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Supporting design decisions for modeling adaptation in tutoring WEB systems

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Abstract
Adaptation or personalization is the key word for Educational WEB based systems. Nevertheless, the absence of a personalization model that could make possible to reason about, to support, to analyze the design of a Personalized Tutoring WEB System (PTWS), a kind of Adaptive Educational Hypermedia System (AEHS), is a great inconvenience. The weakness of the existing approaches is the lack of a justifiably process or method to identify and structuralize adaptation constituents and determinants, as well as to define adaptation rules. In current research, these aspects are unclearly treated. Aiming at overcoming such weakness, this paper presents an approach of how to support design decisions for modeling Personalized Tutorial Web System.

KEY WORDS: adaptation, adaptation modeling, adaptive tutorial WEB system.

Resumo
Suporte para construção de decisões de modelagem da adaptação em sistemas WEB de tutoria. Adaptação ou personalização é a palavra chave de sistemas WEB educacionais. Apesar disso, a ausência de um modelo de personalização, que poderia possibilitar o raciocínio, o suporte e a análise da construção de Sistema Personalizado WEB de Tutoria (SPWT), um tipo de Sistema Hipermídia Adaptativo Educacional (SHAE), é uma grande lacuna. Faltam métodos ou processos para justificar e estruturar a adaptação, identificando seus constituintes e determinantes, bem como o suporte à criação das regras de adaptação. Esses aspectos não são tratados de forma clara nas atuais pesquisas. Esse artigo apresenta uma proposta que trata desses aspectos para a modelagem Sistema Personalizados Web de Tutoria.

PALAVRAS-CHAVE: adaptação, modelagem de adaptação, sistema WEB tutorial adaptativo.

1 Introduction

In general, personalization is a process, which becomes possible to provide user support in accessing, retrieving and storing information, where solutions are built so as to fit individual preferences, characteristics and tastes (Baldoni *et al.*, 2005). In this paper, the terms personalization, customization or adaptation have the same meaning: to offer the users, the learners in this case, WEB navigation and content options according to profiles.

Personalized Tutoring WEB Systems (PTWS) should provide a set of the options of navigation and content adaptation according to each learner. Thus, resulting adaptation in PTWS can be seen as the consequence of a design decision sets related to the following questions (Stephanidis *et al.*, 1997):

- *What* to adapt? – The possible aspects to be adapted, also called adaptation constituents;
- *When* to adapt? – The most appropriate moment for

adaptation and corresponding driving elements, also called adaptation determinants;
- *Why* to adapt? – The goals of adaptation; and
- *How* to adapt? – The adaptation rules.

The adaptation modeling process of a PTWS is mainly featured by the identification of adaptation determinants, such as learner's domain knowledge, background, preferences and learning styles; adaptation constituents, such as suggested links, additional explanation, problem presentation etc; and adaptation rules encompassing both adaptation determinants and constituents. The existing approaches in literature are unclear since they lack indispensable procedures of how to justifiably identify and structuralize adaptation constituents and determinants, and to define adaptation rules.

So, aiming at overcoming such weakness, this paper presents an approach that supports design decisions for modeling PTWS. In broad terms, the approach provides means of identifying and structuring the constituents and determinants adaptation and how to define the adaptation rules with clear justification for adaptation based on the educational aspects.

The paper is organized as follows. Section 2 presents some related works. Section 3 presents an approach to support design decision for adaptation. Section 4 presents a case study. Finally, section 5 presents some concluding remarks.

2 Literature review

Cannataro and Pugliese (2001) mention that due to the complexity of user models that usually capture explicit user requirements, the adaptation process results in a complex task and it is more demanding when considering the dynamic conditions of, such as the available networks bandwidth, time/location of access and other implicit user necessities. It is helpful that an Adaptive Hypermedia System (AHS) possesses an adaptation model in order to manage the adaptation. First, it would be necessary to have a model or architecture for the AHS.

The *Adaptive Hypermedia Application Model* (AHAM) (De Bra *et al.*, 1999; Wu, 2002) was the first one to be developed. This reference model focuses on the Storage Layer which has three parts (sub-models): a *Domain Model (DM)*, a *User Model (UM)* and an *Adaptation Model (AM)*, located between the DM and the UM in the Storage Layer (Stash, 2007). The AM contains a set of adaptation rules that are stated in the form of event-condition-action clauses. They use the structure and content of the domain model and the user model to decide how to update the user model and how to generate the adaptation. An adaptive hypermedia application consists of the structures defined by AHAM also involving an Adaptation Engine (AE). AHAM describes the adaptation functionality at the abstract conceptual level; more specifically, it does not prescribe a specific algorithm for selecting and executing the adaptation rules.

