INFORMÁTICA NA EDUCAÇÃO: teoria & prática Porto Alegre, v.12, n.1, jan./jun. 2009. ISSN digital 1982-1654
ISSN impresso 1516-084X

Personalized e-learning environments: considering students' contexts[1]

Ambientes personalizados de e-learning: considerando os contextos dos alunos

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Abstract: Personalization in e-learning systems is vital since they are used by a wide variety of students with different characteristics. There are several approaches that aim at personalizing e-learning environments. However, they focus mainly on technological and/or networking aspects without caring of contextual aspects. They consider only a limited version of context while providing personalization. In our work, the objective is to improve e-learning environment personalization making use of a better understanding and modeling of the user's educational and technological context using ontologies. We show an example of the use of our proposal in the AdaptWeb system, in which content and navigation recommendations are provided depending on the student's context.
Keywords: Distance Learning. Computer Assisted Learning. Learning models. Personalization. Contextual and Cultural Profiles.

Resumo: A personalização em sistemas de e-learning é fundamental, uma vez que esses são utilizados por uma grande variedade de alunos, com características diferentes. Há várias abordagens que visam personalizar ambientes e-learning. No entanto, esses se concentram principalmente na tecnologia e / ou em detalhes da rede, sem levar em consideração os aspectos contextuais. Eles consideram apenas uma versão limitada do contexto, proporcionando personalização. Em nosso trabalho, o objetivo é melhorar a personalização do ambiente de aprendizagem e-learning, fazendo uso de uma melhor compreensão e modelagem do contexto educacional e tecnológico do usuário, utilizando ontologias. Mostramos um exemplo do uso da nossa proposta no sistema AdaptWeb, na qual o conteúdo e as recomendações de navegação fornecidas dependem do contexto do aluno.
Palavras-chave: Educação a Distância. Aprendizagem Apoiada pelo Computador. Aprendizagem Assistida. Modelos de aprendizagem. Personalização. Perfis culturalmente contextualizados.

1 Introduction

Nowadays, personalization in e-learning environments demands more effective techniques to personalize student assistance in extremely dynamic and heterogeneous contexts. Context is vital to improve personalized access to and presentation facilities of learning resources. Context can be defined as a description of aspects of a situation[2]. If a piece of information can be used to characterize the

1 This work has been partially funded by the international cooperation project Nº 042/07 (Secyt, Argentina) – 022/07 (CAPES, Brazil) and by PICT project 20178 (ANPCT, Argentina)

2 DEY, A.; ABOWD, G.; BROWN, P.; DAVIES, N.; SMITH, M.; STEGGLES, P. Towards a Better Understanding of Context and Context-Awareness. In: HUC '99 – INTERNATIONAL SYMPOSIUM ON HANDHELD AND UBIQUITOUS COMPUTING, 1., 1999, Karlsruhe. *Proceedings*... London, UK: Springer-Verlag, 1999. P. 304-307.

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situation of a participant in an interaction, then that information is context. For instance, the physical location of the student or the temperature of the student's surroundings are possible examples of context.

Research in adaptive educational hypermedia has proved that considering context leads to a better understanding and personalization[3]. Modeling the context leads to the design of systems that deliver more appropriate learning content and services to satisfy students' requirements and to be aware of situation changes by automatically adapting themselves to such changes[4]. An improvement in the user's contextual information leads to a better understanding of users' behavior in order to adapt i) the content, ii) the interface, and iii) the assistance offered to users. Thus, a contextualized e-learning environment provides the student with exactly the material he needs, and appropriate to his knowledge level and that makes sense in a special learning situation. Thus, for each situation, an e-learning environment is dynamically adjusted depending on the context information available. However, while e-learning environments are inextricably linked to the notion of situation, this is only implicitly mentioned and not explicitly modeled. In order to support situation-aware adaptation, it is necessary to model and specify context and situation[5]. More accurately, there is a complex intermeshing and continuous transformation of situations in combination with fluctuating contexts, where meaning changes according to context and through preferences of different participants. In this sense, e-learning personalization is situation-dependent and cannot be managed in an independent form. Ontologies are widely used to model context. In[6], we present an approach to model context using upper-level ontologies. An upper-level ontology provides the basic concepts upon which any domain-specific ontology is built. Based on our previous work, in this paper we use that upper-level model as a framework to describe context for e-learning. Thus, ontologies not only facilitate the specification of context but also the development of guidelines to use it. We are working on strategies and techniques to model students' contextual information for e-learning environments. In addition, we investigate how to integrate the advantages of ontological models into personalized educational systems. Our aim is to increment even more the actual systems personalization capabilities making use of ontologies to model the user's context in different scenarios. As a result, in this paper we describe an approach to improve the personalization capabilities of an e-learning environment called AdaptWeb[7]. Particularly, we improved the models used in this e-learning environment in order to incorporate the notion of context and situation. The article is organized as follows. First, section 2 discusses some related work. Then, section 3 presents our view about context modeling for e-learning, and our ontological-driven approach to model context within the concept of situation using upper-level ontologies. Section 4 argues about the context dimensions and section 5 explains e-learning personalization using the context information. Later, section 6 discusses how context is modeled in AdaptWeb drawing on our previous work. Finally, in section 7 we summarize our results and indicate future research.

