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A Rationale for Conceiving Adaptation in Educational Adaptive Hypermedia Systems

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ABSTRACT

Educational Adaptive Hypermedia Systems (EAHSs) have been used to support customized learning. The adaptation mechanisms provided usually try to define the better concept sequence to be presented and to select the materials and activities more appropriate for a given learner. It is argued that to be supportive in terms of learning, adaptation should be guided by four level of information with the instructional model of an application at the highest level. Preliminary application of these ideas has indicated their usefulness to represent adaptation in EAHSs.

1 INTRODUCTION

Educational Adaptive Hypermedia Systems (EAHSs) are intended to provide customized interaction for learners, in the form of presentation and navigation adaptations [1, 2]. To be able to afford adaptation, EAHSs adaptation models normally use information from learner's domain knowledge, background, and preferences. Learner's cognitive or learning styles have also been used as a source of information for adaptation [3, 4, 5, 6].

Usually composed of a set of rules, the adaptation models described in the literature are normally presented in terms of the final results they provide with respect to presentation and navigation adaptations [6, 7, 8, 9]. Though several aspects are taken into account to form these rules, the rationale on how these aspects are organized to form the rules is not very well defined.

On the basis of four levels of information, this paper presents a rationale on how to conceive adaptation for EAHSs. In this paper, the EAHSs considered are those planned to teach a given body of knowledge to individual learners.

Though the ideas presented have only been used in structuring academic applications, informal evaluations have indicated their feasibility.

The paper is organized as follows. Section 2 presents the rationale for adaptation. Section 3 presents how adaptation is defined in terms of rules. Finally, Section 4 presents some concluding remarks.

2 THE RATIONALE FOR ADAPTATION

In order to be able to teach a given body of knowledge, EAHSs needs to take into consideration several aspects so that adaptation can play a relevant role in the instructional process. Among these aspects are the instructional model to be used, learner's learning styles, domain knowledge and preferences.

Though all of above aspects have been considered in adaptation 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. Subsection 2.1 describes the rationale for adaptation and Subsection 2.2 presents an example of using levels of information for enabling adaptation.

2.1 Rationale Description

An instructional model provides explicit guidance on how to conduct an instructional activity [10]. In fact, the instructional model specifies the instructional support to be provided to the learner, as well as the most appropriate moment for it.

The instructional model, for example, may contain a set of instructional units and a set of instructional strategies. Some of these instructional strategies are related to the instructional units and some are related to the topics of the domain which compose the instructional units. So, the instructional model wraps up all the aspects involved in a given learning activity.

In driving an instructional process, the instructional model usually does not make any distinction between the learners, despite their distinct learning capabilities. These learning capabilities can be expressed in different ways as, for instance, learning styles [11]. So, expressing the learning capabilities in terms of learning styles, allows tuning some aspects of the instructional model in order to accommodate the learners' differences.

When the manner in which people process information is considered an important aspect of learning styles [11], the selection of the information to be provided or suggested to be searched by the learner is a relevant issue. Based on that, as learners can have distinct levels of knowledge, instruction should be provided in accordance with each learner's level of knowledge, in order to present, in the appropriate level, what the learner does not know yet.

The instructional materials related to what the learner still needs to know can be provided in agreement with the learner's preferences. These preferences can include text, graphic or formal presentations or some screen lay-out options.

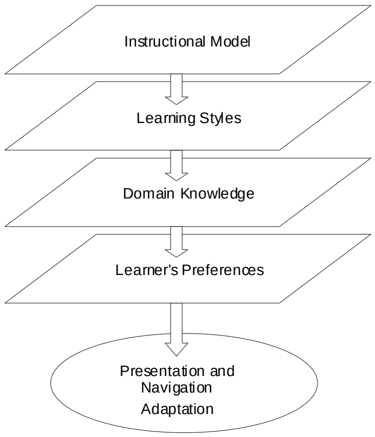
The above discussion indicates an order in which the instructional model, learner's learning styles, domain knowledge and preferences are used in the adaptation process. This order can be seen as distinct levels of information to be considered in the adaptation process. Figure 1 schematically shows how these levels can be organized.