Later, the *Web Modeling Language (WebML)*, the *Munich Reference Model*, the *XML Adaptive Hypermedia Model (XAHM)* and *LAOS* (Stash, 2007) had appeared. Each one of them has its own AM. The *XAHM* allows hypermedia adaptation along with three different "adaptive dimensions": *user's behaviors* (preferences and browsing activity); *technology* (network and user's terminal), *external environment* (time, location, language, socio-political issues, etc.) (Cannataro and Pugliese, 2001). Nevertheless, it is hard to identify how the adaptation rules are built and to find the justification for adaptation based on educational aspects. The main emphasis in XAHM is to distinguish between adaptation driven by user necessities and adaptation driven by technological constraints (Stash, 2007).

According to Oliveira (2004), some Adaptive Hypermedia Systems miss an AM but the functionality of the adaptation can be present in other components.

The adaptation issue is very important. For example, in Stash (2007) a research question was *"Can the adaptation that is required for learning styles be realized through the AHA! system?"* The obtained answers for this question were: only content and links adaptation that are required for the most learning styles can be realized through the AHA! system. However AHA! fails to provide a required layout adaptation, e.g., by field - dependent versus field - independent style.

Then, there is not a personalization model that becomes possible to reason about, to support, to analyze the design of a Personalized Tutoring Web System (PTWS), a kind of Adaptive Educational Hypermedia System. Many adaptation rules appear into the system but how to explain them? The goal of this paper is to present an approach of how to support design decisions for modeling PTWS.

3 Approach to support design decision

Based on the weakness described above, more specific aspects were identified. First, adaptation modeling has been treated as a bureaucratic task, without a clear rationale, justification for its usage. Second, without such a rationale, choosing a general architecture was not a well informed decision. Third, missing a well informed decision for the general architecture, it becomes difficult to decide for the appropriate components and their structure. Finally, lacking all of these aspects, to define adaptation rules can be understood as a tentative process.

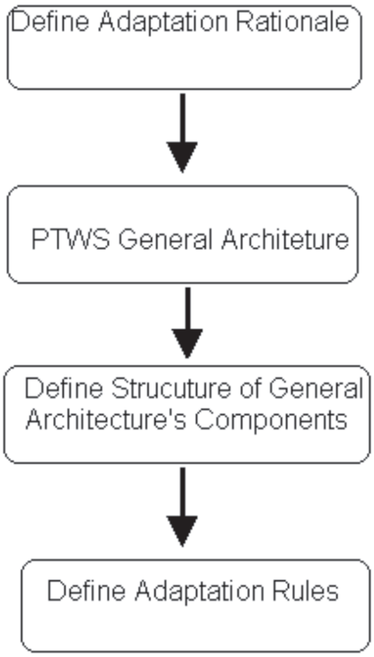

Figure 1. Steps of the proposed approach.

Hence, the proposed approach in this paper pursues to include these missing parts. Figure 1 schematically shows the steps of the approach. The steps are described next.

3.1 The rationale for adaptation

The discussion about how to select and to structure adaptation constituents and determinants, as well as adaptation rules, can be grounded on Design Rationale (DR). DR is essentially a representation of the arguments behind design decisions, in order to justify properly alternative solutions to design problems (Conklin and Begeman, 1989; Shum, 1991). Also, according to Shum (1991), the design arguments structure explicitness facilitates automated manipulation of the structure and allows arguments to be added through cumulative changes to the structure.

A style of argumentation-based DR notation is an Issue Based Information Systems (IBIS). IBIS represents argumentation using issues, positions, and arguments (Conklin and Begeman, 1989). Issues are the design problems to be discussed by team members. Positions are possible ways of addressing an issue. Arguments support the positions. Issues, positions, and arguments are represented as nodes in IBIS diagrams. In order to complement the argumentation representation, nodes can be connected by any of the following eight link types: supports, objects-to, replaces, responds-to, generalizes, specializes, questions, and suggested-by.