3 BRUSILOVSKY, P.; MILLAN, E. User Models for Adaptive Hypermedia and AdaptiveEducational Systems. In: THE ADAPTIVE Web: Methods and Strategies of Web Personalization. Heidelberg: Springer Berlin, 2007. P. 3-53. (Information Systems and Applications, incl. Internet/Web, and HCI , v. 4321)

4 BOUZEGHOUB, A.; DO, K.; LECOCQ, C. A Situation-Based Delivery of Learning Resources in Pervasive Learning. In: EC-TEL 2007 – EUROPEAN CONFERENCE ON TECHNOLOGY ENHANCED LEARNING, 2., 2007, Crete. *Creating New Learning Experiences on a Global Scale*: proceedings. Berlin, Heidelberg: Springer, 2007. P. 450-456.

5 Ibid.

6 EYHARABIDE, V.; AMANDI, A. An Ontology-Driven Conceptual Model of User Profiles. In: ASAI07 – SIMPOSIO ARGENTINO DE INTELIGENCIA ARTIFICIAL, n., 2007, Argentina. Proceedings of... Mar Del Plata, Argentina: Sociedad Argentina de Informática e Investigación Operativa, 2007. P. 101-115

7 FREITAS, V.; MARÇAL, V.P.; GASPARINI, I.; AMARAL, M.A.; PROENÇA JR., M.; BRUNETTO, M.A.C.; PIMENTA, M.S.; PINTO, C.H.F.; LIMA, J.V.; OLIVEIRA, J. P. AdaptWeb: an Adaptive Web-based Courseware. In: ICTE2002 – INTERNATIONAL CONFERENCE ON INFORMATION AND COMMUNICATION TECHNOLOGIES IN EDUCATION, 2002, Badajoz. *Proceedings*... Badajoz, Espanha: Anais, 2002. P. 131-134.

2 Related work

There are several ontology-based user profiling approaches to represent context[8]. However, they are centered in using ontologies to describe the application domain and they usually do not consider the characteristics of contexts that are invariant during certain time intervals (situations). The ones that aim at describing the situation in which certain user information is captured consider only minimal contextual information, such as URL, date or time.

Dockhorn Costa et al. in[9] propose basic conceptual foundations for context modeling. Specifically, they suggest a separation of the concepts of entity and context. According to the authors, context is only meaningful with respect to an entity. While an entity is something that can exist by itself; context is what can be said about an entity. Therefore, context cannot exist by itself; that is, it existentially depends on other entities. Although, they have extended their models with the ontological concept of situation, they have only presented them using an ad-hoc graphical notation. Later, in[10] the authors continued their work to propose an approach to the specification and realization of situation detection for attentive context-aware applications.

As the regards the use of context and ontologies in e-learning,[11] present an ontological framework for e-learning environments and apply it in two applications based on this framework: TANGRAM, to reuse of existing content units to dynamically generate new learning content adapted to the learner's knowledge, preferences, and learning styles, and LOCO-Analyst to help instructors rethink the quality of the learning content and learning design of the courses they teach. In[12] the authors discuss examples of ontologies used both to model material in a Java e-lecture and to model learners' performance and interactions with the e-learning system. This information is used to propose annotated recommendations of different learning resources. Finally, the importance of the user's context of work (given by user platform, user location, and affective state) in adaptive educational systems is discussed in[13].

3 Context modeling in e-learning

To be effective, a learning process must be adapted to the student's context. A context-aware e-learning environment is a web-based educational application that adapts its behavior according to its students' context. Context-aware applications use and manipulate context information to detect the situations of users and adapt their behavior accordingly. Context-aware applications not only use context information to react to a user's request, but also take initiative as a result of context reasoning activities[14].

