Three-dimensional Virtual Environments Adaptive to the Student's Profile for Distance Learning

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Resumo. *Ambientes Virtuais têm utilizado técnicas de Realidade Virtual para gerarem ambientes dinâmicos e próximos das necessidades do aluno. Em um Ambiente Virtual de Ensino, essas técnicas são muito úteis, pois permitem apresentar conteúdos específicos para cada aluno, respeitando seu grau de dificuldade e sua capacidade de compreensão do mundo virtual. Este trabalho apresenta uma infra-estrutura para construção de Ambientes Virtuais que representa o ambiente de ensino em vários níveis de complexidade e se adapta, em tempo real, à evolução do aprendizado do aluno. Esta proposta contribui para o processo de ensino-aprendizagem, permitindo gerar ambientes mais próximos da realidade cognitiva do aluno.*

Abstract. *Virtual Environments use Virtual Reality techniques to generate dynamic environments and to meet students needs. In Virtual Environment Learning, those techniques are very useful because they allow presenting specific contents for each student, respecting of his/her difficulty degree and capacity of understanding the virtual world. This work presents an infrastructure for building Virtual Environments, that consists of a learning environment with several complexity levels that adapt, in real time, to the student's learning evolution. This proposal contributes to the teaching-learning process for allowing generating environments closer to students' cognitive reality.*

1. Introduction

A Virtual Learning Environment (VLE) utilizes devices where students and tutors have several ways of interaction, including on-line learning. The existing tools in these environments integrate Internet communication services such as email and Chat-Rooms, course management and file sending systems (upload/download).

A VLE contributes to the student's knowledge construction. It becomes an active agent of student learning. The use of learning environments can stimulate student learning through the construction of concepts and the student's interaction with the teacher, with colleagues, with resources and with knowledge.

A VLE also makes it possible for students to analyze, interpret and take decisions. Such students can build relationships for stimulating their learning in these environments. AulaNet (http://www.aulanet.com.br), WebCT (http://www.webct.com) and Lotus Learning Management System (http://www.lotus.com) are VLE examples.

The use of Virtual Reality (VR) brings a new interface paradigm to VLE. In this paradigm, the student is not more "in front of" the computer, but can immerse, navigate and interact in a 3D environment, using multi-sensorial channels. VR allows larger visualization and manipulation of objects in a three-dimensional environment, increasing the capacity of the student's perception, which becomes stimulated by the possibility of interaction with the interface.

According to Scheer (2002), VLE that use VR techniques can especially be used for educational purposes when some characteristics are observed, as for instance: there are models as good as the real world; the interaction with the model is motivating (playing, for instance); the experience of creating an environment is important for the learning objective, and simulation can be used.

The evolution of VR technologies, Artificial Intelligence (AI) and Web communication, are turning possible the construction of VE more aware of the student, incorporating procedures of accompaniment of his/her actions and of the modifications in the environment.

Researches have led to techniques that allow the generation of VE that adapt to student's profile. These environments are capable to model the world in accordance to each student’s characteristics.

The personalization of VE proposed in this work, can be used in distance learning applications, in instances where students with several knowledge levels are connected remotely, and for those simulation environments that produce different complexity levels for a same situation as a function of the student's model.

The building of adaptable VE to the student's profile is still an open issue, with only few works published on the subject. One of the existing problems is the evolution of VE in real time, allowing the alteration of the world as the student interacts. Another open issue is the presentation of a VE with several complexity levels, in which these levels can be stored and recovered according to the student profile changes.

To solve these problems, this paper presents an infrastructure to the VE components management, whose adaptability is accomplished in real time, in terms of student's profile and of his/her cognitive learning capacity. The virtual worlds should be built with reusable 3D objects, stored in a Database Management System (DBMS) with XML support [Bourret, 2005] where each one of these objects can contain several information levels. This infrastructure aims at alleviating some of the aforementioned problems.

2. Three-dimensional Virtual Environment Learning

A system that uses VE in learning environments is Steve [Johnson, 1998]: a lively agent that teaches the operation of motors and equipments; see Figure 1. Agent Steve, besides demonstrating the tasks to be accomplished and to explain its actions, monitors the performance of the students' tasks, helping them when necessary.