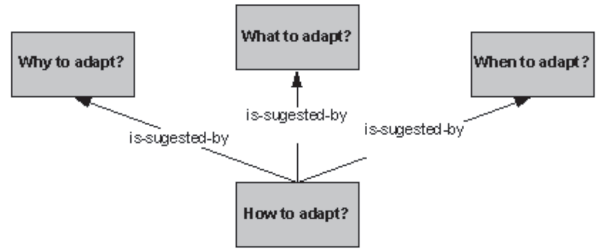

Figure 2. An IBIS diagram for the questions involved in PEWBS adaptation design.

Considering the four kinds of questions for adaptation design in PTWS, an IBIS diagram associating the questions can be elaborated as shown in Figure 2.

"*How to adapt*?" is treated in Figure 2 as an issue, and "*Why to adapt*?", "*What to adapt*?" and "*When to adapt*?" as positions, possible ways of addressing an issue.

PTWS which aims to support the learning of a given body of knowledge, needs to take into consideration on several aspects. Therefore, the adaptation can play a relevant role in the learning process. Among these aspects, the pedagogical model to be used, the learner's learning styles, the learner's domain knowledge and the preferences are included.

Though all of above aspects have been considered in personalization models described in the literature, new ways in which they can be related can provide insights on how adaptation can achieve a clearer educational meaning.

Once the positions *Why*, *When* and *What to adapt* are identified, it is very relevant to know where they come from, which elements of the system can offer the answers for those questions. Taking into account that the adaptation is the outcome of learner's information, available content, learning process and pedagogical strategies used by the system, it is possible to expand the IBIS diagram shown in Figure 2 to express the argumentation diagram for the questions involved in adaptation design of the PTWS, as shown in Figure 3.

Figure 3 shows "*What to adapt*?" as Positions: Content Presentation, Pedagogical Model action, and Navigational Support. A Pedagogical Model provides explicit guidance on how to conduct a learning activity (Reigeluth, 1999). In this manner, the Pedagogical Model specifies the kinds of support that must be provided to the learner, as well as the most appropriate moment. It may contain a set of pedagogical strategies. A set of these strategies are related to the learning units. Some of them compose the content organizational structure, while others are related to the topics of the domain that compose the learning units. Summarizing, Pedagogical Model wraps up all the aspects involved in a given tutoring learning activity.

Why to adapt? It can be answered by the Support Learning Process. During the learning process execution,

