ADAPTIVITY IN 3D VIRTUAL ENVIRONMENTS FOR MULTI-USERS AND ITS APPLICATION IN ADULT BASIC EDUCATION

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Abstract: e-Learning applications have started to exploit web-based three dimensional (3D) Virtual Environments (VEs) to augment learning experiences. Moreover adaptive support in these 3D VEs further endow potential to empower the learner's experiences and enhance effectiveness of learning process by presenting personalized content and navigational support. Adaptivity in these 3D VEs however, sets the new challenges for the researchers. Most of the techniques that are devised for adaptive content presentation and navigation in 3D spaces are focused on single-user environment. Surprisingly few research efforts have been yet dispensed for the adaptivity in multi-users VEs, however based on textual VEs. In this paper, we present an adaptive approach for multi-users in 3D VEs. We customize the Adaptive Web 3D (AWE3D) architecture to provide the adaptive support in 3D VEs for multi-users. We design an adaptive learning scenario for Adult Basic Education (ABE) in 3D VE of OpenSim to explain, the proposed methodology.

1 INTRODUCTION

In the present era, e-learning applications have started to exploit 3D VEs to further augment learning experiences by providing sense of self-presence, social-presence, immersive environment, situated-learning and learning by doing. Educational institutions use these modern technologies and present learning scenarios for distance and blended learning (Molka-Daneilsen, 2009). Adaptive support in these 3D web-based VEs further empower the learner's experiences, enhance effectiveness of learning process and interface usability (Chittaro and Ranon, 2007a). Adaptivity in 3D VEs however, sets the new challenges for the researchers. Most of the techniques that are devised for adaptive content presentation and navigation in 2D Web sites are not applicable to build 3D adaptive Web sites because of different technical requirements of these 3D VEs (Chittaro and Ranon, 2007b).

Some research studies have presented the approaches for personalized content presentation, navigational support and interaction (Chittaro and Ranon, 2002a; Nussbaumer et al., 2009; Santos and Osorio, 2004) in 3D VEs. All of these efforts however focused on single-user VEs. It is surprising that few research efforts have been yet dispensed for the issue of adaptivity in VEs for multi-users (Dieberger, 1996). These efforts are focused on textual virtual environments where text is used to describe an imagined landscape.

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In this paper, we present an adaptive approach for multi-users in 3D VEs. Secondly we customize and exploit the Adaptive Web3D (AWE3D) architecture (Chittaro and Ranon, 2007b) to provide the adaptivity for multi-users in 3D VE. Finally we present an adaptive scenario for Adult Basic Education (ABE) designed in the OpenSim (OpenSim, 2010) environment to explain how the customized version of AWE3D architecture is exploited in education domain.

2 RELATED WORK

Surprisingly, few efforts have been made for adaptivity in 3D VEs. The focal point of these studies has been adaptive content presentation and navigational support in 3D VEs. Santos and Osorio presented an adaptive VE for distance learning that performs content insertion and removal in 3D space and navigational support using intelligent agent (Santos and Osorio, 2004). Apart from educational domain, lot of work is witnessed on business side. Virtual reality interfaces to e-commerce sites are getting more common (Chittaro and Ranon, 2002b). These e-commerce 3D environments are further investigated for adaptive support to facilitate the shopping experience by providing most relevant product in stores and navigational support on the basis of preferences and interests of buyers (Chittaro and Ranon, 2007b). In 2002, Chittaro and Ranon proposed a generic architecture for adaptive 3D Web sites named *Adaptive Web 3D* (AWE3D) that is responsible for generating and delivering adaptive VRML content (Chittaro and Ranon, 2002a). This client-server AWE3D architecture is exploited for e-commerce case studies and favorable user's responses to the system were observed (Chittaro and Ranon, 2002a). Furthermore, adaptivity using competence-based Knowledge Space Theory is presented by Nussbaumer in 3D space of Second Life (SL) (Nussbaumer et al., 2009). All these research studies on adaptivity in 3D VEs are focused towards single-user environment.

For adaptivity in multi-user environments, an approach is presented in (Dieberger, 1996). However this approach is developed for textual VEs (environments base on imagined landscape where locations, objects, users and their interactions are described solely through text instead of metaphors). This approach exploits the concept of 'read wears' to provide adaptive support in multi-user textual VE, where description of objects is changed in imagined landscape according to frequency of their usage (e.g., usage frequency of room exits and posting on bulletin boards).

3 CHALLENGES OF ADAPTIVITY IN 3D SPACES

3D environments are more complex than 2D web sites due to differences in presentation space, content presentation, organization, navigational support and users' actions (Chittaro and Ranon, 2007b). For these reasons, techniques and tools used for adaptivity in 2D environments cannot be directly applied for content presentation and navigation in 3D spaces (Chittaro and Ranon, 2007b).