Figure 1 indicates that the result of processing the four levels of information is adaptation in terms of presentation and navigation. To make the adaptation process possible, an architecture for EAHSs where the four levels of information are properly represented is required.

Usually, the Adaptation Model (AM) found in EAHSs is the system's component responsible for providing presentation and navigation adaptations. Other important components of EAHSs architecture are the following: Domain Model (DM), Learner Model (LM), Instructional Model (IM), Presentation Model (PM), and Learner Interaction Model (LI).

In a more formal way, adaptation can be defined as a function that maps elements from IM, DM, LM, and LI onto LM and PM. This function can be represented in the following composition of functions:

Figure 1. Schematic representation of levels of information for adaptation



i: $\{IMc, IMu, DM, LM, LI\} \rightarrow \{IMa, LM\}$

l: $\{IMa, LM\} \rightarrow \{LM\}$

d: $\{LM\} \rightarrow \{LM\}$

p: $\{LM\} \rightarrow \{LM, PM\}$

$a = p \circ d \circ l \circ i$: $\{IMc, IMu, DM, LM, LI\} \rightarrow \{LM, PM\}$

Function *i* maps elements from the sets IM, DM, LM, and LI to elements of IM and LM. IM is composed of three subsets: Conditions (IMc), Actions (IMa), and Units (IMu). LI comprehends a description of the possible actions the learner may perform when interacting with the system. Function *i* maps elements from Instructional Model Conditions (IMc) onto specific Instructional Model Actions (IMa) to be carried out, in terms of specific instructional units and specific elements of the application domain to be accessed, as well as the corresponding updating in the learner's characteristics. Function *i* corresponds to the transition from the first to the second level in Figure 1.

Function *l* maps elements from the sets Instructional Model Actions (IMa) and LM to elements of LM. Function *l*, which corresponds to the transition from the second to the third level in Figure 1, aims to adjust the instructional action to the learning style of each learner.

Function *d* maps elements from the set LM onto elements of LM. Function *d* corresponds to the transition from the third to the forth layer in Figure 1. It aims to define the elements of the application domain the learner can visit, on the basis of the current instructional unit, his or her learning style and current knowledge level.

Function *p* maps all previously defined elements in LM onto LM and PM. It represents the updating process of LM and corresponds to the final composition of what will be presented to the learner. Therefore, the composition of functions *p*, *d*, *l* and *i* constitutes function *a*, the function adaptation.

Viewing adaptation as a composed function has some benefits. First, it is possible to analyze the involved aspects in a finer level of granularity. For example, the order of individual functions *l*, *d* and *p* could be changed. Though there is no strong evidence already, it seams that function *i* should be the first one to be applied, once the instructional model guides the instructional process and the other aspects subordinated to it. Second, it is possible to include new aspects in each level or define new layers in the scheme of Figure 1, which would mean defining new individual functions.

The highest level in Figure 1, and also function *i*, represents the use of a single instructional model in a given system. This means that every instructional strategy is based solely on this instructional model. Nevertheless, there are systems that use distinct instructional model, especially in the realm of Intelligent Tutoring Systems (ITSs) [12, 13].

2.2 An Example of Levels of Information for Adaptation

The rationale behind the scheme of Figure 1 can better be understood considering a concrete example. As instructional model, Meaningful Learning Theory [14] can be considered. Meaningful Learning Theory prescribes an instructional process in which new information is related to existing concepts in the learner's cognitive structure. Normally, such a relationship occurs when more specific, less inclusive, concepts are related to more general concepts in the cognitive structure [15]. From the viewpoint of instructional strategy, the concepts to be learned should be presented in a manner that reflects the involved ideas, in order to allow the comprehension of each concept and how they are related to each other. Thus, it is possible to introduce progressive differentiations to the learner's ideas, together with some occasional comparisons and generalizations.