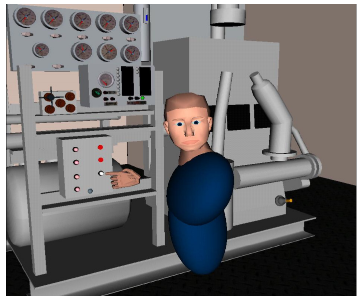


Figure 1. Agent Steve describing the operation of a panel

Another experience is the course of ambient management through the Internet, developed by the Laboratory for Distance Learning - Federal University of Santa Catarina State, Brasil (http://www.led.ufsc.br). In this course, the student participates in an audit simulation, making decisions that will influence the audit (see Figure 2). He/she explores the environment in search of evidences, analyzes the documentation of the Environmental Administration System (EAS), and also is stimulated to identify and to classify the non-conformities of the system. Finally, students can learn over the processes and methods of the activity where the audit is being made.

Figure 2. Simulation of performing an audit at a company visit

Augmented Reality (AR) is the set of techniques that mixes real images with virtual objects. Its purpose is to integrate VR with the reality enriching the user vision. AR provides a different way of learning with computer support. It allows the visualization and manipulation of the objects to be studied, reproducing the complex data under the form of objects and three-dimensional texts. This enhances the student's perception capacity, which becomes stimulated by the interaction. Akagui and Kirner (2004), for instance, show how to visualize tri-dimensionally the geometric objects with the help of a video device (webcam), as shown in Figure 3.

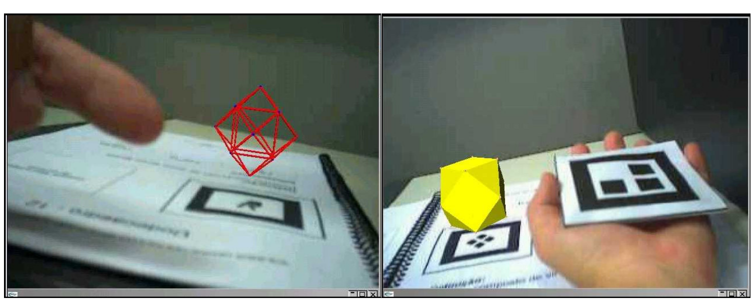


Figure 3. Geometric objects with Increased Reality

3. Personalized Virtual Environments

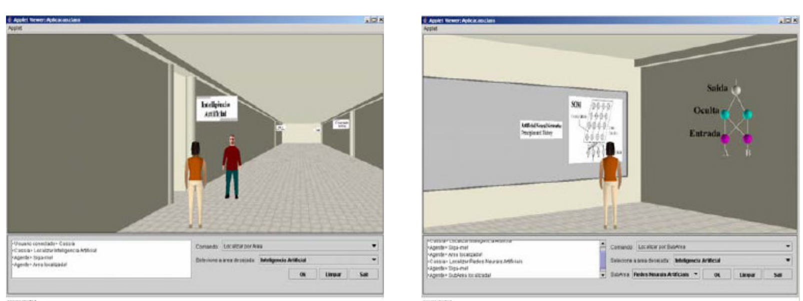
Learning environments that employ VR have not yet incorporated adaptivity techniques to respond to the students' profile. Little has been published in relation of personalization of content problem, navigation and 3D environment presentation, being most of the published work devoted to e-commerce and content presentation. The personalization of those environments seeks for adapting the content according to the students' preferences, navigational style and cognitive capacity.

Frery et al. (2002) describe a methodology for assistance in navigation and exploration with the objective to enhance user satisfaction when exploring three-dimensional virtual environments. This methodology uses "intelligent" avatars as interactive guides, along with information based in navigation strategies. A virtual guide of the Guggenheim Museum Bilbao, in Spain, was developed in this work. It is able to generate navigation routes and accompany the user during the exhibition. The structure of the content and the representation of the avatar are determinate in function of the knowledge that the system has over the user. This knowledge is obtained through forms presented at the beginning of the session.