Ontologies are the most promising technology to support context modeling because they are very useful to disambiguate and also to identify the semantic categories of a particular domain. Ontologies are the description of the entities, relations and restrictions of a domain, expressed in a formal language to enable machine understanding. In particular, an upper-level ontology defines a range of top-level domain-independent ontological categories, which form a general foundation for

8 DEY; ABOWD; BROWN; DAVIES; SMITH; STEGGLES, 1999, op. cit.
KOFOD-PETERSEN, A.; MIKALSEN, M. Context: Representation and Reasoning Representing and Reasoning about Context in a Mobile Environment. *Revue d'Intelligence Artificielle*, Paris, v. 19, n.3, p. 479-498, 2005.

9 DOCKHORN COSTA, P.; GUIZZARDI, G.; ALMEIDA, J.; PIRES, L.; VAN SINDEREN, M. Situations in Conceptual Modeling of Context. In: EDOCW '06 – IEEE ON INTERNATIONAL ENTERPRISE DISTRIBUTED OBJECT COMPUTING CONFERENCE WORKSHOPS, 10., 2006, Hong Kong. *Proceedings*... Los Alamitos, CA: IEEE Computer Society, 2006. P. 1-6

10 DOCKHORN COSTA, P.; ALMEIDA, J.; PIRES, L.; VAN SINDEREN, M. Situation Specification and Realization in Rule-Based Context-Aware Applications. In: IFIP – INTERNATIONAL CONFERENCE ON DISTRIBUTED APPLICATIONS AND INTEROPERABLE SYSTEMS – DAIS, 10., 2007, Paphos. *Proceedings*.... New Orleans: LNCS, 2007. P. 32-47.

11 JOVANOVIC, J.; GASSCEVIC, D.; KNIGHT, C.; RICHARDS, G. Ontologies for Effective Use of Context in e-Learning Settings. *Educational Technology and Society* , Canadá, v. 10, n. 3, p. 47-59, 2007.

12 DOLOG, P.; NEJDL, W. Semantic Web Technologies for the Adaptive Web. In: THE ADAPTIVE Web: Methods and Strategies of Web Personalization. Heidelberg: Springer Berlin, 2007. P. 697-719. (Information Systems and Applications, incl. Internet/ Web, and HCI , v. 4321)

13 BRUSILOVSKY; MILLAN, 2007, op. cit.

14 DOCKHORN COSTA; ALMEIDA; PIRES; VAN SINDEREN, 2007, op. cit.

more elaborated domain-specific ontologies[15]. In this paper, we present a model based on upper-level ontologies to describe a user's context for e-learning.

A user might be involved in several overlapping contexts. Consequently, his/her educational activity might be influenced by the interactions between these contexts. Overlapping contexts contribute to and influence the interactions and experiences that people have when performing certain activities[16]. The definition of an overlapping context is not new. Context can be considered as a multidimensional space where each dimension is represented by one different ontology which should be handled separately[17]. Such a context should be described at least from pedagogical, technological and learning perspectives[18]. Learning processes have to provide extremely contextualized content that is highly coupled with context information, barring their reuse in some other context. Thus, ontologies can be used not only to model domain information but mainly to personalize the services provided to users, in adaptive systems as well as in agent-based ones[19].

As deeply described in[20], our model has three levels: a meta-model, a model and an object level (Figure 1). The meta-model level is represented by an upper-level ontology, the model level with several ontologies to describe context and in the lower level we find the instantiations of the context ontologies. In other words, the ontology concepts of one level are the instantiations of its immediate superior level. Thus, the concepts of the object level are instances of the model level which is further formed by instances of the meta-model level.

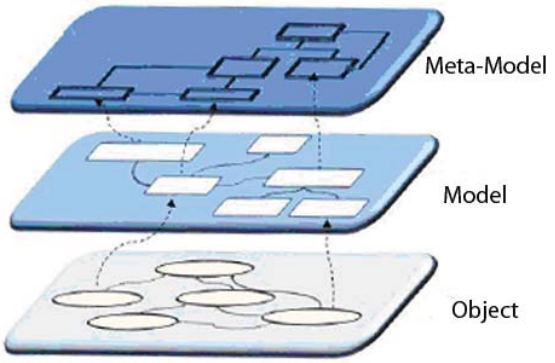

Figure 1 – Three-level model

There are two main reasons for modeling context for e-learning: task oriented focus and reuse. First, the professor might not know which the context differences among the students are. Even though he/she knows them, he/she should concentrate on the educational material; without taking care of how to adapt that material to different students. Second, context might be the same for different students among different courses. Therefore, the e-learning environment could provide support to reuse those repetitive contexts descriptions.

4 Context dimensions

An e-learning environment aims to support the structuring and adaptation of web-based courses material, according to the particular student's model. However, they may be dynamically adjusted not only according to the student's model but also depending on the context. In practice, context' is very difficult to define and most general-purpose definitions are inadequate. In this work, context' is considered as having personal, cultural, technological and pedagogical dimensions.

