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A platform for virtual collaboration spaces and educational communities: the case of EVE

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Abstract This paper presents the design, implementation and evaluation of EVE Community Prototype, which is an educational virtual community aiming to meet the requirements of a Virtual Collaboration Space and to support e-learning services. Furthermore, this paper describes the design and implementation of an integrated platform for Networked Virtual Environments, called EVE Platform, which supports the afore-mentioned educational community. This platform supports stable event sharing and creation of multi-user three dimensional (3D) places, H.323-based voice over IP services integrated in 3D spaces as well as multiple concurrent virtual worlds.

Keywords Networked virtual environments · Multimedia systems · Multimedia interfaces for teaching and learning · Virtual classrooms

1 Introduction

The maturation of the Internet and electronic communication formed the basis for the constitution of on-line communities. In particular, the software applications, which could allow the on line communication among scattered users, have been expanded from e-mail and instant messaging to three dimensional (3D) multi-user spaces, where users have the ability to interact with each other, as it happens in real communities. These virtual communities, whether two or three dimensional, offer a wide variety of functionalities and are supported by technological tools that are proven to be efficient for educational and instructional goals [1]. In this paper such a technological tool, called EVE, is presented. This tool is a platform for supporting Networked Virtual Environments (NVEs). Using NVEs or Collaborative Virtual Environments (CVEs) as communication media, we can offer to the members of these virtual communities the advantage of creating proximity and social presence, thereby making participants aware of the communication and interaction processes with others [2]. The current version of EVE, in comparison with the previous version [3], integrates many improvements mainly on the sharing of events and the audio communication among the users, as described later in this paper. The emphasis on the current version of EVE platform has been given on the flexibility and extensibility of the architecture, its stability as well as the support of an easier way for transforming standalone 3D worlds to multi-user places. NVEs could support not only Virtual Collaboration Spaces (VCS) but also Educational Virtual Environments, which involve the educational aspect of Virtual Collaboration Spaces.

The term "Virtual Collaboration Space" refers to systems, which develop environments that integrate collaborative tools and functionalities in order to provide to the users a sense of realism [4]. These spaces gain increasing interest, and efforts are being made for applying them to more activities. VCSs can be used in order to support e-learning services [5]. The research on the educational aspect of the VCS has been gaining increasing interest both from a technological as well as from a pedagogical perspective. The technological challenge arises from the need to develop a learning environment, which, not only will not fall short compared with the real educational environment but in addition, should also be in position to offer extended functionalities to the users. On the pedagogical part, this concept raises questions on the educational models that can be used and how they can contribute in the most efficient way to the distribution of knowledge in an Educational Virtual Environment. However, the VCSs cannot be used as they are for educational purposes [6]. For this reason we introduce the term "Educational Virtual Environments" in order to define such places. As the term implies, it concerns environments and systems, which are developed in order to simulate and support e-learning services through virtual spaces. The key word in these two definitions is the "collaboration" which is

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essential for learning applications and activities, where students and tutors interact and collaborate in order to achieve a higher level of knowledge.

An Educational Virtual Environment goes beyond a VCS. Therefore an Educational Virtual Environment should agree with the concept and the label of a VCS, satisfying its basic requirements, which are mentioned in [4], and furthermore, it should extend these requirements for supporting the learning process. The main prerequisites and characteristics of Educational Virtual Environments are (a) the information space is well structured; (b) an educational VCS is a social space; (c) the information/social space is explicitly represented; (d) students are not only active, but also actors; (e) the virtual learning environments integrate heterogeneous technologies and multiple pedagogical approaches. The efforts made, so far, have not managed to provide an effective integrated system, which could fully satisfy the requirements of both perspectives as described later in this paper.

This paper is structured as follows. We initially present the related work done concerning Educational Virtual Environments and NVEs. Next, the architecture of EVE platform is presented. This platform is used for supporting the multi-user interaction among the users in the Training Area of EVE Community Prototype. Afterwards, EVE's community model, structural components along with the hierarchy of roles and rights are described. We then continue with a detailed presentation of the functionality, that our community provides. Next, we present the results of the user evaluation on EVE Community Prototype. Finally, some concluding remarks and our vision for the next steps are presented.

2 Related work

This section is dedicated to the investigation of the related work done until now concerning: (a) Basic technologies for supporting VCSs and Educational Virtual environments; (b) Platforms for NVEs s and their potential use for supporting VCSs and Educational Virtual environments; (c) Systems for supporting VCSs and Educational Virtual environments. This investigation is becoming the basis for describing the main rationale for creating both EVE platform and EVE Community Prototype.

2.1 Overview of technologies, tools and platforms for VCSs and educational virtual environments

Concerning basic technologies for supporting VCSs and Educational Virtual environments, many tools and technologies are available today. The current components, tools and systems available can be divided into three different basic concepts as described in [6, 7]: (a) document-focused web-based training tools, (b) meeting-focused tools, and (c) 3D-centered multi-user tools.