In 2D spaces, optional-fragments and altering-fragment techniques are common for content presentation (Chittaro and Ranon, 2007b), whereas hyperlinks are used to navigate across web pages (Hughes, Brusilovsky and Lewis, 2002). For content presentation in 3D space, same techniques are used where metaphors instead of text (as in 2D) are selected and 3D spaces are created; however special care is required to avoid overlapping of metaphors (Chittaro and Ranon, 2007b). Whereas for navigational support in 3D space, intelligent agents (Chittaro, Ieronutti and Ranon, 2004; Chittaro and Ranon, 2000) and patterns of interaction from usage data (Celentano and Pittarelo, 2004) are known approaches instead of simple hyperlinks (as in 2D space).

All adaptive efforts in 3D VEs focused on single-user; unfortunately no application is reported in literature that considers adaptivity in 3D spaces for multi-users (Chittaro and Ranon, 2007b). In single-user 3D environments, it is relatively trivial to provide personalized content and navigational path according to the user's needs because there is no concept of space sharing. On the contrary, adaptivity in 3D space for multi-users is a complex job. In multi-users 3D VEs, as the same 3D space is shared by more than one user simultaneously, adaptive content presentation for all users in the same 3D space raises conflicts (like overlapping of contents) in content presentation that leads towards new challenges. Similarly navigational support cannot be customized for an individual user because other users are sharing the same 3D space and demarcation in navigational cues for each individual user is a difficult job (Chittaro and Ranon, 2007b).

4 METHODOLOGY FOR ADAPTIVITY IN 3D MUVE

In 3D Multi-Users Virtual Environment (MUVE) as more than one user share the same 3D space and it causes conflicts in adaptive content presentation, and navigation as discussed in Section 3. We propose an approach that reduces the conflicts by optimizing the best common adaptation strategy, where a group of users (or learners) able to share a portion of 3D space, customized according to their preferences. In order to optimize best common adaption strategy, we divided the 3D space in multiple zones (called learning- zones for application of ABE) based on language, domain, level (Beginner or moderate), and difficulty level in each beginner or moderate levels. The Figure 1 describes division strategy of 3D space, where 3D space is divided into sixteen different zones. Two centric circles set the difficulty level in 3D space, the outer one is level one (lower difficulty level) and inner one is level two (higher difficulty level). In the circular shaped 3D learning space, the left half of circle is for English language and the right half of the circle is for Urdu language. Similarly the upper half of the circle represents a domain D1 and the lower half of the circular space forms domain D2. Two lines at diagonal positions from the upper left quadrate to the lower right quadrate and from the upper right quadrate to the lower left quadrate divides 3D learning space for alphabet learning (for beginners) and vocabulary (for moderates) learning with respect to language domain and difficulty level. Each unit of this 3D learning space is called Learning-Zone as shown in the Figure 1. Each learning-Zone consists of stage setting proposed in the Section 6.

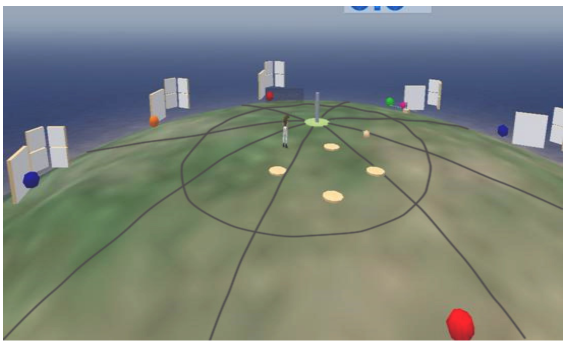

Figure 1: Division Plan of 3D Space.

For adaptivity in 3D space for multi-users, we propose an algorithm. This algorithm exploits the proposed enhanced AWE3D architecture. When a learner logins in the 3D space for learning, the system reads his/her profile. On client-side Linden Scripting Language (LSL) script initiate a request for contents (for each learner when he/she logins) and forward it to the server-side, where the *Personalization* module reads the learner profile and accordingly formulate a query and determines through the *content ontology*, what the learner needs to learn and forward these results (list of LOs) back to client-side. The *OpenSim content Presenter* on client-side finds whether these LOs already available in some Learning-Zone, if yes, the adaptive system teleport the learner to the target Learning-Zone, in case of no, it creates new Learning-Zone with desired LOs and teleport the learner to the newly created Learning-Zone, where personalized contents are presented to the learners and learners' profiles are updated accordingly. However if a learner during a session learns all LOs and more Learning-Zone are still unlearned, in this case adaptive request within a session initiated through LSL, forwarded to server-side application and in response receives description of imminent LOs, if these LOs already available in some Learning-Zone then the leaner is teleported to that zone otherwise new Learning-Zone is created with selected LOs and learner is teleported there. The adaptive system also allows learners to leave the session anytime, in this case their profiles are updated by the system and they can logout the system.