Personal context is widely considered in e-learning. This type of context is usually gathered in user profiles. A user profile is a model containing the most important or interesting

15 GUIZZARDI, G.; WAGNER, G. Towards Ontological Foundations for Agent Modelling Concepts Using the Unified Fundational Ontology (UFO) In: INTERNATIONAL BI-CONFERENCE WORKSHOP ON AGENT-ORIENTED INFORMATION SYSTEMS, 2., 2005, Klagenfurt. *Proceedings*.... Berlin: LNCS, 2005. P. 110 - 124

16 BOUZEGHOUB; DO; LECOCQ, 2007, op. cit.

17 YANG, S.J.H.; HUANG, A.P.M.; CHEN, R.; TSENG, S.-S.; YEN-SHIH, S. Context Model and Context Acquisition for Ubiquitous Content Access. In: ULEARNING ENVIRONMENTS. IEEE INTERNATIONAL CONFERENCE ON SENSOR NETWORKS, UBIQUITOUS, AND TRUSTWORTHY COMPUTING, 2006. *Workshops*. Taiwan: IEEE, 2006. V. 2, p. 78-83. BOUZEGHOUB; DO; LECOCQ, 2007, op. cit.

18 ABARCA, M.; ALARCON, R.; BARRIA, R.; FULLER, D. Context-Based e-Learning Composition and Adaptation. In: ON THE MOVE to Meaningful Internet Systems 2006: OTM 2006 Workshops. Heidelberg: Springer Berlin, 2006. P. 1976-1985.

19 EYHARABIDE, V.; AMANDI, A. Semantic spam filtering from personalized ontologies. *JWE - Journal of Web Engineering*, Princeton, NJ, v. 7, n. 2, p. 158-176, 2008.

20 EYHARABIDE; AMANDI, 2007, op. cit.

facts about the user, such as user preferences or user interests[21]. For general purposes, typical characteristics of user profiles include age, scholarship, background, genre, among others. It considers the student's personal information (such as name or address) and also the student's personal preferences (like colors or layouts).

Cultural context is also vital for e-learning environments. Cultural aspects are preferences and ways of behavior determined by the person's culture. Regarding e-learning environments, the cultural aspects are just the features that distinguish between the preferences of students from different regions[22]. Cultural context is referred to different languages, values, norms, gender, social or ethnic aspects. An e-learning environment must be personalized in relation to a particular student's cultural properties. Thus, modeling culture profiles can be a tool to improve cultural awareness in global knowledge sharing and learning processes. They describe cultural characteristics on different levels, such as national, organizational or individual characteristics. In turn, culture can be analyzed in some levels: national and regional aspects, organizational aspects, professional aspects and fields, and individual aspects. Thus, cultural profiles describe cultural and individual characteristics on diverse levels.

Technological context is related to many different technological constraints (e.g., device processing power, display ability, network bandwidth, connectivity options, location and time). Indeed, cultural and technological adaptation is an important and hot research topic that has not been yet supported by most of e-learning environments, although some pioneering work has been reported by[23]. Technological context includes concepts such as browser type and version, operating system, IP address, devices, processing power, display ability, network bandwidth or connectivity options.

Pedagogical context is multifaceted knowledge. In fact, there are many distinct works about different viewpoints of pedagogical information needed to personalize e-learning. In practice, many adaptive systems take advantage of users' knowledge of the subject being taught or the domain represent in hyperspace and the knowledge is frequently the only user feature being modeled[24]. Recently, various researches started using others characteristics, such as learning styles[25]. In general, for educational web sites or e-learning environments we may be concerned with some specific aspects related to user role or information related to the activity being done like the student's background or preferences, the student's objectives, hyperspace experience, learning styles, personality stereotypes, cultural and contextual aspects.

5 E-learning personalization using context information

We personalize an e-learning environment for each user based on the information stored in a user profile. In our work, the typical characteristics of students are extended to include the context dimensions mentioned in the previous section. Among all the information gathered in the user profile, in this paper we are especially interested in modeling user preferences because they change according to context. Preferences may depend on the situation the user is in and on external factors. Therefore, it is important to model in which context the user prefers something. Hence, we define user preference as an entity that the user prefers in a given situation, a relevance denoting the user's preference for that entity, a certainty representing how sure we are about the user having that preference and a date indicating when that preference is stored:

User Preference = {entity, situation, relevance, certainty, date}

Situations are the key to include temporal aspects of context in a comprehensive ontology for context modeling, since they can be re-

21 BRUSILOVSKY; MILLAN, 2007, op. cit.

22 GUZMAN, J.; MOTZ, R. Towards an Adaptive Cultural E-Learning System. In: LA-WEB '05 – Latin American Web Congress, 3., 2005, Buenos Aires. *Proceedings*... Washington, DC: IEEE Computer Society, 2005. P. 183.