According to Table 1, it seems that 3D-centered multi-user tools could be used for supporting VCSs and Educational Communities. However, the theoretical advantages of multi-user virtual environments are not exploited in an extended manner as they mainly offer text chat communication and users' representation through avatars. For example, advanced communication features, as voice or user gestures are not commonly utilized. Currently, there are many commercial and research platforms that support NVEs. In general, commercial products target to large groups of users: "the more people, the better" [11]. This leads commercial platforms to be reliable, attractive and easy to use as well as to work on available networks, mainly aiming at leisure or 3D chat. The generality that characterizes commercial systems makes their use for educational purposes premature, as most of them do not support audio/video and multi-modal user communication. Furthermore, an attempt to modify them by integrating additional components may not be cost effective, because most of them are not based on open standards, and, aside from that, their development toolkits are very expensive. In the area of research platforms for supporting NVEs much work has been done. Research platforms emphasize on specific research issues such as facial communication, support of heterogeneous networks [12] or reliability, and tend to be limited in breadth [11]. Furthermore, they focus on particular applications and their re-usability is limited [13]. This gives rise to a proliferation of independent, often partial systems, making them inappropriate for educational purposes. The solution of integrating or combining work from different groups may be very difficult because of different philosophies and assumptions.

In the area of integrated applications for VCSs, the efforts made, so far, have not managed to provide an effective integrated system, which could fully satisfy the requirements of both perspectives. C-VISions [19] focuses on the implementation of a networked multi-user 3D environment for educational purposes. Mind Bridges [10] aims at the implementation of an environment, where users communicate through messages and are represented by their photo, in order to get the sense that they belong to a community. Socialized Collaborative Learning in Multimedia Virtual Worlds aims at a multi-user 3D environment where users can meet, discuss and maintain knowledge. The above projects provide solutions that focus either on the technical implementation and representation of the 3D worlds that comprise the environment, as reported by [19], or mainly emphasize on the exchange of ideas and the intellectual communication of the users involved, without paying so much attention on the representation of the means that are going to be used, as described in [10].

2.2 Results and motivation

To summarize, there are several platforms to support online virtual communities. However, current platforms rarely support both Educational Virtual Environments and VCSs. The current 3D multi-user communication platforms do not

Table 1 Technologies and tools for supporting VCSs and educational virtual environments

Category	Characteristics
Document-focused web-based training tools	*Short description*: Focus on the management of documents and on individual learning. *Pros*[a]: Suitable for Resource Based Learning. Support of standardised learning content. *Cons*[a]: Not suitable for a complete VCS or Educational Virtual environments. Limited use of synchronous collaboration applications. *Example application(s)*: WebCT, www.webct.com
Meeting-focused tools	Short description: Focus on the support of synchronous communication of a user group, which is independent of place. They can be separated into video conferencing tools and synchronous training tools. They offer web-based communication support, where participants are represented with their name and live video picture. Some of the video conferencing tools were designed especially for the purpose of training situations. *Pros*[a]: Suitable for frontal learning. Some of these tools offer learning content management. *Cons*[a]: They provide reduced social presence of the participants that are represented in windows, by means of live pictures. This arrangement makes it difficult for the participants to tell who is talking to whom, and there is no sense of immersion. *Example application(s)*: Microsoft's NetMeeting, www.microsoft.com, (video conferencing tool) and Centra Symposium, www.centra.com (synchronous training tool)
3D-centered multi-user tools	*Short description*: Focus on letting each participant experience the existence and interaction of other participants. In 3D-centered tools the participants of a virtual session are represented as avatars, which can navigate through 3D environments, and all other participants can view the events of single participants as well. *Pros*[a]: They support proximity and social presence through avatars, thereby making participants aware of the communication and interaction processes with others. *Cons*[a]: "The theoretical advantages of multi-user virtual environments are not exploited in an extended manner as they mainly offer text chat communication and users' representation through avatars. Most of these platforms do not offer specific tools such as 3D shared whiteboards and brainstorming boards which are essential for supporting VCSs and Educational Virtual environments. The lack of such type of tools is a major issue due to the fact that the integration of the current platforms with these tools may not be cost effective (in case of commercial platforms) or very difficult (in case of research platforms which are not easy customisable). Moreover, the creation of multi-user virtual worlds from single user virtual environments requires further programming skills for each specific platform." *Example application(s)*: • *Commercial NVE platforms*: blaxxun platform (www.blaxxun.com), Bitmanagement solution (www.bitmanagement.de), Active Worlds (www.activeworlds.com), Octaga (www.octaga.com), Sense8 (www.sense8.com), ParallelGraphics' solution (www.parallelgraphics.com), SmartVR's SmartVerse (www.smartvr.com) • *Research NVE platforms*: DIVE: Distributed Interactive Virtual Environments (www.sics.se/dive) [8], SPLINE: Scalable Platform for Large Interactive Environments (http://www.merl.com/projects/spline/), VLNET: Virtual Life Network [9], MASSIVE (http://www.crg.cs.nott.ac.uk/research/systems/MASSIVE-3/) • *Integrated applications for VCSs*: C-VISions [19], Mind Bridges [10], Socialized Collaborative Learning in Multimedia Virtual Worlds (http://www.comp.nus.edu.sg/labs/ learning/vrml.htm)

[a] For supporting Virtual Collaboration Spaces and Educational Virtual environments

really take advantage of their (theoretical) potentials for supporting collaborative e-learning. They are mainly dedicated to avatars' movement and text chat collaboration. Features that aim on transporting content or supporting collaborative work are not integrated neither are represented over extra windows or in separate frames. Thus, the increase of social presence is not accomplished. These reasons guide us to design and develop EVE Networked Virtual Environments platform.

Furthermore, concerning integrated applications for VCSs, research has not yet presented an integrated educational platform, which could provide both the material as well as the pedagogical features for the 3D simulation of a real learning environment. This notation leads to the design and implementation of the EVE Community Prototype. EVE Community Prototype focuses on the satisfaction of both aspects and is presented in this paper. EVE Community Prototype aims at providing a virtual learning environment, which can simulate, in an efficient way, the interactions, the educational material and the learning process of a real educational environment as more realistically as possible.

