Decision table for adaptive e-learning systems

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The easy access to training and content in the digital age has greatly accelerated the level of competitiveness of individuals and organizations. The e-learning space is outside the context of academic and corporate. It supports lifelong learning which has become central to the development of competitive advantage and for the affirmation individual. This implies that training is paid to individuals are characterized by requirements training extremely varied.

The designers of e-learning systems have, in this context, the task of developing systems with adaptive and flexible functions in order to adapt the path training, the pedagogical models and the interactions between attending to their needs and preferences. In literature, these systems are called adaptive e-learning systems.

Adaptive e-learning systems adopt a system of rules with complex logic. This may involve a high number of anomalies which correct can be difficult and expensive. In this study presents the conceptual models and technology of adaptive e-learning more accredited in the literature and a framework based on the technique of decision table for the representation and validation of complex business logic in the rules.

Keywords Adaptive systems, decision table, user modeling, SCORM

1. Introduction

The term Adaptive e-learning or adaptive multimedia systems [1] refers to the ability of a system of e-learning to provide courses and learning objects calibrated on the training needs of the learner [2]. The underlying assumption is that teaching content adapted for some users may not be appropriate for the others [3].

The Adaptive e-learning systems employ utilize models of the user. A user model is an internal representation of the user's properties [4].

In literature there are presented different methodological approaches for building adaptive systems and in each of them correspond a technological systems.

The degree of accuracy in the construction of a user model is an important factor in the effectiveness of the systems. The personalized learning path utilizes contents. There is a lot of standard about content. In this field, particularly important is the standard SCORM. SCORM is a set of specifications for developing, packaging and delivering high-quality education and training materials whenever and wherever they are needed. SCORM - compliant courses leverage course development by ensuring that compliant courses are RAID (Reusable, Accessible, Interoperable, Durable) [5].

The recent standard SCORM 2004 3th edition incorporates new functions that allow the logic of narrative and sequencing among the SCO (Shareable Content Objects). In the standard the sequencing, can be appropriately tailored to training needs stated or shown by the learner.

This allows the construction of adaptive systems with higher complexity and accuracy.

At the same time, the increased complexity of the user modeling systems can lead to problems of government decisions. Tools and techniques for controlling complexity are therefore important for the effectiveness and efficiency of learning.

This work is divided into the follow sections:

The section two presents the related works on adaptive e-learning approaches and technology major.

The section three proposed the decision table for modeling the user modeling in adaptive e-learning systems or inside the standard SCORM 2004.

2. Related works

A system of adaptive e-learning is defined by Stoyanov and Kirschner [6] as follows: "... is an interactive system that customizes and adapts content e-learning, pedagogical models and interactions between participants and the environment to meet the individual needs and preferences of users, if and when they arise. " Burgos et al. [7] have defined an environment adaptive e-learning as "a method to create a learning experience for students, but also for the tutor, depending on the configuration of a set of elements in a given period in order to increase performance measured against predetermined criteria. " These criteria can be educational, economic, time-based, user satisfaction or on any other deemed important by stakeholders.

In general, the adaptation process can be described by three stages: retrieving the information about the user, processing the information to initialize and update the user model, and using the user model to provide the adaptation. In the process of adaptation there can be distinguished between two different personas. At first the learner or student with its goal to acquire knowledge and second the teacher. The goal of a teacher is to mediate the covered knowledge of a course to the learners. Therefore, both points of view must be present in ad-e-learning system.
It's necessary to distinguish between adaptive and adaptive e-learning systems. According Brusilovsky and Maybury [8], an adaptive system is presented in Figure 1.

![Figure 1: Adaptive systems in Brusilovsky and Maybury (2002)](image)

In it, the system works in three stages during the adaptive process: during the collection of user data (user profile), in the process of constructing the time the user model and in the process of adapting the system to the user model.

The user model is an essential component in adaptive e-learning systems. The adaptation of an e-learning system mainly involves choosing and presenting each successive teaching activity as a function of entire scope of learner's knowledge of the subject being taught and other relevant features of the learner, which are in turn maintained in a learner model. Therefore, the learner model is used to modify the interaction between system and student to suit the needs of individual students [4].