On the basis of the Meaningful Learning Theory, and assuming that some instructional units have been defined, the following instructional strategies can be defined for the IM:

- At the beginning of a course, the system presents a course overview with a short description of the instructional units.
- At the beginning of an instructional unit, the system presents an advance organizer, a unit overview or the content of the most inclusive topic of the unit.
- In a given instructional unit, the learner accesses the topics according to the restrictions imposed by the topic relationships defined in the domain model.
- Having visited every not yet known topic in a given unit, the learner is provided with an exercise, an integrative reconciliation and a test, respectively in this order.
- Topic contents are presented in accordance with the type of objective of an instructional unit, which can be based on the following types of knowledge: conceptual, procedural or operational.
- When a learner reaches the last topic in a giving unit, the system suggests links to content of the next type.
- If the current topic is conceptual and the subordinated topics have been visited, then present synthesis for conceptual content.
- If the current topic is conceptual and operational and the procedural subordinated topics have been visited, then present the operational content.
- When the learner completes a unit, the system suggests an integrative reconciliation for the unit.

Two classical examples of learning styles are sequential and holistic [11]. Sequential learners prefer to study a limited number of issues in sequence, while holists tend to set 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 profound influence on the navigation adaptation [4, 5]. 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 instructional model can be adjusted according to the learning styles of learners.

The learner's domain knowledge can be adapted through his or her navigation process [1, 2]. Once the system has registered that the learner knows a given topic, the system would not suggest the learner to visit it again, but would suggest him or her to visit 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 [16].

3 THE ADAPTATION MODEL RULES

As described before, the Adaptation Model's decisions about what should be done in terms of presentation and navigation adaptation can theoretically be represented by the following function:

$$a = p \circ d \circ l \circ i : \{IMc, IMu, DM, LM, LI\} \rightarrow \{LM, PM\}$$

In practical terms, the Adaptation Model corresponds to a set of rules describing the decisions that are to be 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:

- Condition of an instructional 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 in conformity with the following sequence of consequents:

- Instructional action
- Navigation support according to the learning style
- Domain topics to satisfy the kind of navigation support defined
- Presentation of instructional material for the domain's topics in accord with learner's preferences

To exemplify how the rules' elements are defined, suppose the learner is at the beginning of a course, his or her learning style is holistic, there is linear order between course units, the learner does not know the units yet, and his or her content preference is for graphical presentation. As the elements of this situation correspond to the layers of Figure 1, the transition from a layer to another corresponds to a mapping of information. So, the following adaptation effects are to be carried out:

- As the learner is at the beginning of the course, then a course overview is presented.
- As the learner's learning style is holistic, then access to the first instructional unit in the order is allowed.
- As the learner just started a course 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 course overview is presented by means of a graphical representation of a concept map.

Table 1 shows how each element of the first rule above, for example, relates to each kind of element of the adaptation decision rules. Following the table, when a learner is at the beginning of a course, has a holistic learning style, there is linear order between the course units and the learner does not know the units, and the learner prefers graphical presentations, then the correspondent actions are to present a course overview, allow access to the first course unit, according to the learning style, and to present a concept map of the course's units, according to the learner's preferences.

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

It should be noticed that the adaptation model cooperate with other EAHSs architecture. For this cooperation it is necessary that the architecture prescribes a clear separation of concerns for its components [17, 18, 19].

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

Rule							
Conjunction of Antecedents				**Conjunction of Consequents**			
Condition	Learning Style	Domain Knowledge	Preferences	Action	Navigation Support	Domain Topics	Instructional Material
Course beginning	Holistic	Does not know units and order between units	Graphical Presentation	Present course overview	Allow access to first unit in the order		Concept map

4 CONCLUSIONS

The proposed four levels of information involved in the adaptation process in EAHSs clearly provide a fine grain size view of the adaptation process. It provides the basis to support thinking about the necessary adaptation elements and how they can be related to each other in an EAHS.

One important aspect of the four levels of information for adaptation is that the information in each level can be as comprehensive as desired. An important implication of this comprehensiveness is the possibility of increasing the complexity in the correspondent components of the EAHSs architecture.

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

Normally, adaptation models are of general purpose and described in terms of the information required to provide it. One problem of this kind of framework is that they require only a low level trait of the aspects involved in adaptation.

An important aspect of the adaptation rationale is that it must be supported by an architecture that prescribes clear separation of concerns of the components. Otherwise the information mappings would be difficulty to be structured. As a way to verify the adaptation model, a simulation program will be developed. Such a program will allow simulating all the elements involved in the information layers and the corresponding mappings.