3 EVE architecture

EVE's architecture (Fig. 1) is based on a client-multiserver platform model. Each of the servers that constitute EVE is dedicated to serving and supporting certain type of processes, which will be described later in this section.

The current form of EVE constitutes an open and flexible architecture with simple structure, which allows and supports the basic functionality that the platform is intended

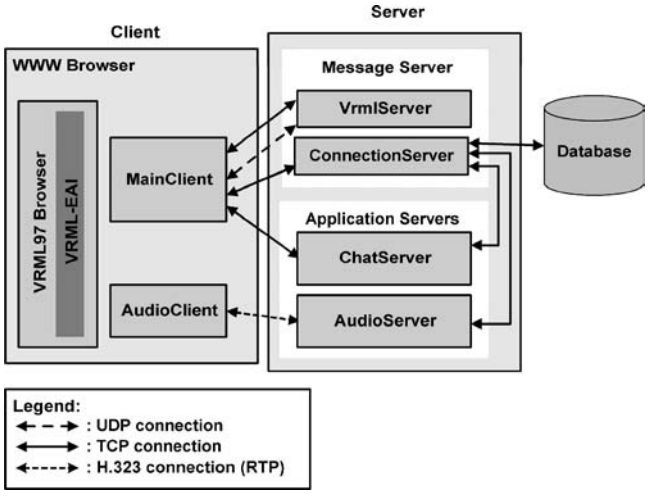

Fig. 1 Architecture of EVE

to offer. For this reason the servers on which the platform relies, are the message server and two application servers, a chat and an audio server. This model offers scalability and flexibility to the EVE architecture, as it allows the addition of more application servers in order to offer additional functionality and furthermore, the processing load is distributed among the above set of servers. In addition EVE is characterized from openness due to the fact that is based on open technologies and international standards. More specifically, the implementation of the platform is mainly based on (a) Virtual Reality Modeling Language (VRML, www.web3d.org), for the representation of the 3D worlds and for describing 3D objects; (b) VRML External Authoring Interface (VRML-EAI, www.web3d.org) for implementing an interface between the 3D worlds and external tools; (c) Java, for the development of the client-server model, and the network communication among the different components of our platform; (d) H.323 (www.itu.int), for offering audio conferencing services through the Internet.

EVE, in comparison with the previous version, is improved mainly on the sharing of events, as well as the audio communication among the users. The previous version of EVE [3] was based on a client-multi-server architecture similar to the current version. However, it has some limitations concerning the sharing of events as well as the audio communication. The creation of a multi-user VRML virtual environment from a single-user VRML virtual environment was based on the creation of a VRML-like file called SVE (Shared Virtual Environments) file. The SVE file contains the definition of the nodes that we want to share [14]. This solution has some limitations on the initialization process and late comers support concerning dynamic-created shared objects. The current version of EVE not only solved this problem but it also goes beyond other platforms, by offering easy transformation of any standalone VRML 3D space to multi-user. Typically, the author of 3D models for multi-user worlds designs them specifically to support distribution. However, the vast majority of 3D models is not designed for use in a multi-user world. Moreover, making the models multi-user is costly in terms of additional complexity [15]. The new EVE's approach for the sharing of the multi-user events is based on a VRML parser that has been implemented. This VRML parser runs on the server side and it helps the server to recognize the shared events. Exploiting this approach the new version of EVE platform has the following advantages in comparison to the previous version:

- It offers enhanced stability through better interface with EAI (External Authoring Interface) a, better support of avatar and avatar's gestures, as well as server-side syntax checking of 3D spaces in order to support better and faster sharing of multi-user events.
- It supports easy creation of a multi-user space from a standalone one, through the integration of the VRML parser. Actually, the shared events are commented out (i.e. marked with a "#"), in the original VRML file and thus the standalone world is transferred to a multi-user one. This is a major advantage of EVE platform.
- It supports execution of shared scripts and VRML routes, full support of scripts sharing (both on javascript and java format), server-side execution of scripts (which offers better sharing of events even if they are based on time-triggering), dynamic insertion of shared objects in multi-user places and specific PROTOs (Prototypes), such as "chair" for avatar's sitting.
- It supports better initialization of the virtual environment, which takes place when the user is connected to the environment. In other words the consistency of the view of the multi-user virtual environment has been improved.

Concerning the audio communication, the previous version of EVE was based on UDP communication without multiplexing. The current version of EVE is based on a standardized solution and supports the H.323 protocol for the audio communication. H.323 is an ITU recommendation, which defines a network architecture and the associated protocols necessary for voice and multi-media calls establishment. H.323 is a protocol suite that can be used in order to establish, modify and terminate multimedia sessions or calls. Main reason for this choice was the H.323's modular structure that offers flexibility and allows the usage of many well-known codecs and mechanisms for the transmission of the data. Furthermore, H.323 supports much more services than voice over IP, such as videoconferencing that could be integrated in future versions of the EVE platform. The following paragraphs describe the main components of EVE architecture.

3.1 Server side

As mentioned in a previous section, the servers on which the platform relies, are the message server and two application servers, a chat and an audio server.