2.1 Theoretical approaches to adaptive systems

The literature dealing with adaptive systems for over a century. The main approaches [9]: Following are present in ascending chronological order:

- Macro-adaptive approach
- Aptitude-treatment interaction approach,
- Micro-adaptive approach
- Collaborative-constructivist approach.

2.1.1 Macro-adaptive approach (macro-adaptive approach)

The first attempts to personalize the education of the students acted on a plan called "macro-level." In it, the learners are grouped or classified by degrees. The group is directed to a homogeneous group of learners' skills input. The activities to be associated with groups that depend on the training objectives for each group to be pursued. They are usually skill or achieving a passing score on tests of learning curriculum [4][10].

Each group is provided that the designer of the course content in accordance with the view to:

- Achieve the learning objectives
- Compensate for the lack of students
- Development of new skills and attitudes of students

The above skills are grouped in the literature into three types:

- Intellectual
- Cognitive skills
- Ability to learn

In these systems the user templates are not updated during the course and no activity or errors are logged.

2.1.2 Aptitude-treatment interaction (ATI - interaction with treatment according to the inclination)

The aptitude-treatment interaction (ATI - interaction with treatment according to the inclination) adapting teaching strategies to students' attitudes. This strategy goes beyond the division of learners in homogeneous groups and suggests the use of content and / or different activities for each student who has, by definition, different characteristics. Some authors [11] list the characteristics on which to customize content and activities:

- Intellectual,
- Cognitive styles,
- Learning styles,
- Prior knowledge
- Anxiety

ATI systems offer the user the ability to control all or part of their training.

They defined three levels of control [4][11]:

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Complete independence (the user selects free educational materials and activities, the measure of learning and control of their work is their own responsibility)
- Independence and control only within a fixed scenario
- Control of activities and patterns of limited study as tutor or given to third

Some studies have shown that the attitudes of students affect the learning outcome depending on the level of control given to the student. In particular, it was determined that students with low initial knowledge in the domain of the course contents perform better if they are placed in an environment where they can exert a low control [12].

ATI's approach has several problems both from a technological and educational. The research on the subject is alive.

Some authors [13] have proposed a model in eight steps to provide practical guidance for applying the model of ATI for the design of courseware. According to this model, the designer must identify the course objectives, specify the tasks, define the relevant characteristics of the learner in the learning process, determine how the treatments, which is an adaptation of educational materials and activities should be trained. ATI's approach in general is considered expensive.

2.1.3 Micro-adaptive approach

The micro-adaptive approach requires that the educational needs that emerged during the learning process are used to adapt the learning path. The needs are examined and the system responds to them with a redefinition of the path and then, with the redefinition of the sequence of activities to which the learner is exposed. The performances are observed by measuring the outcomes of the assessment tests, response times and, in some cases, emotional states.

Park and Lee [10] have highlighted the spread of the following approaches:
- Mathematical model
- Model of the trajectory
- Model based on Bayesian probability
- Model structural and algorithmic

2.1.4 Collaborative-constructivist approach

Constructivist collaborative approach is focused on how a system of e-learning can be integrated in the learning process. Learners take an active role in it when the knowledge is built through experience in accordance with the objective of socio-costructivism theories. Such an approach strongly the use of technologies for interaction and collaboration [4].

Soller [14] identifies five characteristics of the constructivist collaborative calls as identifiers:
- Participation
- Social behavior
- Performance analysis
- Interaction primitive
- Interaction and conversation in the group

2.2 Technological approach to adaptive systems

Below we present the support systems of the first explicit theoretical approaches: macro-adaptive systems, education systems are managed by the computer (CMI), intelligent tutoring systems and adaptive hypermedia systems.

2.2.1 Adaptive system macros

The macro-adaptive systems have been developed to cut the learning skills of learners. Park and Lee [10] mention Dalton Plan, the Plan and the Winnetka Burke as the first macro-adaptive systems. With these systems, students were able to use the educational material at their own pace.

2.2.2 Education systems managed by the computer (Computer-Managed Instructional Systems (CMI))

Educational systems managed by the computer provide, in general, the same set of functions provided by systems with adaptive macro the ability for the instructor to monitor and control the learning activities of the learner [4]. This makes these systems close to the conceptual model of micro-adaptive and adaptive, more support for learning provided in the e-learning pure (not hybrid) [4].