The proposed approach is able to assign names at run time to the different partitioned spaces (Learning-Zones) and to select relevant Learning-Zone according to user profile; however static division may reduce the performance lags.

The selected 3D VE of OpenSim is capable to fulfill all the technical requirements to develop the proposed adaptive system. A region in the OpenSim version 0.6.3.873 allows 45000 prims (OpenSim, 2010). A prim is short version of primitive, means 3D shape. The proposed method exploits less than hundred prims in all 16 regions that is much lesser than allowed limit. This consideration of limited prims avoids performance lags in selected 3D spae of OpenSim. The reason for the selection of OpenSim is its support for 1) content scripting, 2) editable avatars, 3) available for educational purposes or easily modifiable, 4) capable to run as standalone application or as collaborative world, 5) in-world 3D content creation etc (de Freitas, 2008), and also the proposed methodology is equally applicable to other 3D spaces offer the same support.

5 ENHANCED ADAPTIVE WEB 3D (AWE3D) ARCHITECTURE

The architecture we proposed for adaptivity in 3D VEs for multi-users is based on the Adaptive Web 3D (AWE3D) (Chittaro and Ranon, 2002a). We customize and use this AWE3D architecture to provide adaptive support in 3D VEs for multi-users (see Figure 2). The customized AWE3D consist of following eight modules;

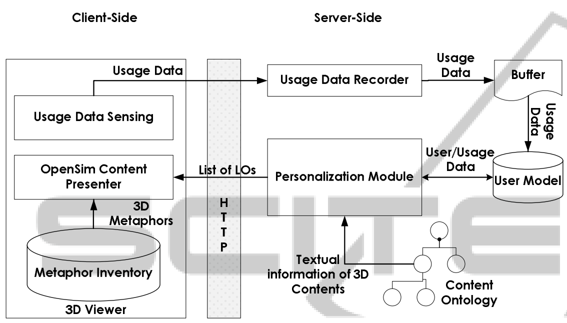

Figure 2: Customized AWE3D for multi-users adaptive Support in 3D VE.

Usage Data Sensing Module - This is a client-based module and it is responsible to collect data about the users' interaction in the OpenSim and sends the collected data through HTTP protocol to the server-side. This module uses built-in functions of Linden Scripting Language (LSL) for sensing the user's interaction in the OpenSim. This users' interaction data includes information about user's region in which his/her avatar is teleported, current position of user's avatar, walking-status of user's avatar, flying-status of user's avatar, sitting-status of user's avatar, away-status, touches to metaphors in 3D space and distance from learning object (LO). The adaptive system collects this usage data using sensors designed in LSL. Script for sending this data is also written in LSL.

Usage Data Recorder Module - This module is responsible for receiving data sent by the Usage Data Sensing module from OpenSim and stores it into the Buffer. It is located on the server-side. For its implementation, we use PHP scripts to deal with the usage data sent by client-side. This module receive HTTP request with POST method from the client-side sending script and it first stores the data into a buffer and finally transfers and saves it into the User Model database.

Buffer - The Buffer is a part of server-side application and its purpose is to reduce the number of accesses to relational database. It temporarily stores all the data into a text file, sent by the Usage Data Recorder module and when stored data exceeds the set limit of the buffer, it transfers into the User Model.

Personalization Module - The Personalization Module is a core component, located on server-side. It interacts with three components of the architecture 1) User Model, 2) Content Ontology and 3) OpenSim Content Presenter. It provides session-based adaptive support. For personalizing the contents for the users in 3D space, it first takes the user's data and usage data from the User Model, formulate a SPARQL query from this information and forward it to the Content Ontology. The Personalization module receives results against the query. These results (include text-based description of LOs) are sent back to the OpenSim Content Presenter Module, against the HTTP request made by client-side application. The Personalization module is written in PHP that integrate ontology model, mySQL database and SPARQL query execution.

For adaptive navigation support, the *Personalization* module finds the location where relevant contents for the user are available in the 3D space and teleport the user to that particular location in 3D space. This personalized navigational support also addresses the issue of usability (inadequate user assistance in 3D space) at the cost of user's control in 3D space.

User Model - The User model keeps track of users' data and usage data sent to it. We use, MySQL to develop the User Model database. Information storage and retrieval in the user model database is made possible by scripts written in PHP.

OpenSim Content Presenter - This is a client-based module receives the responses against HTTP request from the *Personalization* module and present the personalized content to the users in the OpenSim. The *OpenSim Content Presenter* is developed using LSL.