3.1.1 Message Server

The message server is responsible for the manipulation of the virtual worlds that constitute the Training Area of the platform. In addition, this server creates and supports the illusion to the participants that they share a common space by updating the view of the world every time that a shared object is modified. Two servers, each of which is used for a specific sequence of operations, constitute this message server. These servers are the Connection Server and the VRML server. The Connection Server maintains a database, which the system accesses in order to authenticate the user and allow him or her to enter the virtual space of EVE. It also reports every entry or departure that takes place in the platform to all other servers. The VRML server monitors and records every event that takes place in the virtual space and reports these changes to all participant clients of the platform. Thus, the system assures that the users will have the illusion of sharing a common space. The VMRL server also maintains constantly an updated copy of the world, which is sent to the clients when they enter the system. Thus, the new users share the same updated view that the existing users already have.

3.1.2 Application servers

The application servers are responsible for providing specific functionality to the participants of the virtual world. In the current form of EVE there are two application servers available, a chat server and an audio server. The Chat Server is responsible for the text chat support. It allows group chat (i.e. text chatting between multiple users) or whispering (i.e. one-to-one communication between two users). The Audio Server is responsible for the audio communication between the users of the platform. The Audio Server uses H.323 as its main protocol. H.323 is a very powerful multimedia communication protocol, which can transfer voice, video or data over IP networks, and is especially fitted for this application. The main audio service offered by the platform is the audio communication among all participants in a virtual world, or between pairs of them. So, the audio server is in fact an H.323 Multipoint Conference Unit (MCU), which supports audio conferencing among the platform users. By using H.323, compatibility with a large range of H.323 audio servers and clients is achieved and the use of audio as a separate service of the platform is permitted, whilst the numerous applications of H.323 can enrich the functionality of the platform—for example, by adding video conferencing capabilities in the future.

3.2 Client side

As depicted in Fig. 1, in order for the users' clients to communicate with EVE's servers and have access to the provided functionalities they need a web browser, a VRML browser, the Main EVE client and an audio client. The Web Browser is used for the communication with the web server of the system, which provides an initial interface and entry point between the user's client and EVE's environment. The VRML Browser is an essential plug-in, for the navigation of the user's avatar in the virtual training space. The Main Client is responsible for the primary connection of the user to the Message Server, the interaction between the user's avatar and the 3D virtual space of EVE and the text chat communication between the users of the same virtual space. In particular, the main client, which is a java applet, makes an initial connection to the connection server, which allows it to present the current connection status and when the user is authenticated, it passes on to the VRML server. During the initialization phase, the list of the current participants in the virtual space is retrieved, as well as some information about the user avatar. Then, the normal message exchange with the VRML server begins. The first message received always contains the world, in its current state, and the user avatars, so that it completes the initialization phase, and starts normal operation. During normal operation, this client is responsible for the interaction between the user's avatar and the 3D virtual space of EVE. In particular, every time a user acts on an object, this client reports the modification and interaction to the VRML server of the platform that performs the update and transmits it to all other current participants. The main client also includes a chat client. This part of the main client is responsible for the text chat communication between the users of the same virtual space. Every time that a message is sent from the client's side, this is passed to the chat server that in turn transmits it to the appropriate destinations. The Audio Client is a java applet that records the audio stream from the user's side and transmits it to all appropriate destinations, allowing the audio communication between participants in the same space. As already described, H.323 is used to support the audio services. The audio client communicates only with the audio server, which is used as an MCU, handling and mixing the audio streams that are sent by the clients, and forwarding them to the proper destinations.

4 EVE community prototype

EVE Community Prototype (http://ouranos.ceid.upatras.gr/vr/) is a prototype, which is developed in order to meet the previously described requirements of an Educational Virtual Environment. EVE Community Prototype aims to provide the necessary, synchronous and asynchronous e-learning functionalities to its members, in order to simulate a real-learning environment. In particular, and regarding to the basic requirements mentioned before, EVE Community Prototype forms a collaborative educational social space, where members have the capability to gain knowledge through dynamic procedures and activities. The system focuses on the interaction between the users and encourages the communication among them by providing synchronous and asynchronous means of communication and collaboration. A critical factor for the Educational

Virtual Environments is the awareness of other users and the awareness of learning objects and material [6]. If members of a group are not co-present, there is a lack of community feeling [16]. In order to enhance the awareness of the users, especially in the synchronous interaction, EVE Community Prototype exploits multi-user 3D environments where the users are represented by 3D avatars [17, 18]. Therefore, the community, based on the notation that users are influenced by the virtual representation, is supported by a 3D platform, which can facilitate the e-learning process and offers all the tools necessary for simulating a real classroom.

Every course is held in a 3D world, which virtually consists of all the "physical" equipment that could be found in a real classroom. The courses are synchronous (real time) where groups of users (students) can collaborate in order to gain knowledge on a specific topic. This topic is defined by the tutor or the course manager. Furthermore, specific content that supports the studying of this specific topic can be uploaded by the tutor as well as by the students. This content could be in various formats such as video, images, 3D objects and text (pdf, word, etc.) files and can be presented in the 3D presentation table of the Training Area in a multi-user way. Moreover, this table offers additional functionality such as a shared whiteboard and the simulation of a brainstorming board. During the presentations the users can discuss and communicate through audio and text chat as well as avatar's gestures. Furthermore, the text chat is shown in the 3D space as a bubble over the avatars head in order for the other users to see who is chatting. The functionality provided in the 3D Training Area is described later in this paper.