In practical terms, the adaptation model points out to a way of finely differentiating learning objects. As future work, experiments on this aspect will be conducted as well.

REFERENCES

[1] Brusilovsky, P. Adaptive Educational Systems on the World-Wide-Web: A Review of Available Technologies. *ITS'1998 – Workshop WWW-Based Tutoring*, 1998.

[2] Brusilovsky P. Adaptive Hypermedia. *User Modeling and User Adapted Interaction*. Kluwer Academic Publishers, 11, 2001, 87-110.

[3] Graff, M. Learning from Hypertext and the Analyst-Intuition Dimension of Cognitive Style. *World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education*, AACE, Montreal, Canada, 2002, 361 – 368.

[4] Triantafillou, E.; Pomportsis, A.; Georgiadou, E. AES-CS: Adaptive Educational Systems Based on Cognitive Styles. *AH´2002 – Workshop on Adaptive Systems for Web-based Education*, Malaga, Spain, 2002.

[5] Bajraktarevic, N.; Hall, W.; Fullick, P. Incorporating Learning Styles in Hypermedia Environment: Empirical Evaluation. *AH'2003 – Workshop on Adaptive Hypermedia and Adaptive Web-based Systems*, 2003, Budapest, Hungary.

[6] Cristea, A.; Calvi, L. The Three Layers of Adaptation Granularity. UM'2003 – *User Modeling*, Pittsburg, US, 2003.

[7] De Bra, P.; Calvi, L. (1998). AHA! An Open Adaptive Hypermedia Architecture. *The New Review of Hypermedia and Multimedia*. Taylor Graham Publishers, 4, 115-139.

[8] Wu, H. (2001). A Reference Architecture for Adaptive Hypermedia Systems. *ACM Conference on Hypertext and Hypermedia –Hypertext' 01*, Arhus, Denmark, 2001.

[9] Assis, P. S.; Schwabe, D.; Barbosa, S. D. J. Meta-models for Adaptive Hypermedia Applications and Meta-adaptation. ED-MEDIA'2004 – World Conference on Educational Multimedia, Hypermedia & Telecommunications, AACE, 2004.

[10] Reigeluth, C. What Is Instructional-Design Theory and How Is IT Changing? In: REIGELUTH, Charles M (Ed.). *Instructional-Design Theories and Models*. Mahwah: Lawrence Erlbaum, 1999, 5-29.

[11] Pask, G. Styles and Strategies of Learning. *British Journal of Educational Psychology*, 46. 1976.

[12] Marietto, M. G. B. *Dynamic Definition of Instructional Strategies in Intelligent Tutoring Systems: A Multiagents Approach for WWW.* Doctoral Thesis, Technological Institute of Aeronautics, S. J. Campos, Brazil, 2000.

[13] Viccari, R. M.; Giraffa, L. M. M. The Use of Multiagent Systems to Build Intelligent Tutoring System. *International Journal on Computing Anticipatory Systems*, 2002.

[14] Ausubel, D. P.; Novak, J. D.; Hanesian, H. *Educational Psychology*. Mexico City: Trilhas, 1989.

[15] Novak, J. D. *Learning Creating and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations*. New Jersey, Lawrence Erlbaum Associates, 1998.

[16] Kobsa, A.; Koenemann, J.; Pohl, W. Personalized Hypermedia Presentation Techniques for Improving Online Customer Relationships. Technical Report no. 66, German National Research Center for Information Technology. St. Augustin, Germany, 1999.

[17] Kulkarni, V.; Reddy, S. Separation of Concerns in Model-Driven Development, *IEEE Software, Sept/Oct*, 2003. p. 64-69.

[18] Oliveira, J. M. P., & Fernandes, C. T. Adaptation Architecture for Adaptive Educational Hypermedia Systems. *World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education*, AACE, Montreal, 2002.

[19] Oliveira, J. M. P.; Fernandes, C. T. A Framework for Adaptive Educational Hypermedia Systems. *Workshop on Applications, Products and Services of Web-based Support Systems in conjunction with the IEE/WIC International Conference on Web Intelligence*, Halifax, 2003.

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