Metaphor Inventory - The *Metaphor Inventory* is located on client-side. It is responsible to store 3D contents in the OpenSim environment. All the metaphors required for the complete 3D space are uploaded beforehand and stored in this inventory.

Content Ontology - Domain ontology for content serves as contents' repository on server-side. This ontological model defines contents of a course. It consists of two main classes, Learner and Content. Learner class provides information about the learner's domain (to whom he/she belongs) through specialized subclass named Domain. Instance of the subclass Domain of class Learner specifies learner's domain e.g., farming, office-worker, kitchenware etc. The Content class defines contents and it consist of four subclasses; Alphabet, Common-Vocabulary, Numeracy and Domain-Specific-Vocabulary. The *Personalization* module exploits this ontology for contents selection according to the learners' profiles through SPARQL query and specified rules provide results to the *Personalization* module.

6 AN APPLICATION IN ABE

In this section, we describe the reasons for the selection of learning scenario for Adult Basic Education (ABE) and use of 3D spaces. Then brief introduction of learning scenario is presented and finally personalization support for contents and navigation is explained through this scenario.

6.1 Why ABE and Why 3D MUVE?

Due to bad experiences from schooling in past, adults do not prefer to go to literacy programs (Eberle and Robinson, 1980). Thus educationist and technologist are striving to offer technology-based literacy program to augment learning and to attract these illiterates to the literacy (Hopey, 1998). Unfortunately, main theme of most of techno-literacy solutions is text-based, that is not suitable for absolute illiterates. According to Visual Literacy, these text-based learning and communication applications are not acceptable in the present era of visual literacy and there is need to provide image dominant learning environments (Aanstoos, 2003). For effective learning, Gardner's theory of Multiple Intelligences recommends to exploits multiple intelligences in learning environments (Gardner, 1983). Furthermore, features such as sense of self-presence, social presence, embodied environment, learning by doing, situated learning, and collaborative learning, recommended in learning theories (Dale, 1969; Koh et al. 2007; Kolb, 1984; Lave and Wenger, 1990) and considered important for learning are achievable by exploiting 3D MUVEs.

6.2 Scenario for ABE in 3D Space

We design learning scenarios in the OpenSim for ABE. In this 3D learning space each learner is represented by an avatar (an embodied object of a learner) that can walk, fly, sit, speak and chat under the control of learner. The learning scenarios are intended to educate the illiterate learners (target users of the proposed environment) and these scenarios are categorized into 1) linguistic scenario, 2) numeracy scenario and 3) game-based scenario. This paper focuses on the linguistic learning and game-based evaluation scenarios in order to validate the multi-users adaptive support in 3D space using the customized AWE3D architecture. The proposed scenario serves for learning and evaluation simultaneously, where a learner may learn alphabetic characters and commonly used domain specific words in 3D space with adaptive support of content presentation and navigation. These scenarios offer learning material in two languages English and Urdu (national language of Pakistan), where alphabetic characters and words are offered for learning in each language with different difficulty levels (level I is easier one and level II is difficult one). Furthermore selection of these learning contents (alphabetic character/Word and their metaphors) depends on the learner's working domain (scenarios presents different content for different domains, for instance, house worker, farmer etc). In 3D space, a stage setting with five 3D objects presents the learning contents to the learners as shown in the Figure 1. The larger object on the left displays alphabetic character/word (written text) where as four smaller objects on the right present metaphors (against the alphabetic character/word on left object). Out of these four metaphoric answers, only one is a correct answer. Learner is required to select one metaphoric answer through mouse click. The adaptive system evaluates whether the learner's response is correct or incorrect and update learner's profile accordingly.

6.3 Personalized Content Presentation and Navigation Support in 3D Learning Space

User data (both usage and user data of learner) serves as basis for adaptivity in 3D space. For adaptive content presentation, we consider four parameters; these are language, domain, learner's level (moderate or beginners), and LO last-learned. These parameters are used to formulate the query to find out the forthcoming contents for learning. The *Personalization* module formulates this query to personalize content that is executed on ontology. The results obtained from this query consist of a list of forthcoming personalized contents for a group of learners. These results consist of textual information that is forwarded to the *OpenSim Content Presenter* Module to present 3D content in the space.

Adaptive navigation support is achieved through the teleporting facility offered by the proposed system, where learner's avatar is teleported at desired location in the 3D space after the recommendation of user model.

7 CONCLUSIONS

In this paper, we presented an approach that describes how adaptivity in 3D VE for multi-users is realized. A customization in the AWE3D architecture is proposed to achieve adaptivity in multi-users VEs. We presented application of proposed approach in 3D learning scenarios for ABE designed in 3D VE of OpenSim. Using presented learning scenarios, we described the implementation strategy of multi-user adaptivity in 3D spaces.

Future work will focus on investigation of learners' behavioral data in collaborative learning scenarios.

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