Chittaro and Ranon (2000), for instance, present a 3D adaptive virtual environment, that represents a virtual store where users can navigate and obtain information on the objects that move in the environment. The information about the user's interests, used for the personalization of the environment, is collected through forms and by monitoring users' actions in the environment (such as visualizing products and purchase made).

In a more recent work, Chittaro et al. (2003), introduce a virtual agent designated to aid the user in the navigation through a virtual museum. The agent creates an appropriate path from the description of places or objects of interest to be visited. Furthermore, the agent is capable to stop during the itinerary and to present each object or place.

Santos and Osorio (2004) proposes the AdapTIVE (Adaptive Three-dimensional Intelligent and Virtual Environment) that has its structure and contents presentation adapted in agreement with the users' interests and preferences. A process of automatic categorization of contents is applied in the creation of content-models, used in the environment space organization. Besides, an intelligent virtual agent acts as the user assistant for navigating on the environment and for locating important information (Figure 4).



(a) (b)

Figure 4. (a) User's request of a content and its localization by the agent; and (b) visualization of the Artificial Intelligence content

4. Presentation in complexity levels of 3D objects for adaptive VE

Virtual Environments (VE) can be generated through the representation of objects in progressive levels of complexity. It can be implemented with Virtual Reality applications using Levels of Detail (LOD). There are many techniques for selecting each version of LOD [Constantinescu, 2000]. Frery et al. (2004) propose the automatic generation of worlds with varying degrees of complexity using cartographic generalization techniques.

However, the LOD techniques do not consider the knowledge level of the user to carry through the adaptation. The identification of the user's cognition capacity and his or her knowledge over the VE are important for the system to decide which level of detail can be realized.

In this sense, the adaptive VE proposed in this work is capable of presenting the information relative to certain content with increased (or decreased) detail level according with the student's profile. The personalization proposed in this work is based on the principle that user should visualize the same virtual world, but different detail levels. The objective is not to overload the beginner with information for which the student is not prepared for. The experienced student, who is familiarized with the application, is able to observe with more attention the details that before he/she wouldn't perceive.

Thus, the environment can be presented with the required level of detail relative to the student's knowledge needs. For instance, in a Virtual Learning Environment, each student has his/her own profile, including knowledge level and cognitive capacity. In case the student has little knowledge on a certain subject, the world to be presented cannot have a lot of information, presenting only the essential elements at their lowest possible level of detail. On the other hand, for more experienced students, or those who learned through interaction, more complex information can presented by means of a more complete and, therefore, more interesting environment.

In order to satisfy this requirement, we propose mechanisms for the representation of VE at several levels of complexity, as well as a system for level identification.

Since the implementation of this proposal requires dynamic interaction, the X3D language (http://www.web3d.org/x3d) appeared as a feasible technology. X3D is a subset of XML and stores the objects of the world in a hierarchical way, describing three-dimensional scenes such as nodes inside nodes. JDOM (http://www.jdom.org), a Java library for access to XML documents, is used to navigate through this structure.

Using techniques of artificial intelligence such as those described by Rosatelli and Tedesco (2003) for users' modeling, the system proposed in this work generates the User Model (UM) and classifies it according to the user profile. This classification defines the *user level* for each user. The *user level* determines the knowledge level that the user has about the environment and, therefore, the level of complexity to be presented. As the user interacts with the environment, the *user level* can be modified in case it identifies an increase of the users' knowledge level. According to the *user level*, the system determines new objects which should be inserted and/or updated in the environment. This way, the system adapts while the user is interacting with the environment.

A solution found during the project was to include complexity levels in each object. The presentation of a certain object, or part of it, occurs only if its *user level* matches the user's level. In other words, the *user level* identifies which users can have access to a certain node and its children. These characteristics are included in the X3D code, without altering the syntax used in the presentation of the objects of the world.

Figure 5 shows an example of a same virtual world presenting different contents according to the student. The environment is composed of a room with walls, a bookshelf and, amongst other objects, a TV. Two students, classified respectively with *user levels* A and B, enter the room. Figures 5 (a) and (b) show their views of the same world.

Figure 6 shows the code representing the objects of the world of Figure 5. The attribute `userLevel="B"` in the object "TV" indicates that *B* can interact with the object TV (seeing, opening, moving around etc.), while *A* will not be aware of its existence.