2.2.3 Intelligent tutoring systems (Intelligent Tutoring Systems-ITS)

Intelligent tutoring systems (Intelligent Tutoring Systems (ITS)) are adaptive learning systems that use artificial intelligence techniques.

The goal is to provide the benefits of one to one in an automatic and low cost [15] As in other systems, the ITS consists of members representing the teaching content, strategies and objectives of learning and logical understanding.
of what activities the students should or should not play. These components are called "expertise module", "student modeling module", "Modular tutoring" "user interface module." (Fig. 2) [16]

![Components of ITS systems](image)

**Figure 2** components in ITS systems (Brusilovsky, 1994)

The module "expertise" evaluates the performance of students and creates learning content. [4]. The module "student modeling" represents the level of knowledge attained by the learner and reasonings and concepts made by the students. This information is used by the ITS to determine how the learning process should continue. The module "tutoring" gathers information for the selection of teaching materials. This information describes how the material should be presented and when. The form "user interface" is the component that takes care of the interaction between students and the system.

Used a lot of artificial intelligence techniques. Some ITS systems collect the related topics within the rules. This allows the system to generate problems on the fly, mix and apply rules for their solution allowing students to compare their solutions with those processed by the system.

The development of an expert system that allows the coverage of these features remains the biggest problem for the ITS.

2.2.4 Adaptive hypermedia systems (AHS Adaptive Hypermedia Systems)

The development of adaptive hypermedia systems can be traced from the early nineties. AHS systems are inspired by the ITS systems and seek to combine the functions of ITS systems with systems based on hypermedia. Brusilovsky [16] describes AHS systems as follows

"By adaptive hypermedia systems we mean all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various aspects of the system visible to the user."

The systems are based AHS and then the following features:

- Are based on Hypertext or hypermedia
- It uses a user model
- The system is able to adapt the hypermedia to the user model.

The content may be adjusted according to different degrees of detail and difficulty in order to meet the learning needs of users. The navigation through the content is called "adaptive navigation support group." It is implemented by rearranging or hiding content hypermedia, noting links, maps etc. … adapting

2.3 SCORM standard

SCORM is a specification of the Advanced Distributed Learning (ADL) Initiative, which comes out of the Office of the United States Secretary of Defense.

SCORM 2004 introduced a complex idea called sequencing, which is a set of rules that specifies the order in which a learner may experience content objects. In simple terms, they constrain a learner to a fixed set of paths through the training material, permit the learner to "bookmark" their progress when taking breaks, and assure the acceptability of test scores achieved by the learner. The standard uses XML, and it is based on the results of work done by AICC, IMS Global, IEEE, and Ariadne.

SCORM 2004 provides various mechanisms for control of navigation and narration in a teaching subject. In particular, among the atomic objects in a LO consists (SCO: Sharable Content Object) are defined:

- Control modes
- Pre and post condition rules
- Roll-up rules.

Control mode rules are defined at the aggregation (cluster), not Sharable Content Object (SCO), levels:

- All of the children must follow all of the rules of the parent
- No child is special; all of the children are equal in the eyes of the parent

The pre and post condition rules lay down the rules for navigating between the SCO, allowing conditioned and non-linear navigation.
### Table 1: Pre condition and post condition in SCORM 2004

<table>
<thead>
<tr>
<th>Pre condition (If item is/has):</th>
<th>Post condition (Then):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfied</td>
<td>_____ before the SCO is launched Skip</td>
</tr>
<tr>
<td>Objective Status Know</td>
<td>Disable</td>
</tr>
<tr>
<td>Objective Measure Know</td>
<td>Hide from Choice</td>
</tr>
<tr>
<td>Objective Measure Greater Than</td>
<td>Stop Forward Traversal</td>
</tr>
<tr>
<td>Completed</td>
<td>_____ after the SCO terminates Exit Parent</td>
</tr>
<tr>
<td>Progress Known</td>
<td>Exit All</td>
</tr>
<tr>
<td>Score Greater Than</td>
<td>Retry</td>
</tr>
<tr>
<td>Score Less Than</td>
<td>Retry All</td>
</tr>
<tr>
<td>Attempt Limit Exceeded</td>
<td>Continue</td>
</tr>
<tr>
<td>Time Limit Exceeded</td>
<td>Previous</td>
</tr>
<tr>
<td>Outside Available Time Range</td>
<td></td>
</tr>
</tbody>
</table>