4.1 Community model

When designing and implementing a VCS, there are two main issues that should be taken into account. One concern is that users may not be computer experts nor have a great experience on how to navigate in such system. Thus, the community architecture should offer a friendly to use interface and well-distinguished functionalities, which will guide the user through the learning process and will not spend much of his time on trying to figure out what each component is used for. EVE Community Prototype is, therefore, structured in sections, where each user, depending on his/her role, can access and use the functionalities offered. The second issue is the consistency and efficiency of the hierarchy used in the framework of the community. In order to obtain and maintain a well-structured hierarchy, EVE stratified the involved entities and assigned to each of them rights of access. The main concepts that EVE Community Prototype adopts are the concept of "Organization" and the concept of "Place". The first one is used for organizing the courses offered by the EVE Community Prototype. The second one is used for the virtual areas that can be visited by the user. Therefore, we could describe EVE community as a set of Organizations, which provide e-learning courses and Places, which can be used privately by each member or concurrently by groups of users who attend a course. An Organization constitutes the entity, which can provide knowledge through courses and can be an educational institute, a University or even a company. Every Organization has the capability to develop and create categories and subcategories of on-line synchronous courses, which can be accompanied by e-learning material. These courses are available to all members of the community who can navigate in the system, through a friendly to use interface, and have the capability to view and choose from all the available courses those, which meet their interests, as well as view information about the courses for which are already registered as students or tutors. The model, for organizing the courses offered by the community, is hierarchical and their terms of reference for the levels of the hierarchy (organization-category-subcategory-course) contribute to the flexibility and easy scalability of the community. Also, from the developer point of view, this hierarchy contributes to the consistency of the database schema and the organization of the learning material. EVE Community Prototype adopts the concept of Places in order to simulate and actualize the learning process. The community area is therefore categorised into two places. The first one, called "Personal Desk" constitutes the user's personal workplace, which is enhanced with asynchronous features and the second one, called "Training Area", constitutes the place where courses are realized and the learning process is completed. These two types of places are described in detail in the following.

- *Personal desk*: This term refers to a two-dimensional (2D) Place, which contains all the asynchronous features a user can access. The Personal Desk constitutes the unique, for each member, central Place. There the member can administer his/her personal holdings. The access levels in this space are altered in regard to the user's role in the community. Thus, the roles that maintain more privileges from others can view additional features when entering their Personal Desk. Therefore, the user's interface diversifies according to each role. Furthermore, it contributes on making the users active, due to the fact that they are free to choose the courses that they wish to attend.
- *Training area*: This Place constitutes the virtual classroom, where the courses take place. In EVE Community Prototype this Place adopts a 3D representation based on the notation that 3D environments reflect positively on users' performance by creating a sense of presence and realism. Therefore, just as in real classrooms, the virtual classrooms must obtain all the prerequisites necessary for the conduction of the learning courses.

4.1.1 User roles and rights

An important factor to be taken into account is the definition of the users' roles in the community, as well as the levels of access that each role involves. More specifically, in EVE Community there are six, well defined, user roles each of

which dispose certain privileges. These user roles are the following:

- *Visitor*: This type refers to users who have not yet been registered to the system. The users of this category can register to the system by completing a registration form. They can only view information (mainly static) and demos about EVE Community Prototype and what it can offer, without being able to navigate and test the functionality offered by the system.
- *Member*: Members of the community are considered to be users who have not yet joined any of the available courses but are already registered to the system, which means that each has a unique username and password, wherefrom they are recognized. These users have the capability to navigate though the available courses and post registrations for the courses that correspond to their interests. In addition, they have the capability to use all the asynchronous features that the community provides, which are the forum, a personal calendar, send and receive messages, maintain their personal profile and view other members' profile. However, these users, since are not registered for any class, cannot enter the 3D virtual world, the virtual classroom, where the courses take place.
- *Student*: This user role corresponds to members that have registered for at least one course. Therefore, these users have all the asynchronous functionality mentioned above as well as some additional collaboration features that arise from their registration to a class and their entrance to the Training Area.
- *Tutor*: The tutor role is assigned to only one person per course. This user must be a member of EVE Community Prototype, without necessarily being registered as a student for the given course. The users who are assigned as tutors in a certain course conserve the capabilities of the student category but obtain some additional "privileges" in relation to the lower levels of the hierarchy. The tutor's role is distinguished in two instances. The first one consists of the asynchronous components that this kind of role can manipulate. The second one is related to the existence of the tutor in the 3D virtual classroom. In this Place, the tutor is the most privileged among the users, as the management of the course falls to his/her jurisdiction. In particular, the tutor can create groups of students, assign them tasks, which she/he supervises during the course, and decide what will be presented on the whiteboard. Furthermore, the tutor is the floor manager of the classroom, which means that every time a student wishes to speak, or pose a question, she/he must get the tutor's approval. In general, this type of user is responsible for the efficient realization of the course and the management of the students, which she/he has the ability to expel in cases thought necessary.
- *Course manager*: Each organization appoints a course manager, a person who is responsible for the creation and management of the categories, the subcategories and the courses, in general. This entity is authorized to set a tutor for every course and decide which members, that expressed interest for the course, will become registered students. In addition, the course manager can view the users' profiles, consider their research areas and create new categories, sub-categories and courses that correspond to the majority's interests. Alike the tutor's role, the course manager is responsible for the organization and management of all students and tutors who have subscribed to courses of the organization that the course manager represents. Thus, this user can add or delete users, accept or deny requests for the creation of courses by tutors and accept or deny requests for the attendance of a course by students. Furthermore, the course manager is responsible for the administration of some of the asynchronous means of communication and collaboration, such as the calendar of events. Regarding these components, the course manager is responsible for the selection of the topics that are going to be posted in the calendar.
- *EVE administrator*: There is only one person who holds this role and she/he is the platform owner. Hierarchically, the administrator presents full access to the system, in which she/he can add, remove and modify functionalities, fix possible feeblenesses of the system, and create new organizations. In addition, she/he is responsible for the management of the course managers, and the users of the community in general.