23 ABARCA; ALARCON; BARRIA; FULLER, 2006, op. cit.

24 BRUSILOVSKY; MILLAN, 2007, op. cit.

25 SCHIAFFINO, S.; GARCIA, P.; AMANDI, A. eTeacher: Providing personalized assistance to e-learning students. *Computers and Education*, Maryland Heights, v. 51, n. 4, p. 1744-1754, 2008.

lated to suitable notions of time[26]. As context varies during certain time intervals, it is vital to consider it within the concept of Situation. Examples of situations could be "John was at home using his notebook to read lesson number 3 of the Human Computer Interaction course" or "A Japanese Professor who speaks English is adding new exercises to the course Introduction to Java using a high speed connection while she travels by train". Therefore, we define situation as a set of contextual information in a particular period of time:

Situation = {Context, initial time, final time}

An example of contextual information would be: "The student named John is reading lesson number 7". This is a description relating an entity (the student John) to another entity (the lesson number 7) via a property (is reading). We represent this contextual information as (Student.john, isReading, Lesson.lesson#7). We define context as a set of triples composed by concepts, instances and relations between them. It is important to emphasize that the concepts and instances might belong to the same ontology or different context ontologies:

Context = {(Concepta1.Instancea1, Relation1, Conceptb1.Instanceb1), ...,

(ConceptaN.InstanceaN, RelationN, ConceptbN.InstancebN)}

To clarify these ideas, consider again John's example. As we mentioned before, John prefers to read visual learning material when he is at home using his notebook to read lesson number 3 of the Human Computer Interaction course. Hence, the corresponding context1 will be:

Context1={ (Person.John, **locatedIn**, Location.home),

(Person.John, **uses**, Device.notebook),

(Person.john, **reads**, Lesson.lesson#3),

(Lesson.lesson#3, **belongsTo**, Course.HCI)}

Figure 2 depicts the situation model proposed. The meta-model is an upper-level ontology describing abstract concepts like user, application, user profile, situation or date. The model depicts the different contextual dimensions. Each contextual dimension is represented by a different ontology, such as a cultural ontology (with concepts like culture, social norm or language), education ontology (course, learning style, discipline), personal ontology (name, genre, birthday) or techno-

26 DOCKHORN COSTA; GUIZZARDI; ALMEIDA; PIRES; VAN SINDEREN, 2006, op. cit.

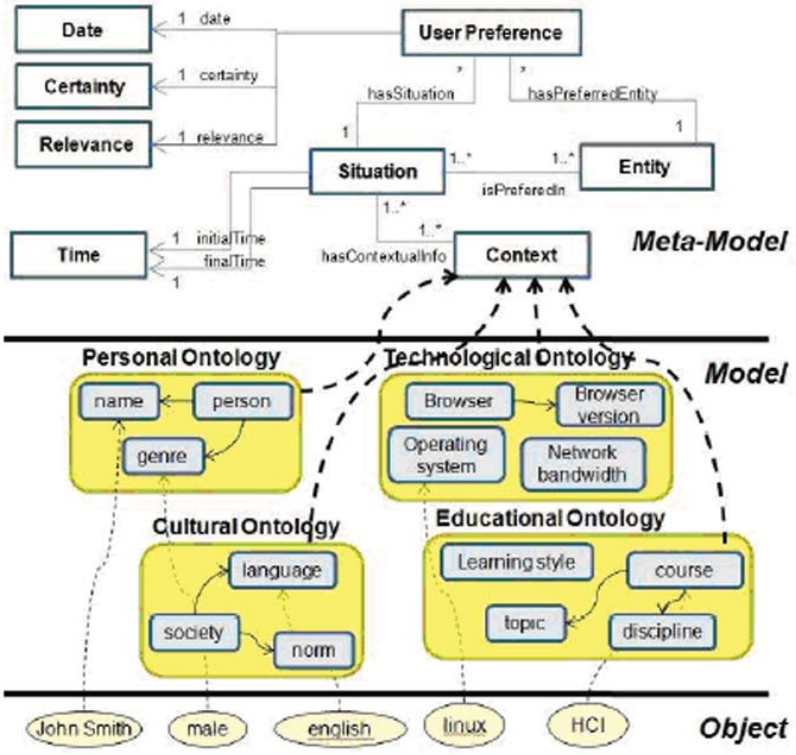

Figure 2 – Exemple of a situation model

logical ontology (operating system, browser, network bandwidth). Finally, the object model will comprise instances describing the context of a particular user like a concrete name (John Smith), a course (Human Computer Interaction) or a particular language (English).