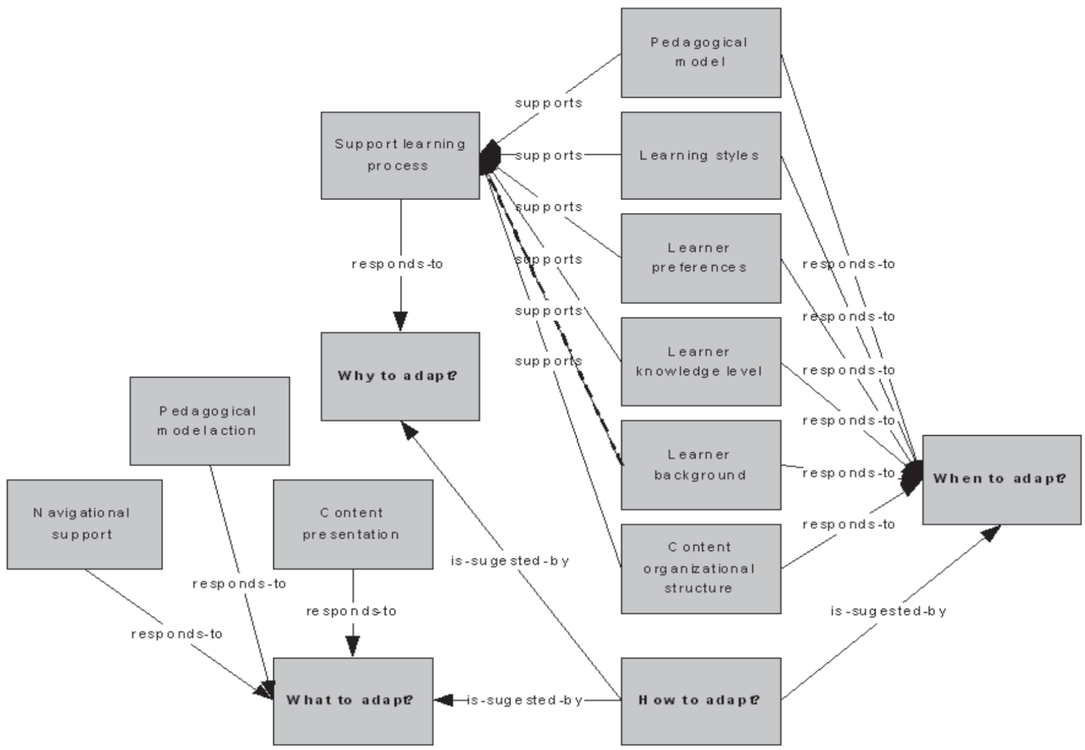

Figure 3. An IBIS diagram with positions and arguments for the questions involved in adaptation design of PTWS.

usually any distinction is made by the pedagogical model among the learners, despite their singular learning capabilities. These learning capabilities can be expressed in different ways as learning styles exemplified by Pask (1976) and Stash (2007). Thus, expressing the learning capabilities in terms of learning styles, allows the adjustment of some aspects of the Pedagogical Model in order to accommodate the learners' differences. The way of addressing the Support Learning Process issue has as supporting arguments the use of Pedagogical Model, Learning Styles, Learner's Preferences, Learner's Knowledge Level, Learner's Background and Content Organizational Structure.

How people process information is considered an important aspect of learning styles (Pask, 1976). Also, providing or suggesting at selection of information to be searched by the learner is a relevant aspect. Based on these aspects and on the fact that, the learners can have distinct levels of knowledge, the learning activities should be supported in accordance with each Learner's knowledge Level. As one result, unknown information for the learners can be present, according to their respective and appropriate level. Besides, the learning materials related to what the learner still needs to know can be provided in accordance with the Learner's Preferences, which can include text, graphics, formal presentations, or some screen lay-out options.

When to adapt? It can be answered by the arguments that support the *Support Learning Process*: Pedagogical model, Learning styles, Learner's preferences, Learner's knowledge level, Learner's background and Content organizational structure.

The previous description indicates the order in which the Pedagogical Model, Learner's Learning Styles, Domain Knowledge and Learner's Preferences can be used in the adaptation process. This order can be seen as distinct levels of information to be used in the adaptation process. Figure 4 shows in outline form, how the levels can be organized.

The rationale behind the scheme presented in Figure 4 can be better understood considering a concrete example. Meaningful Learning Theory (Ausubel *et al.*, 1989) can be considered as a Pedagogical Model. It prescribes a pedagogical process in which new information is related to existing concepts in the learner's cognitive structure. Normally, such relationship occurs when more specific and less inclusive concepts are related to general concepts in the cognitive structure (Novak, 1998). From the pedagogical strategy viewpoint, the concepts to be learned should reflect the involved ideas when presented, in order to enable the comprehension of each concept and how they are related to one another.

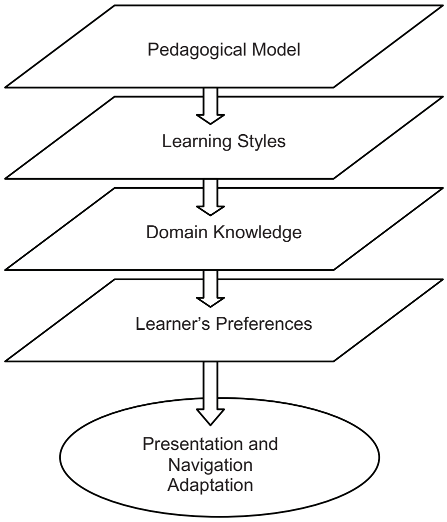

Figure 4. Schematic representation of levels of information for adaptation.

Thus, it is possible to introduce progressive differentiation to the learner's ideas, together with some occasional comparisons and generalizations.

Based on the Meaningful Learning Theory and assuming that some pedagogical units have been defined, the following pedagogical strategies can be defined:

- At the beginning of a tutoring, the system presents a tutorial overview with a short description of the learning units.
- At the beginning of a learning unit, the system presents an advance organizer, a unit overview or the content of the most inclusive topic of the unit.
- In a given learning unit, the learner accesses the topics according to the restrictions imposed by the topic relationships defined in the domain model.
- Having visited every unknown topic in a given unit, the learner is provided with an exercise, an integrative reconciliation and a test, respectively in this order.
- When a learner reaches the last topic in a giving unit, the system suggests links to the next unit content.
- If the current topic is conceptual and the subordinated topics have been visited, then it is presented a synthesis for a conceptual content.
- When the learner completes an unit, the system suggests integrative unit reconciliation.