In Table 2 the access rights of each role are presented. Also Fig. 2 depicts the hierarchy of courses in the EVE Community Prototype according to organization concept, and their relation to the roles and rights that EVE Community Prototype supports. What should be significantly emphasized is that the privileges that accompany the role of the tutor stand only for the courses this user is assigned to. Similarly, the attributes of the course manager stand for the organization that this user represents. For every other entity these users are treated by the system as members.

4.2 Functionality

The main goal of an Educational Virtual Environment is to provide all the tools, applications and conditions necessary for creating a space where communication and collaboration can be efficiently used for the maintenance and exchange of rich knowledge. Thus, EVE Community Prototype, trying to simulate the learning process from its very beginning until its completion, is enhanced with the tools necessary for the advising, the notification, the encouragement and interaction of the users, as it would happen in real educational communities.

4.2.1 Personal desk services

These services (Fig. 3) constitute, in a way, the anteroom, which prepares the users before attending a class and is mainly comprised of asynchronous features.

Table 2 Table of rights and roles

Place	Rights	EVE administrator	Course manager	Tutor	Student	Member
Organization	Create organization	v				
	Delete organization	v				
	Edit organization's info	v	v			
	Assign course managers	v				
Course category/subcategory	Create course categories		v			
	Delete course categories		v			
	Edit course categories info		v			
	Create course subcategories		v			
	Delete course subcategories		v			
	Edit course subcategories info		v			
Courses	Create courses		v	v		
	Delete courses		v			
	Assign tutors		v			
	Validate course creation		v			
	Edit courses' info		v	v		
	Accept/delete students		v			
	Register for course			v	v	v
	Attend course			v	v	

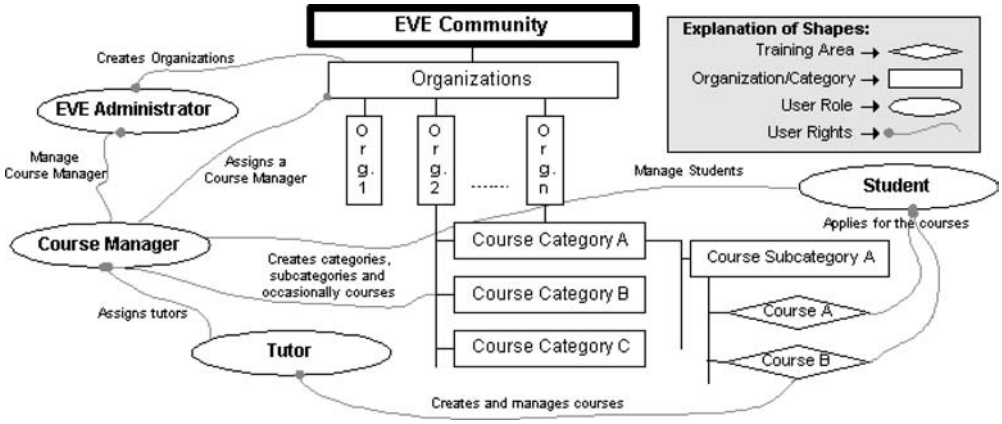

Fig. 2 Roles and rights in EVE community prototype

This space and the information provided are always available for the users, even if no courses are taking place at that time, and contribute to his/her advising, notification, reminding and troubleshooting in the scope of the community.

– *Forum*: One of the main services of the EVE's Personal Desk, as well as of every virtual community [1], is a forum, which comprises a mean of asynchronous communication. Every registered member can post a topic to the forum with information that she/he thinks that is important. At this point is should be mentioned that the administrator of the system has the ability to add new categories, each of which contains a number of forums relative to the category theme. The administrator also has the ability to specify which types of users can view and access these forums (i.e. members, visitors, course managers, etc). The users of the community, according to their role within the community, can only view the forums they have access to and the posting to these forums is realized without the interference of an administrator or a course manager.
– *Calendar of events*: It is a timetable that stores a collection of events and lists them in chronological order. It's an asynchronous mean of communication, which can be used for the scheduling of events that take place in the virtual learning community. Each registered user can dispose a private calendar of events, which means that only this user can see the contents and posts in this calendar. The calendar provided by EVE Community Prototype can support three types of events: public, private and related to each course. In the public calendar of events the members can post their announcements to the course manager, who in turn, will decide if the announcement is "qualified" to be posted. Furthermore, there can be a course calendar that includes class schedules and venues, schedules assignments, examinations and topics to be covered. The calendar consists of three views. The day view, which is also time scheduled, the month view and the year view.
– *Text chat*: This feature allows participants to communicate in a synchronous mode. More specifically a group of people, who share common interests, can create its own

Fig. 3 Personal desk services

chat rooms. Also, this component allows to users to send private messages in the chat room, which cannot be seen by the other members.