6 Adopting Contextual Modeling in AdaptWeb

In this section we describe some improvements of the personalization capabilities of the e-learning environment: AdaptWeb[27] in order to provide support to this contextual modeling purpose. Particularly, we improved the models used in those e-learning environments in order to incorporate the notion of context and situation.

AdaptWeb[28] (Adaptive Web-based learning Environment) is an adaptive application for Web-based learning, whose purpose is to adapt the content, the presentation and the navigation in an educational web course, according to the student model. Currently, it is an open source environment in operation on different universities. The environment is adapted to the student's profile and domain model that nowadays uses characteristics of personal, pedagogical and technological context: the student's preferences, learning styles, background, knowledge, navigational history, network characteristics, time of presentation, and quality of didactic material components presentation.

In our approach, the fundamental metadata describing the instructional material is partial generated automatically and stored in a web ontology. Now, we are incorporating more characteristics of context-awareness, as some culturally aspects into the student model, expecting the environment to become more adaptive to the students and reusable.

For each situation, the AdaptWeb e-learning environment is dynamically adjusted depending on the context information available. Once the learning situation is modeled, it is important to associate one (or more) situation(s) to each learning activity in order to contextualize the student preferences. That is to say, in situation 1 the student prefers the activity A; on the contrary, when situation 2 holds, the user prefers the activity B. For example, John prefers to see visual learning material when he is reading about the course "human computer interaction" and he has a high network connection. On the contrary, John prefers to listen to the teacher explanation when the course is "Algebra" and his network connection is slow.

We show some examples of contextual adaptation in AdaptWeb in an Artificial Intelligence course. In this paper, for a simplification purpose, we have a few variables: user's knowledge, subject, network connection and learning style.

In a situation 1, Mary does not have knowledge about the subject Bayesian networks. She is trying to do exercises about that subject but unfortunately she is not doing well. In addition, she has a high network connection and according to Felder's model[29] is active. As others students are on-line, the system infers that the best action is to suggest her to talk with them through chat in order to solve the exercises and acquire knowledge in that subject. Thus, the adaptive system shows the "chat" link in a different and blinking color.

In another situation 2, the learner John is also learning the subject Bayesian networks but he has a low network connection and his Felder's learning style is reflective. In consequence, the system sends a message by email to his teacher advising to contact the student and disables links related to videos material.

Finally, suppose another situation 3 in which Mary (the same learner in situation 1) now is learning decision trees and she has obtained enough knowledge about that subject. She continues having the same network connection and Felder's learning style. Therefore, the system suggests her to read the next subject of the course by hiding links to known subjects and highlighting those pointing to new subjects.

These situations are depicted in figure 3 and descripted as follows according to the notation in section 5.

27 FREITAS; MARÇAL; GASPARINI; AMARAL; PROENÇA JR.; BRUNETTO; PIMENTA; PINTO; LIMA; OLIVEIRA, 2002, op. cit.

28 http://sourceforge.net/projects/adaptweb

29 FELDER, R.; BRENT, R. Understanding Student Differences. *Jounal of Engineering Education*, Washington, v. 94, n. 1, p. 57-72, 2005.

Context1 = {(Student.Mary, **isLearning**, Subject.bayesianNetworks),
(Student.Mary, **hasKnowledge**, Knowledge.bad),
(Student.Mary, **hasConnection**, NetworkConnection.high),
(Student.Mary, **hasStyle**, LearningStyle.active)}

Context2 = {(Student.John, **isLearning**, Subject.bayesianNetworks),
(Student.John, **hasKnowledge**, Knowledge.bad),
(Student.John, **hasConnection**, NetworkConnection.low),
(Student.John, **hasStyle**, LearningStyle.reflective)}

Context3 = {(Student.Mary, **isLearning**, Subject.decisionTrees),
(Student.Mary, **hasKnowledge**, Knowledge.good),
(Student.Mary, **hasConnection**, NetworkConnection.high),
(Student.Mary, **hasStyle**, LearningStyle.active)}

The adaptation mechanisms in AdaptWeb decide to assist students by the following actions:

Context1 —› "show highlighted links"
Context2 —› "hide or disable links" + "show highlighted links"
Context3 —› "hide already known content"

7 Conclusions

As e-learning systems become more sophisticated, it is interesting to investigate more sophisticated personalization mechanisms. One example is the need to deal with context modeling and its relation with user modeling. Context modeling extends traditional user modeling techniques, by explicitly dealing with aspects we suppose to have a significant influence on the learning process assisted by an e-learning environment, such as personal, pedagogical, technological and cultural aspects. We propose the use of ontologies to model this contextual information. Particularly we propose a three level model to capture different levels of detail.