Two classical examples of learning styles are serialist and holistic (Pask, 1976). Serialist learners prefer to study a limited number of issues in sequence, while holistic learners tend to have a wider focus, opening up more topics in a learning episode and hence working with a more complex organizational structure.

The Learning Styles can have a deep influence on the navigation adaptation (Triantafillou *et al.*, 2002; Bajraktarevic *et al.*, 2003) For example, in a domain represented as a concept map in which the topics are progressively differentiated from more abstract to more specific concepts, a sequential learner would be provided with a depth-first navigation adaptation scheme, with the system suggesting more specific topics, whereas a holistic learner would be provided with a breadth-first navigation adaptation scheme, with the system suggesting topics at the same level of abstraction of the current topic. Therefore, the elements of the Pedagogical Model can be adjusted according to the Learner's Learning Styles.

The learner's domain knowledge can be adapted through his/her navigation process (Brusilovsky, 1998, 2001). Once the system has registered that the learner knows a given topic, the system would not suggest the learner to visit it again, instead would suggest visiting those unknown yet. Finally, the learner's media preferences can also be considered in order to satisfy the learner's needs and preferences for the topics to be visited next (Kobsa *et al.*, 1999).

Concluding, the result of processing the four levels of information reveals the adaptation (Figure 4) in terms of presentation and navigation by a PTWS.

3.2 PTWS general architecture and structure of components

As any educational or not adaptive WEB system, the conceptual system architecture is required to accommodate and to organize the system's components to such a degree that the adaptation may be put in concrete terms.

According to Oliveira (2004), the majority of adaptive hypermedia reference models present some problems, being the most prominent the fact that in their architecture some components encompass distinct responsibilities, reducing separation of concerns and increasing complexity of communication among its components. Another problem is the inflexible implementation of the considered pedagogical strategies, difficulting the use of different Pedagogical Models. Oliveira (2004) defined a reference model for Educational Adaptive Hypermedia Systems in order to minimize the above mentioned inconveniences. Figure 5 presents a reference model, which is considered part of the proposed approach of this work, since it provides the means to accommodate the levels elements as shown on Figure 4.

This architecture was already used in practice. It offers separation of concerns among the components, once each component of the architecture can be seen as a model that represents specific concerns (Jacinto and Oliveira, 2006).

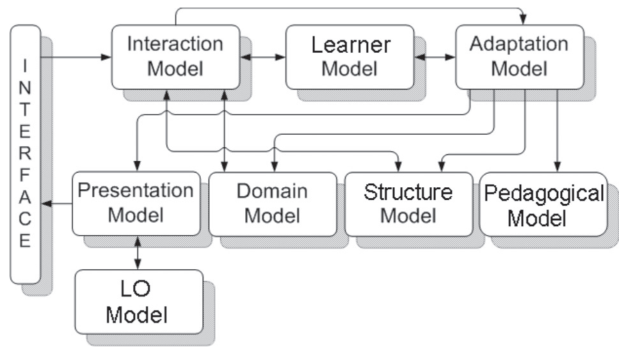

Figure 5. Architecture for PTWS.

In the architecture, the Interaction Model (IM) represents the description of possible user's behavior. Based on the description and the actual user's actions, the system tries to infer the user's intentions.

The Learner Model (LM) contains information about the user, the learner. This kind of information is constantly updated by monitoring of the learner's access, which is made by IM, and used by the Adaptation Model (AM) to draw conclusions or decisions. Learning Style and Learner's Preferences are stored into the LM.

The Domain Model (DM) represents the application domain structure and refers to Domain Knowledge. This model provides information for the IM as well as for AM.

The Structure Model (SM) specifies how the concepts of the DM are grouped into semantic units, for instance, learning units. This model provides information for the Interaction and Adaptation Models.

The Pedagogical Model (PM) specifies the application's Pedagogical Model rules. These rules are based on expressions such "if…then…". This model provides information for the AM.