During the conversion process, the student's level is taken into consideration, so only what should be exhibited to the student is converted. When the converter cannot find the object within the level corresponding to the current student, such object is simply ignored, as if it would not being part of the world.

(a) Room seen by the level A student (b) Room seen by the level B student

Figure 5. Presentation examples of virtual worlds viewed from different student levels

```
<Group linkID="Room">
   <Group DEF="Walls"../>
   <Group DEF="Bookshelf"../>
   <Group DEF="TV"
       userLevel="B" ../>
</Group>
```

Figure 6. Objects presentation in X3D of the VE from Figure 5

The knowledge domain is irrelevant as far as complexity of conversion is concerned. For instance, the aforementioned property can be observed in Figure 7 that contains X3D objects of an environment representing Brazil's cartographic relief. This environment was built at three complexity levels. The N1 level, addressed in this content to beginner students, presents only the main cartographic information. The second level (N2 level), that can be used for students that have a little more knowledge on the subject, adds to the previous level hydrographic and vegetation information. In a third level (N3 level), the student who already acquired previous knowledge can visualize and navigate through an environment with details that include, for instance, the socioeconomic distribution of the area.

```
<Group linkID="BrazilMap"
     Group Def="CartographicRelief"
         user level=("N1","N2","N3").../>
     Group Def="HydrographicalAndVegetation"
         user level=("N2","N3").../>
     Group Def="SocioeconomicDistribution"
         user level=("N3").../>
</Group>
```

Figura 7. X3D objects of an environment representing Brazil's cartographic relief

5. The VEPersonal Architecture

The VEPersonal (Personalized Virtual Environment) proposed in this article is capable of creating and maintaining a three-dimensional virtual environment, accessible through the Web for navigation and interaction with dynamic objects. In this environment support is given to the student to explore the virtual world, visualizing, approximating or playing with the objects. As an answer, the environment accomplishes the modification of the world in function of the student's cognitive evolution.

This adaptation occurs in response to the student preferences and interests, defined at the beginning of a session, as well as accordingly to the acquired knowledge during the interaction with the system. VEPersonal is capable of monitoring the student actions and, as a function of the current state of the environment, of looking for new objects to be added to the virtual world in a DBMS.

Figure 8 presents the architecture of VEPersonal. In this architecture, the student's characteristics and his or her behavior are stored in the User Model (UM), whereas modifications in the environment are stored in the Environment Model (EM). This information is obtained through the student's interface with sensors that detect the actions accomplished by the student. The UM and the EM are important for the accompaniment of the evolution of the world.

Four agents are responsible for the analysis of the information stored in UM and EM, and for updating the virtual world objects: the *Personal Agent*, which accompanies the student's actions and updates the UM whenever some profile-alteration is being detected, the *Environment Agent*, which verifies the current state of the virtual environment and the modifications stored in the EM, the *Communication Agent*, which helps the student providing information about the environment, and, finally, the *Updating Agent*, which manages the process of updating the world using the information supplied by the other agents.