As described in this article, AdaptWeb adapts the student's model depending on the pedagogical, technological and students' personal context information available. The main traits are the student's preferences, learning styles, background, knowledge, navigatio-

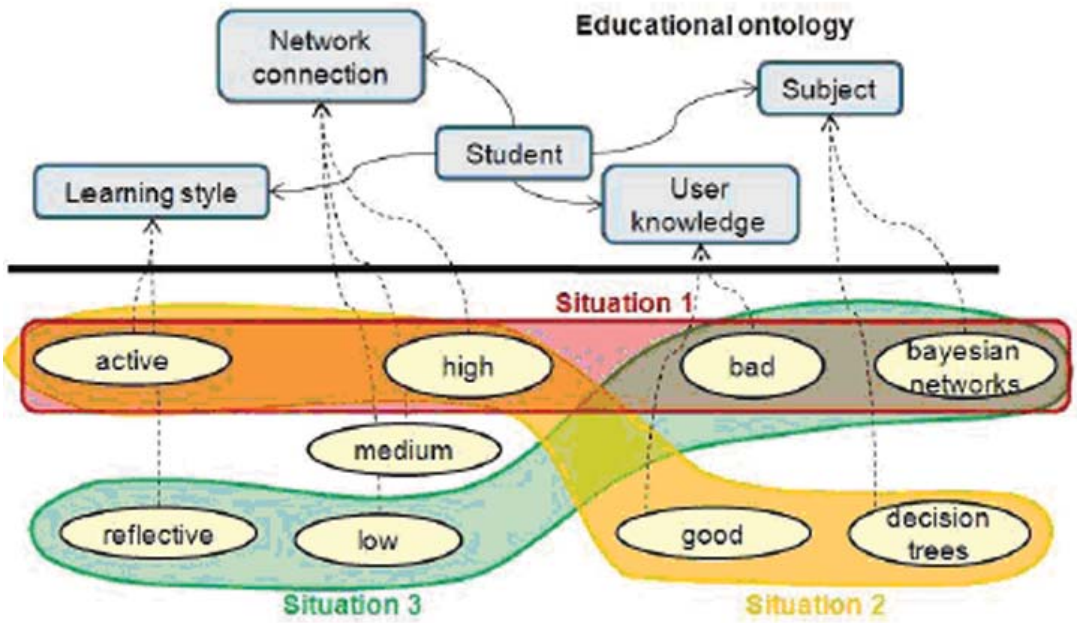

Figure 3 – Proposed user profiling technique

nal history, network characteristics, time of presentation, and quality of didactic material components presentation. Our work has been applied to academic examples but has yet to be tested in actual use.

As e-learning systems progress increasingly towards more personalized configurations, it is becoming ever more important to have approaches that can help to improve the dramatic benefits of context modeling to personalization and also to allow reuse of this contextual information. In this paper, we offer only one approach for that. Therefore, it is yet a limited excursion into a territory which includes many other possible perspectives and paths to explore.

References

ABARCA, M.; ALARCON, R.; BARRIA, R.; FULLER, D. Context-Based e-Learning Composition and Adaptation. In: ON THE MOVE to Meaningful Internet Systems 2006: *OTM 2006 Workshops*. Heidelberg: Springer Berlin, 2006. P. 1976-1985.

BOUZEGHOUB, A.; DO, K.; LECOCQ, C. A Situation-Based Delivery of Learning Resources in Pervasive Learning. In: EC-TEL 2007 – EUROPEAN CONFERENCE ON TECHNOLOGY ENHANCED LEARNING, 2., 2007, Crete. Creating New Learning Experiences on a Global Scale: *Proceedings*... Berlin, Heidelberg: Springer, 2007. P. 450-456.

BRUSILOVSKY, P.; MILLAN, E. User Models for Adaptive Hypermedia and AdaptiveEducational Systems. In: *THE ADAPTIVE Web*: Methods and Strategies of Web Personalization. Heidelberg: Springer Berlin, 2007. P. 3-53. (Information Systems and Applications, incl. Internet/Web, and HCI , v. 4321)

DEY, A.; ABOWD, G.; BROWN, P.; DAVIES, N.; SMITH, M.; STEGGLES, P. Towards a Better Understanding of Context and Context-Awareness. In: HUC '99 – INTERNATIONAL SYMPOSIUM ON HANDHELD AND UBIQUITOUS COMPUTING, 1., 1999, Karlsruhe. *Proceedings*... London, UK: Springer-Verlag, 1999. P. 304-307.