– *User profiling*: Every member of the community, at the time of his/her subscription to the system enters personal information, which include his/her interests, hobbies, the research areas, which she/he prefers, etc. Thereby, a profile for each user is created which is constantly enriched with additional information, which arises from the selection of courses that she/he decides to attend. This functionality could contribute to an interplay between the community members and the system, which, in turn, could result in effective distribution of knowledge.
– *Manipulation of e-learning content*: A simulation of a real classroom presupposes that the tutor of the class has the capability to add and manage learning content, which should be dynamically changed, and dispose knowledge to the students, providing them the capability to have and process this learning material. In addition, there could be no efficient simulation if the students did not have the capability to maintain their own notebook, which in terms of an e-learning environment means a directory with files and folders for personal use. Such functionality can be supported by two basic operations, the uploading and downloading of files, in the framework of the collaborative virtual environment.

4.2.2 Training area services

The Training Area is exploited in order to host synchronous e-learning sessions. It combines 2D and 3D features in order to provide the users with communication and collaboration capabilities and necessary tools for realizing collaborative e-learning scenarios. There is one Training Area per course. The main feature of the Training Area is the 3D representation of a multi-user virtual classroom. This virtual classroom is the central Place for realizing the learning process. The participants in the virtual classroom could have two different roles: tutor (only one participant) and students according to its privileges in the EVE Community Prototype.

The users that participate in the virtual classroom are represented by avatars. The users' avatars are able to make various types of gestures: expressing opinions (e.g. agree, disagree), expressing feelings, mimics (e.g. happy, sad), as well as showing actions (e.g. move learning content, pick learning content). The virtual classroom is supported by audio and text chat functionality, which is available to all participating users for supporting and promoting collaboration, cooperation and communication among them. The users can also use text chat bubbles where their text chat entry is depicted on top of his/her avatar's head. The virtual classroom also provides a specific place where the users can upload their content and show it to other participants in the course. This space is a 3D presentation table. Moreover, this table offers additional functionality such as a shared whiteboard and the simulation of a brainstorming board. At this point it should be mentioned that the presentation table can also operate as a video presenter for displaying multimedia content. Furthermore, on top of the presentation table the users can drag and drop 3D objects that can facilitate the learning process. For example, the tutor can upload a 3D animation concerning the creation of a chemical combination. The user interface of the Training Area is depicted in Fig. 4.

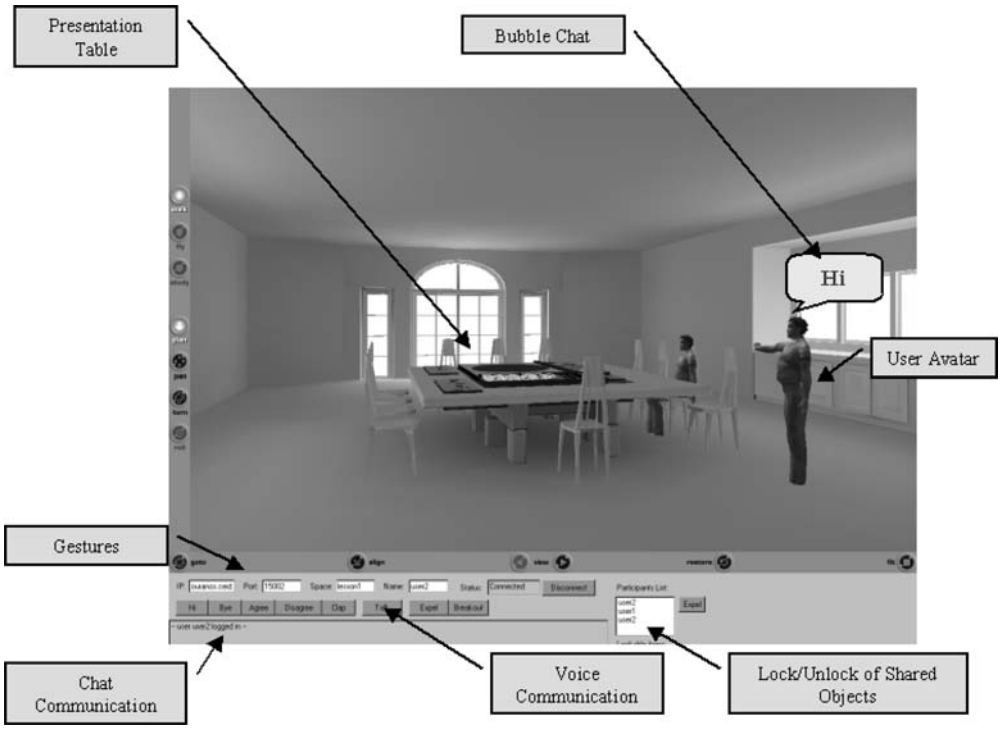

Fig. 4 User interface of the training area

5 Evaluation of the EVE community

An important factor for the success of EVE Community Prototype is its evaluation by users, which will bring out any possible deficiencies that EVE may have. The collection of the users' feedback and their elaboration will lead to an integrated, from both pedagogical as well as technological aspect, Educational Virtual Environment. The evaluation conducted was mainly focused on the usability and acceptability of the EVE Community Prototype. In particular, the goals of the usability evaluation were to (a) assess usability problems of EVE interface, and (b) investigate additional requirements of the end-users for improving the functionality of the EVE prototype. The aim was to evaluate the current functionality as well as the interface usability, in order to obtain results for future enhancements on the prototype. Furthermore, the degree of acceptance of the system by the end-users, and their evaluation concerning the suitability of the system in supporting the learning process were recorded. In the following paragraphs we briefly describe the evaluation process that has been followed along with a summary of the evaluation results.