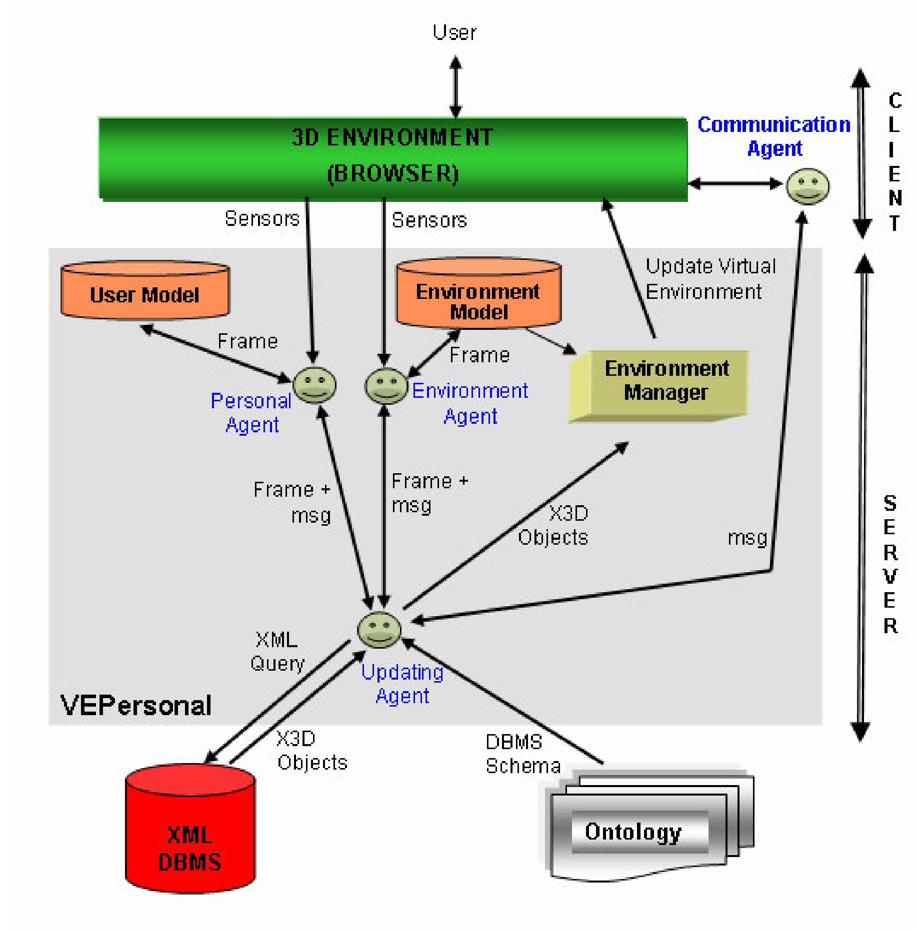


Figure 8 – VEPersonal Architecture

During the decision process, the *Updating Agent* consults the *Domain Ontology* that has the representation of the VE model. In agreement with that representation, it generates queries to DBMS to retrieve those objects that should be used for updating the world.

A DBMS with XML support stores all the defined objects for the ontology. Their retrieval is accomplished through XML queries, having in view those objects to be specified in X3D.

The *Environment Manager* receives 3D objects from the *Updating Agent*, generates the 3D structure of the virtual environment and sends it to the student's interface.

The architecture here developed can be used regardless of the language in which virtual worlds are represented.

6. Conclusions

This work proposes an architecture capable of generating three-dimensional VE for the Web, presenting an environment adapted to the level of the student's knowledge. Two contributions can be identified for the process teaching-learning. The first contribution is the student's participation in a dynamic environment, adapted to his/her knowledge level and preferences.

The second contribution is the identification of the evolution of the student's learning and the updating, in real time, of the content in the studied environment. This updating can represent the inclusion of new contents to the world or add more detail to the existing contents. There will be more student motivation in the learning process because the environment will always present contents with different complexity levels.

The adaptation process in the virtual world is accomplished by starting from the generation of objects with several representation levels. X3D made this representation possible, since it is based on XML and allows including new attributes to its code without altering the existent syntax. The system does this by determining which objects (or parts of them) should be shown to the student. A same object can have different behavior and representations (colors, forms and details, for example) in relation to the student's profile.

The result of this work is also promising for applications where several students, with different know-how levels, interact with the environment. In this case, the modeling of the world can be the same for all the students, just including the complexity levels for each object in function of the students' profiles.

This proposal represents a solution to problem adaptability in real time. As the student's cognitive capacity increases, a new *user level* is attributed. Consequently, the environment is reorganized, presenting the objects corresponding to the new *user level*.

In this paper it is also proposed to generate UM by monitoring the students' actions. For example: if the student interacts with some object – he/she clicks on it and obtains new information – it means that he/she has acquired knowledge on the object and can access other related objects, which were not present in the environment before. This inference allows deducing information about the students, starting from his/her navigation in the environment and of the objects he or she interacts with. It becomes a powerful tool for the UM updating, supplying a precise information of students' knowledge and preferences of the environment.

Future work will focus on the development of system adaptivity towards knowledge domain independence. Domain-specific systems are under assessment.

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