The roll-up rules are rules that are used to calculate the results obtained by users on the entire package from results obtained on single SCO that compose it: these rules may therefore be different in each package SCORM 2004. They are:

### Table 2: Pre condition and post condition in SCORM 2004

<table>
<thead>
<tr>
<th>If</th>
<th>Then the parent is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Satisfied</td>
</tr>
<tr>
<td>Any</td>
<td>Not Satisfied</td>
</tr>
<tr>
<td>None</td>
<td>Completed</td>
</tr>
<tr>
<td>At least “x”</td>
<td>Incomplete</td>
</tr>
<tr>
<td>At least “%”</td>
<td></td>
</tr>
<tr>
<td>of the children are:</td>
<td></td>
</tr>
<tr>
<td>- Satisfied</td>
<td></td>
</tr>
<tr>
<td>- Completed</td>
<td></td>
</tr>
<tr>
<td>- Attempted</td>
<td></td>
</tr>
<tr>
<td>- Objective Status Known</td>
<td></td>
</tr>
<tr>
<td>- Objective Measure Known</td>
<td></td>
</tr>
<tr>
<td>- Activity Progress Known</td>
<td></td>
</tr>
<tr>
<td>- Attempt Limit Exceeded</td>
<td></td>
</tr>
<tr>
<td>- Time Limit Exceeded</td>
<td></td>
</tr>
<tr>
<td>Outside Available Time Range</td>
<td></td>
</tr>
</tbody>
</table>

The navigation and the narration between the SCO, are sufficient to enable IT to think about an adaptive learning object with responses to training of the learner.

### 3. Decision table for the user modeling: the proposed approach

The approach here proposed consists of two different levels:
- *Theoretical Level*, representing concepts and functions supporting the learning path approach;
- *Logical Level*, implementing the theoretical level through the decision table formalism.
3.1 Theoretical Level

At this level the proposed approach is formalized through specific functions.

The theoretical level consists of two steps:

- **Learning Path Step**: beginning from a specific profile, we identify an appropriate learning object to support the solution.
- **SCO Step**: for each sco contained in each learning object, we define the suitable narration and sequencing.

3.1.1 Learning Path Step

The learners’ skills have an influence on learning paths and must be taken into account when we model them. So, after having identified the suitable combination of questions able to characterize the learners’ skills, we can define a specific questionnaire assigning such skill values.

A learner profile characterizes a specific learner’s skills and can be represented as a vector of instantiated questions \( Q_1 \), \( Q_2 \), ..., \( Q_n \). Each \( Q_i \) is a question investigating a particular aspect of the environment and has a definition domain \( [Q_i] = \{r_{i1}, r_{i2}, \ldots, r_{iq}\} \) where each \( r_{ij} \) is a response of \( Q_i \). So we can say that the set \( LP \) is:

\[
LP = [Q_1] \times [Q_2] \times \ldots \times [Q_n]
\]

\( \forall lp \in GLP \) given a learner profile, we have to identify the set of the learning objects able to specialize \( lp \) according to that specific learner profile. If we call \( LO \) the set of the learning objects we can apply to specialize \( lp \), and \( LOS \) the set of the \( LO \) subsets, i.e. the set of all the possible learning objects selection, we define:

\[
\Phi : LP \rightarrow LOS
\]

\( \forall lp \in LP : \Phi(lp)=los, \text{ with } los= \{lo_1, \ldots, lo_{\text{r}}\} \]

where \( \varphi \) is the function that, given a learner profile, determines \( los \) the set of the appropriate learning objects corresponding to the specific learning profile.

Moreover, fixed a specific profile in some cases it can be useful to specify it much more through a more in-depth survey considering a more specific learner profile. This requires in some cases the investigation of a hierarchy of more and more specific learner profiles before the identification of the set of learning objects. In these cases the function \( \Phi \) becomes the function:

\[
\forall lp \in LP : \Phi(lp)= \{lo_1, lo_2, \ldots, lo_{\text{h}}\} \cup \Phi_1(lp_1) \cup \Phi_2(lp_2) \cup \ldots \cup \Phi_k(lp_k)
\]

where \( lo_i \) are learning objects, \( lp_j \) are learner profiles specifying \( lp \) and \( \forall j \Phi_j \) is a \( \Phi \)-type function able to investigate more specific profiles.

