteria for selecting the most appropriate content. This article will present a methodology for creating adaptive course namely following this approach.

Described methodology is used in ADOPTA - adaptive technology-enhanced platform for edutainment to develop XML course with gaming elements [5]. This course has two levels of adaptability - adaptability on the learning style and adaptability on the level of knowledge of each learner. The platform and the storyboard design methodology of the course are consistent with a new model of adaptive hypermedia systems (AHS).

## 2 ADOPTA Software Platform

Since the storyboard design methodology, which is in the focus of this article, is implemented in the ADOPTA platform, in this section there will be briefly presented the adaptability model, whereon ADOPTA is based and its general process workflow.

### 2.1 Principal Adaptability Model

The ADOPTA platform is consistent with a new model of AHS [6]. This model is based mainly on AHAM reference model [7], however, it adds several new elements, namely:

- support of different learning styles such as the style family of Honey and Mumford, which includes activist, theorist, pragmatist and reflector categories of learners [8].
- metadata about both content and adaptable rules
- content packaging according the SCORM standard [9].

Thus, the adaptive process reflects all modern trends from the area of adaptive e-learning such as systems interoperability, reusable of training content, aligning e-learning content with learning styles, etc.

The proposed model has hierarchical structure with three main sub-models and two levels of each of them. On the first level it is divided into the following sub-models:

- Learner model – on its turn, it contains three sub models: *Goals and preferences*, *Learning styles* and *Knowledge and Performance*. They store data for the learner profile.
- Adaptation model – it was again divided into three sub-models: *Narrative metadata*, *Narrative storyboard* and *Storyboard rules*. They include description of each course storyboard graph (presented by directed graph), its metadata, and rules for passing through it. This model is of key importance for this article, since the creation of course and setting

pedagogical strategies in the course must comply with it. Each course storyboard graph may have two type of nodes – narrative pages (containing learning content in form of listed learning object) and control pages (containing test questions and threshold). Content of the narrative pages may consist solely of learning objects defined in different ontology graphs of the *Domain model*. In control pages, a test is generated consisting of randomly selected questions, which in the ontology graph (to which they belong) are associated with learning objects visited by the learner. Thus, students who visited different learning objects will receive different questions.

- Domain model – it consists of following three sub-models: *Ontology graph*, *Learning objects*, *Content Metadata*. These sub-models concern with the structuring of learning content. It is organized in a domain ontology, whose elements are learning objects. Each ontology and learning object is described by appropriate metadata. Ontology Metadata Vocabulary (OMV) standard [10] for ontology metadata and IEEE LOM specification for learning objects metadata [11] are used for this purpose.

In the core of the adaptability mode is the *Adaptation Engine* that communicates with each one of above described sub-models and is responsible for generation and delivery to learners of the most appropriate learning content.

All the three main sub-models are strongly independent one from another. This enables to add new features to each one of them without being affected by other. Thus, the model is flexible and easily extensible.

### 2.2 General Process Workflow

The ADOPTA platform for adaptive e-learning contains following modules:

- authoring tool – it is used by the author of e-learning content. The content author is responsible for design of learning materials (objects). She/he organizes learning objects (LOs) within domain ontology and uses two type relationships - *has-a* and *is-a* and describes metadata about LOs (by IEEE LOM) and about ontology(by OMV),
- instructor tool – the instructor uses the this tool to design an adaptive course as a narrative storyboard graph, whose nodes are course pages. She/he uses learning object from different ontologies and trough drag-and-drop fills content pages.
- adaptive engine – it is used by supervisor or the instructor for controlling the adaptation engine. She/he can start and stop of adaptation behaviour, tracking learner paths, etc
- administration tools – it is used by the administrator and users of the system for creating, updating and view of user account and by learner for course enrolment.

The process workflow of all modules is shown in fig. 1. They communicate each other through a common repository. Finally, the learner follows a course by receiving adaptive content and solving tests at control points. The learner

is supposed to start at the first control point by making an initial test about determining his/her learning style. Next, he/she follows the most appropriate path from the narrative storyboard graph proposed by the adaptation engine or selected by her/him.

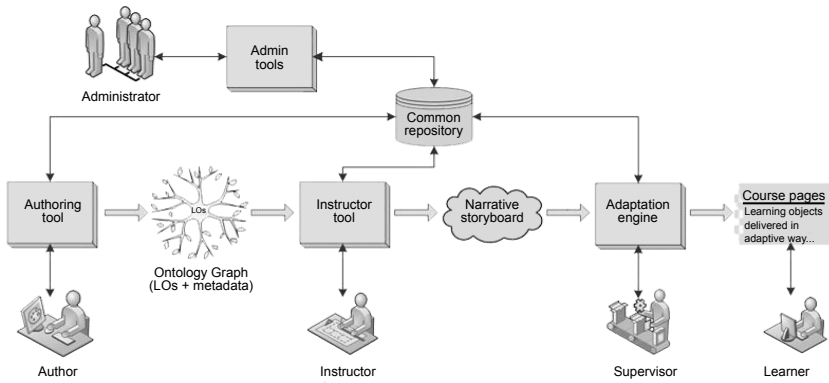


**Fig. 1.** View of the ADOPTA general workflow [12].

## 3 Storyboard Graph Design and Management for Adaptive Course

Storyboard graph design and management have to follow the principal adaptability model. These activities are mainly related to the *Adaptation model* or to description of the storyboard graph and rules for passing through it. The main requirements for these descriptions that must be observed are as follows:

- working paths (WP), i.e. paths in the storyboard graph, should be tailored so that there is an appropriate WP for each student regardless of her/his learner model.
- the storyboard graph has to be valid. It means that the storyboard graph must be designed in a way allowing the student to pass freely through it - without cycles in nodes and with test in the last node.
- management settings of adaptive content delivery must be made depending on the pedagogical strategy used to create a particular adaptive course.

### 3.1 Storyboard Graph Design for Adaptive E-learning Course

In designing and constructing of a storyboard graph the instructor has to take in mind the *Learner model* and the *Domain model*. Her/his duty is to select, group and distribute learning objects according to current knowledge, opportunities and learning style of a particular learner.

In this paper, under learning styles we will understand the family of learning styles defined by Honey and Mumford [8] as far as reasoning for other models of learning styles is rather similar.

At the beginning of the course, the instructor should be guided only by learning styles of students and for this purpose it is necessary the storyboard graph to have a few initial nodes or to start from a node giving basic information and, next, to fork. To cover the four learning styles of Honey and Mumford, the sto-

ryboard graph must have at least two WP in which the pedagogical strategy is directed primarily at two poles of the x-axis or y-axis in fig. 2. As well, each path has to include elements from the other axis, respectively y-axis or x-axis. For example, a storyboard graph has to include at least one WP for activist and one WP for theorist, both included elements for pragmatist and reflector (fig. 2).

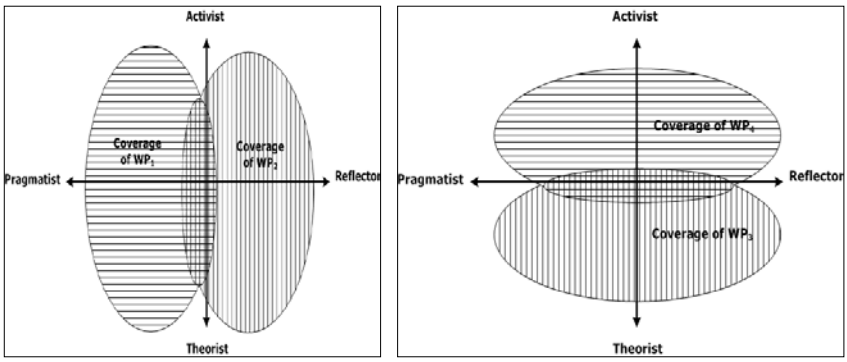


**Fig. 2.** Two examples for coverage of the four learning styles of Honey and Mumford from a storyboard graph.

After defining the first control point (CP), adaptation of educational content can be completed except for learning styles and level of knowledge gained. Therefore nodes of storyboard graph, i.e. narrative pages can be composed of different difficulty learning objects. The difficulty may be presented in the form of a few levels (e.g. very easy, easy, medium, difficult and very difficult). In such cases, for each of them the instructor must determine in what test result of the learner in a CP the relevant learning object is visible for her/him. For example, if for a learning object is set level of vision 67, it will be seen by students who have visited the page in which it participated and who have result over 67% in the last CP.

In creating courses, the instructor may add annotations (comments and clarifications) to the links between two pages of the course storyboard graph. They will be seen by the student in transition from current to next page. This is important especially if the current page is split to several other belonging to different WPs. Then the instructor should give a brief description of the contents of the WP and what is directed. Thus, the student will be allowed to decide to continue in a WP, which is different from that proposed by the system. This will give her/him more freedom to choose which of the different approaches to learning to choose and the learner does not be restricted only by the instructor suggestions.

### 3.2 Tuning of Adaptive Engine

The principal adaptability mode supports two levels adaptation of learning content delivery, namely:

- adaptive navigation – at this level the learner is guided in the course storyboard graph according to her/his profile and available pedagogical strategies;

- adaptive selection of content – based on the results of tests in the CP, the learner receives relevant content.

For these two levels of adaptation, settings can be made during the creation of learning content and course or later during the learning process.

In drawing up a course for each CP it must be a certain threshold. If the student result of the test in this CP is above this threshold, she/he continues forward in the storyboard graph. Otherwise it is assumed that the learner has not obtained the minimum necessary knowledge to continue and she/he will be returned back to the previous CP. There, the system should offer her/him another WP assuming that the previous proposed was not enough suitable. At a later stage the instructor is supposed to analyze what are the reasons for this failure (in the selection or arrangement of content, in the test questions or in the learner) and to adjust what is necessary.