The Learning Object Repository possesses the contents to be presented to the user. These contents are stored as Learning Objects, which are described and accessed by means of metadata.

The Presentation Model (PS) is responsible for composing the information to be presented to the learner based on of the decisions extracted by the AM. The Presentation Model requests the contents to the Learning Object Model (LOM) in accordance with the decisions informed by the AM.

The AM works with a base of rules, axioms and heuristics for decision making. The decisions are made on the basis of the information contained in the Learner Model, Interaction Model, Pedagogical Model, Structure Model and Domain Model.

3.3 The adaptation rules

In practical terms the Adaptation Model corresponds to a set of rules describing the decisions that are sent to the Presentation Model. The rules are expressed as a conjunction of antecedents and a conjunction of consequents. The left side of the rules is structured according to the following sequence of antecedents, which corresponds to the adaptation determinants:

- Condition of a pedagogical strategy;
- Learning Style;
- Learner's Domain Knowledge and domain structure;
- Learner's Preferences.

The left side of the rules contains the conditions for the decisions specified in the right side of the rules. So, the right side of the rules is structured according to the following sequence of consequents, which corresponds to the adaptation constituents:

- Pedagogical action;
- Navigation support according to the Learning Style;
- Domain topics to satisfy the kind of navigation support defined;
- Presentation of pedagogical material for the domain's topics according to Learner's Preferences.

In order to exemplify how the rules' elements are defined, suppose the learner is at the beginning of a tutoring session, his/her Learning Style is holistic, there is a linear order between learning units, the learner does not know the units yet, and his/her content preference is for graphical presentation. As the elements of this situation correspond to the layers of Figure 4, the transition from a layer to another corresponds to an information mapping. So the following adaptation effects are carried out:

- As the learner is at the beginning of the tutoring session, then a tutorial overview is presented;
- As the Learner's Learning Style is holistic, then access to the first learning unit in the order is allowed;
- As the learner just started a tutoring session and no unit has been accessed yet, no topic domain is suggested to be accessed;
- As the Learner's Preference is for graphical presentation, the tutorial overview is presented by means of a graphical representation of a concept map.

Table 1. Kinds of elements of the adaptation decision rules and example of corresponding elements.

Rule							
Conjunction of antecedents				Conjunction of consequents			
Pedagogical condition	Learning style	Domain knowledge	Preferences	Action	Navigation support	Domain topics	Pedagogical material
Beginning of the tutoring session	Holistic	Does not know units and order between units	Graphical presentation	Present tutorial overview	Allows access to first unit in the order		Concept map

- As an example, Table 1 shows how each element of the first rule described above, relates to each kind of element of the adaptation decision rules.

The action "*Domain topics to satisfy the kind of navigation support defined*" is not applicable to the rule described above, because the learner is at the beginning of a tutoring session and consequently has not had access to any topic. This is an example of how the structuring method used for the rules of the Adaptation Decision Model can facilitate the integration of the most appropriate elements for a given decision.

It should be noticed that the Adaptation Model cooperate with the other components of the PTWS's architecture. For this cooperation it is necessary that the architecture prescribes a clear separation of concerns for its components (Kulkarni and Reddy, 2003; Oliveira and Fernandes, 2002, 2003).

An important aspect of the proposed approach is that the adaptation rationale allows identifying the major elements involved in adaptation at present, as well as allowing future evolution of these aspects. Then the adaptation elements are on the basis of the contents of the architecture's components and for defining the adaptation rules.

4 A case study

Aiming at illustrating the feasibility of the proposed approach, this section presents a case study with the main elements of the proposal for a tutorial with the following design decisions:

- Tutorial theme: Introduction to C Language.
- Domain Model in the form of a concept map to facilitate the visualization of the involved concepts.
- Learning Units made of sets of concepts of the concept map.
- Pedagogical Model based on Ausubel's Meaningful Learning Theory.
- Learner Model containing learner's Domain Knowledge, learning units and Learner's Styles being serialist or holistic.

For space limitation the concept map is not presented, but the learning units derived from the concept map are the following:

- Unit 1 – Expressions. Topics: Expressions, Operators, Data types, Constants, and Variables;
- Unit 2 – Control Commands. Topics: Control, conditional, Selection and Repetition Commands;
- Unit 3 – I/O Commands. Topics: Keyboard and Buffer Entries, Screen Presentation, File Reading and Writing;
- Unit 4 – Structured Variables and Pointers. Topics: Structured and Indexed Variables, Strings, Structures, Arrays of Structures, Structures of Structures, Pointers;
- Unit 5 – Functions. Topics: Functions Definition and Calling.