DOCKHORN COSTA, P.; ALMEIDA, J.; PIRES, L.; VAN SINDEREN, M. Situation Specification and Realization in Rule-Based Context-Aware Applications. In: IFIP – INTERNATIONAL CONFERENCE ON DISTRIBUTED APPLICATIONS AND INTEROPERABLE SYSTEMS – DAIS, 10., 2007, Paphos. *Proceedings*.... New Orleans: LNCS, 2007. P. 32-47.

DOCKHORN COSTA, P.; GUIZZARDI, G.; ALMEIDA, J.; PIRES, L.; VAN SINDEREN, M. Situations in Conceptual Modeling of Context. In: EDOCW '06 – IEEE ON INTERNATIONAL ENTERPRISE DISTRIBUTED OBJECT COMPUTING CONFERENCE WORKSHOPS, 10., 2006, Hong Kong. *Proceedings*... Los Alamitos, CA: IEEE Computer Society, 2006. P. 6

DOLOG, P.; NEJDL, W. Semantic Web Technologies for the Adaptive Web. In: *THE ADAPTIVE Web*: Methods and Strategies of Web Personalization. Heidelberg: Springer Berlin, 2007. P. 697-719. (Information Systems and Applications, incl. Internet/Web, and HCI , v. 4321)

EYHARABIDE, V.; AMANDI, A. An Ontology-Driven Conceptual Model of User Profiles. In: ASAI07 – SIMPOSIO ARGENTINO DE INTELIGENCIA ARTIFICIAL, n., 2007, Mar Del Plata. *Proceedings*... Mar Del Plata, Argentina: Sociedad Argentina de Informática e Investigación Operativa, 2007. P. 101-115.

EYHARABIDE, V.; AMANDI, A. Semantic spam filtering from personalized ontologies. *JWE - Journal of Web Engineering*, Princeton, NJ, v. 7, n. 2, p. 158-176, 2008.

FELDER, R.; BRENT, R. Understanding Student Differences. *Jounal of Engineering Education*, Washighton, v. 94, n. 1, p. 57-72, 2005.

FREITAS, V.; MARÇAL, V.P.; GASPARINI, I.; AMARAL, M.A.; PROENÇA JR., M.; BRUNETTO, M.A.C.; PIMENTA, M.S.; PINTO, C.H.F.; LIMA, J.V.; OLIVEIRA, J. P. AdaptWeb: an Adaptive Web-based Courseware. In: ICTE2002 – INTERNATIONAL CONFERENCE ON INFORMATION AND COMMUNICATION TECHNOLOGIES IN EDUCATION, 2002, Badajoz. *Proceedings*... Badajoz, Espanha: Anais,2002. P. 131-134.

GUIZZARDI, G.; WAGNER, G. Towards Ontological Foundations for Agent Modelling Concepts Using the Unified Fundational Ontology (UFO) In: INTERNATIONAL BI-CONFERENCE WORKSHOP ON AGENT-ORIENTED INFORMATION SYSTEMS, 2., 2005, Klagenfurt. *Proceedings*.... Berlin: LNCS, 2005. P. 110 - 124

GUZMAN, J.; MOTZ, R. Towards an Adaptive Cultural E-Learning System. In: LA-WEB '05 – Latin American Web Congress, 3., 2005, Buenos Aires. *Proceedings*... Washington, DC: IEEE Computer Society, 2005. P. 183.

JOVANOVIC, J.; GASSCEVIC, D.; KNIGHT, C.; RICHARDS, G. Ontologies for Effective Use of Context in e-Learning Settings. *Educational Technology and Society*, Canadá, v. 10, n. 3, p. 47-59, 2007.

KOFOD-PETERSEN, A.; MIKALSEN, M. Context: Representation and Reasoning Representing and Reasoning about Context in a Mobile Environment. *Revue d'Intelligence Artificielle*, Paris, v. 19, n. 3, p. 479-498, 2005.

SCHIAFFINO, S.; GARCIA, P.; AMANDI, A. eTeacher: Providing personalized assistance to e-learning students. *Computers and Education*, Maryland Heights, v. 51, n. 4, p. 1744-1754, 2008.

YANG, S.J.H.; HUANG, A.P.M.; CHEN, R.; TSENG, S.-S.; YEN-SHIH, S. Context Model and Context Acquisition for Ubiquitous Content Access. In: ULEARNING ENVIRONMENTS. IEEE INTERNATIONAL CONFERENCE ON SENSOR NETWORKS, UBIQUITOUS, AND TRUSTWORTHY COMPUTING, 2006. *Workshops*.Taiwan: IEEE, 2006. V. 2, p. 78-83.

Recebido em janeiro de 2009.
Aprovado para publicação em abril de 2009

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