The instructor has to define weight for each WP that reflects how much corresponding WP is suitable for each one of the learning styles. For example, it can be defined following weight for WP *WP1.1* of fig. 3 $W_{WP1.1}$ = (40, 50, 20, 70). The weight is represented by a set containing four values that correspond to the level of relevance for each of the four learning styles of Honey and Mumford - activist, reflector, theorist and pragmatist.

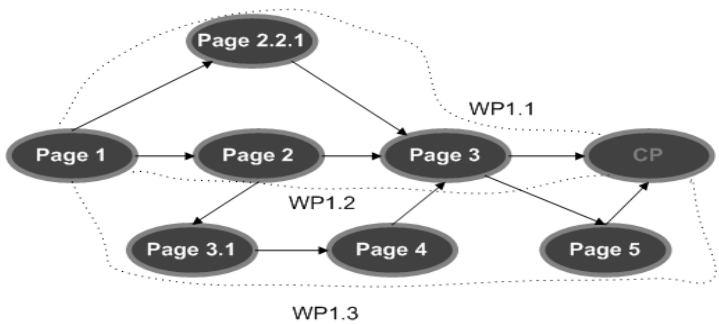


**Fig. 3.** Example for a narrative storyboard graph.

It should be taken in account, that the learning style of a learner is polymorphous, i.e. it is represented by quadruple like the weight of the WP. The purpose of this presentation is the learner should not be bound to a particular learning style but rather to all four in varying level.

On the basis of weights for WPs defined by the instructor and depending on what extent a student belongs to each leaning style, the adaptive engine calculates the most suitable WP for her/him, by the following:

$$\max_{(k)} \left\{ \sum_i W_{WPk}(c_i) * Wc_i(l) \right\} \qquad (1),$$

where – $k$ is number of WPs from the current CP to the next; $c_i$ is one of learning styles or in the present case $i = 1 \div 4$; $W_{WPk}(c_i)$ is the weight of the k-th path $WP_k$ for $c_i$; $W_{Ci}(l)$ is level in which a learner $l$ belongs to the learning style $c_i$.

Primarily, the weight of each WP is determined by the instructor during the creation of the training course. In the next stage where the learning process is starting, the weight is changed automatically from the adaptive engine depend-

ing on the results of learners shown in CP. For this purpose, it uses the following formula:

$$W_{WPk}(c_i) = W'_{WPk}(c_i) + \frac{W''_{WPk}(c_i) + (R - P) * Wc_i(l)}{N} \qquad (2),$$

where - $WP_k$ is relevant WP from CP $k$ to CP $k+1$; $W'_{WPk}(c_i)$ is originally defined weight by the instructor for path $WP_k$ for $c_i$; $W''_{WPk}(c_i)$ is the difference from the current weight and originally defined weight $WP_k$ for $c_i$; $W_{WPk}(c_i)$ is the new weight of $WP_k$ for $c_i$; $R$ is test result of a learner $l$ for CP $k+1$; $P$ is adjustment parameter with default value equal to the threshold defined for CP $k+1$. The goal of $P$ to restrict the increase of the value of $W_{WPk}(c_i)$ in case of unsatisfactory test results; $Wc_i\ (l)$ is level in which a learner belongs to the learning style $c_i$; $N$ is the number of students passed until the moment through the path $WP_k$. Thus, it will avoid the incorrect situation, where weights of the WPs which have passed more students through are higher.

Formulas (1) and (2) present new suggestion respectively for choosing the most suitable WP and for assigning weights of WPs. They are specifically for the proposed principal model and described methodology.

The more learners pass through a WP, the more statistical results will be accumulated for it and its weight will have more reliable value. If for a large percentage of learners passing through a WP, the WP current weight has slight deviations from the previous, this means the weight has reached statistical stability and its real value. Otherwise, its weight and/or content of the course it must be analyzed and modified.

## 4 Conclusions

The paper presented a storyboard design methodology for creation of adaptive course based on a new principal adaptability model. Moreover, it explained how the adaptation process can be controlled and managed by setting different adaptation parameters such as WP's weight, visibility of learning objects, etc. The proposed approach is used in the ADOPTA platform for creation training course in XML. Used pedagogical strategies in this course are consistent with Honey and Mumford learning styles but the most of described principles can be used similarly for other models of learning styles. Therefore, the proposed approach can be useful for authors of adaptive e-learning courses, without any restriction of usage of learning styles families.

Currently, practical tests are being prepared for training students in XML using the ADOPTA platform and a specially developed XML course. For the effectiveness of the adaptability achieved, assessment results will be measured and, as well, the learner satisfaction level for this course.

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