In terms of the adaptation rational, only the same elements previously discussed are considered. Also the same components of the mentioned architecture are used. In relation to the Pedagogical Model, after careful analysis of its aspects, rules can be derived. For Meaningful Learning, the following rules were derived:

1 Tutorial started → present Tutorial overview &&
allow access to highest level
Learning Units

2 Learning Unit started → present Learning Unit
overview &&
allow access to highest level
topics of Learning Unit

3 Topic accessed → present topic content &&
allow access to topic example &&
allow access to subordinate topics

4 All topics of Learning
Unit accessed → allow access to Learning
Unit summary &&

allow access to Learning
Unit exercise &&
allow access to Learning
Unit test

5 Learning Unit test succeeded → Learning Unit
successfully
completed &&
allow access to
subordinate Learning
Units
6 All Learning Units successfully completed →
present Tutorial
summary &&
present
Tutorial final test

7 Tutorial final test succeeded → Tutorial successfully
completed

Rule 4, for example, states that when the learner has already accessed all topics of a Learning Unit, he/she is allowed to access the summary, exercise and test of this Learning Unit. It should be noticed that pedagogical rules do not say how actions are realized. Instead they only specify what should be done in terms of pedagogical actions.

As mentioned before, the Adaptation Model takes into account information from the Interaction Model, Learner's Model, Pedagogical Model, Domain Model and Structure Model. On the basis of this information, fourteen adaptation rules were derived. Two of these rules are presented next:

1 Present Learning Unit overview &&
allow access to highest level Topics of
Learning Unit &&
Learner's Style is holistic &&
there is no order among Topics &&
Topics' status &&
Learner's Preference →
display Learning Unit overview
according to Learner's
Preference &&
display links for Topics: known
Topics in dark blue, not known
Topics in green.

2 Present Topic Content &&
allow access to Topic Example &&
allow access to Subordinate Topics &&
Learner's Style is holistic &&
there is no order among Subordinate Topics &&
Subordinate Topics' status &&
Learner's Preference →
display topic content according
to Learner's
Preference && display links for
Subordinate
Topics:known Topics in dark
blue, not known
Topics in green.

According to the information levels for adaptation presented in Figure 4, the rule 2 conditions of the adaptation described above contains the pedagogical actions of the pedagogical rule 3, the Learner's Style is holistic. There is no order among the subordinate topics of the accessed topic. The learning status of the subordinate topics should be retrieved from the Learner's Model and Learner's Preferences are also retrieved from the Learner's Model. The corresponding actions of the rule 2 are the following: display topic content according to Learner's Preference and display links for subordinate topics, being the known topics in dark blue, not known Topics in green.

The adaptation rules, defined on the basis of the adaptation rationale, are guide to structure the PTWS components, since such components should support the entire adaptation process.

5 Conclusions

The proposed approach to support design decision for modeling adaptation in tutoring WEB systems provides a fine grain size view of the adaptation process. It also provides the basis to support the process of thinking about the necessary adaptation elements and how they can be related to one another in a PTWS.

One important aspect of the proposed approach is that the information related to each level of the Adaptation Model can include other elements. A significant implication of this fact is the possibility of increasing the complexity of the correspondent components that compose the PTWS's architecture.

The adaptation rationale described in this paper suggests that the kind of information and content to be used at each level of the AM can vary from one application to another, since the PTWS architecture used provides the appropriate support for that.

Though, the proposed modeling approach conceived for PTWS has the potential to be adapted to other kinds of personalized WEB information systems by changing the components of the system's architecture. In order to clarify this changing, the Pedagogical Model of a system that provides touristic information, can be substituted by a Rule Model that describes the types of personalization allowed, for instance restaurant and place to visit according to visitor's interest and preferences. The other architecture's components would demand different and specific adaptations.

The proposed approach is technology independent, allowing implementers to choose the most appropriate technology. Nowadays, semantic WEB technologies are being the leading ones for WEB based information systems due to the facilities offered for knowledge representation, rule definition and inferences.

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