3.1.2 SCO Step

When the appropriate learning objects are identified, for each one it’s necessary to establish the suitable rules for the suitable “sco” sequencing and narration.

For each \( sco \) related to the \( lo \in LO \), we can collect a specific learner profile \( lp \) can be represented as a vector of instantiated questions \( Q_{k1} \), \( Q_{k2} \), ..., \( Q_{km} \). Each \( Q_{kj} \) is a question/event referred to the learner interaction in the \( sco \) and has a definition domain \( [Q_{kj}] = \{r_{k1}, r_{k2}, \ldots, r_{km}\} \) where each \( r_{kj} \) is a result of \( Q_{kj} \). So we can say that the set \( LP_k \) is:

\[
LP_k = [Q_{k1}] \times [Q_{k2}] \times \ldots \times [Q_{km}]
\]

If we call \( SCO \) the set of the \( scos \) referred to a given learning object, and \( SCOS \) the set of the \( SCO \) subsets, i.e. the set of all the possible sco selection, given a \( lo \in LO \) we define:

\[
\chi_k : LP_k \rightarrow SCOS
\]

\( \forall lp_k \in LP_k : \chi_k(lp_k)=socos \text{ with } soscos=\{sco_1, \ldots, sco_t\} \]

where \( \chi_k \) is a function that starting from the learner profile collected for the \( sco_k \) in the \( lo \in LO \) is able to define the sequencing and narration for the \( sco \).

3.2 Logical Level

This level aims to implement the theoretical level functions through the decision tables formalism.

A decision table is a tabular representation of a decision-making task, where the state of a set of conditions determines the execution of a set of actions \([17] [18] [19] [20]\). In general, a decision table has four quadrants: conditions (Cond), conditional states (S), actions (Act) and rules (x) as shown in figure 5. The table is defined so that each combination of conditions and conditional states corresponds to a set of actions to carry out. The conditional-oriented approach of a decision table allows to express knowledge related to the examined problem.

At this level, we implement the functions defined in the Theoretical Level (\( \Phi, \chi_k \)) through suitable decision tables:
- Learning Objects Decision Table (DTLP)
- Scos Decision Table (DTSCOS)

### 3.2.1 Learning Path Decision Table

For each function $\Phi$, a DTLP is implemented and structured as following:

- the CONDITION quadrant contains questions $Q_i$, $i=1,...,n$ characterizing the learner profiles
- the CONDITIONAL STATE quadrant contains the possible response of each question: $[Q_i]=\{r_{i1}, r_{i2}, ..., r_{iq}\}$
- the ACTION quadrant contains:
  - all the possible learning objects supporting the target learning path
  - a set of links to more specific DTLP in order to investigate more specific learner profiles
- the RULE quadrant identifies the relationship between each learner profile and corresponding learning objects and links to more specific DTLP.

### 3.2.2 Scos Decision Table

For each function $\chi_k$, a DTSCOS is implemented and structured as following:

- the CONDITION quadrant contains questions $Q_k$, $k=1,...,q$ referred to the all possible interactions/events performed in the scok by the learner
- the CONDITIONAL STATE quadrant contains the possible responses/values: $[Q_k]=\{r_{k1}, r_{k2}, ..., r_{ks}\}$
- the ACTION quadrant contains:
  - the possible navigation towards the more appropriate sco
- the RULE quadrant identifies the relationship between each learner profile in the scok and the next scos to perform.

It is clear that the previously described structure allows to verify the completeness and effectiveness of the executed actions and consequently to extend and update the experience acquired during process execution.

The figure 6 shows a typical example of the structure of a Decision Tables Set build according the proposed approach.
4. Conclusion and open problems

This paper represents a contribution in the field of adaptive e-learning path. In particular it concerns with the relationships between the SCORM standard for the learning objects interoperability and the decision table. Some there are still open issues. They concern the measurement of time and cost of learning objects using decision tables and ease of use in real production environments.

Moreover, the application of advanced iterations of narrative involves a dimension of learning objects such as to reduce their use. It is likely therefore that the necessary guidelines to mitigate the risk. Actually the research group experiment the solution in a real context with encouraging results. That will be explained in the next studies.

References