5.1 Evaluation process

The target group for the evaluation was professors and students of the Computer Engineering and Informatics Department at University of Patras in Greece. More specifically one professor and nine students were recruited. Also, a technical expert and an observer were present in order to help the evaluation process. It should be noted that the users (professor and students) were familiar with the use of Information and Communication Technologies but not with the use of 3D multi-user virtual environments. The topic of the synchronous course was "Computer Networks". The usability evaluation has been conducted in two phases in order to meet our goals: (a) an introductory phase, with guidance by a technical expert, and (b) an e-learning session without guidance. Each of these sessions last about 3 h.

The first phase was conducted for exploring and becoming familiar with the basic functionalities of the EVE Community Prototype. The main areas of interest for this phase were (a) the user model of the community; (b) the functionality of the Personal Desk: forum, instant messages, calendar of events, text chat, user profiling as well as, manipulation of e-learning content; (c) the functionality of the Training Area: the basic avatar navigation in the 3D space, controllability of avatar gestures, the chat tool, the audio tool and the usage of the presentation table. A technical expert has guided the users explaining them the functionality of the community. In that phase the think-aloud method was used: an observer of the session has asked the users about the functionality that they have used in order to get a deep understanding of the user's problems with the interface.

The second phase was an end-user learning session, where the end-users work within an authentic situation. The objectives were to observe how users could get along without a strong guidance, and the way they use the

forum, the user profiling, the gestures and the communication channels in the 3D Training Area. In order to get information about the advantages and disadvantages of the prototype as well as the appropriateness of different kinds of learning processes, questionnaire and interview data were collected.

The main questions asked were the following: (1) How did you get along with the EVE Community Prototype in general? (2) Did you enjoy learning with the EVE Community Prototype? (3) Did you miss any function? (4) What functions did you like? (5) Did you like the possibility to make gestures with the avatar? (6) Did any problems occur while (a) using the Personal Desk ("forum", "calendar of events", etc.); (b) navigating with the avatar (walking, sitting down, standing up ...); (c) using the chat function? (d) using the Presentation Table (icons, controls for presentations, brainstorming etc.), (8) Do you have any suggestions for technical improvements or additional functions?

In order to survey the results the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis has been used.

5.2 Summary of evaluation results

In this paragraph, a summary of the results of the usability evaluation is presented. Furthermore, suggested enhancements and functionality by the end users are presented. In overall, the range of data gathered led to a largely consistent picture: that whilst work to be done still remains, the community software has been regarded as largely usable and acceptable on a number of different parameters, and able to support a thriving virtual learning community. The concept of EVE Community Prototype has been rated, by most of the end users (i.e. 90%), as an interesting and promising solution for collaborative e-learning. However, 70% of the users stated that the error tolerance of the system should be improved. Concerning the user-model of the community, 70% of the users stated that it is well structured and provided many degrees of freedom to the students to decide on the courses to attend. Furthermore, 80% of the users stated that this model was quite general and could be easily used for supporting, not only the curriculum of a university but also, the needs of an organization/company that would wish to offer e-learning courses. Concerning the functionality of the Personal Desk they found the user interface usable in general. 80% of the users stated that Personal Desk services were very useful not only for personal use but also for enhancing the co-operation and interaction among the Students and Tutors. Concerning the functionality of the Training Area the 90% of the users stated that the 3D-metaphor of a virtual classroom has been a useful approach for supporting synchronous e-learning, especially for small groups of learners. Furthermore, they said that the simplification of the user interface using 3D metaphors (80% of the users indicated that), the support of different files formats (70% of the users indicated that) and the use of the audio communication channel (all users indicated that) have been the main factors for the general acceptance. It should be mentioned that the usability of the Training Area user interface has been as well-rated positively by 80% of the users. All the users thought that they got along well with the system. However, 70% of the users stated that the interface of the 2D tools of Training Area needed improvement.

During the evaluation of the EVE Community Prototype the end users have mentioned various advantages. Concerning the Personal Desk area, the features that had major acceptance were the forum (90% of the users), the calendar of events (80% of the users) and the private messaging (80% of the users). Furthermore, 80% of the users rated the process of registering and attending a course easy and reasonable. Also 70% of the users stated that the user profiling has been proven very useful for supporting the encouragement of user co-operation. Concerning the Training Area the main advantages were the combination of 3D interface (80%), audio communication (100%), text chat (70%), and the visualization of users' actions on the presentation table (70%). 80% of the users stated that the virtual environment of the Training Area is intuitive because it is structured according to a real-world domain which they are familiar with. Furthermore, they said that the classroom metaphor generated to them a feeling of social presence and belonging to a specific group. Also, 70% of the users believed that EVE prototype is well suited for presenting and discussing a topic. Collaboration while working on a theoretical task as well as informal exchange of information and collaboration while solving a practical task were also rated positively by 70% of the users. Other features that have been rated as helpful for collaboration and for supporting collaborative learning were: the bubble chat (80% of the users indicated that), the brainstorming board (70% of the users indicated that), the whiteboard (90% of the users indicated that), and the facility of uploading of e-learning material in the 3D world using the drag and drop functionality in the library tool (80% of the users indicated that).

One of the main results of the evaluation was the suggestion of new features that could be integrated in the current prototype. The main suggestions by the end-users concerning the Personal Desk area were: (a) The integration of a tool for adding links to useful web resources indicated by 60% of users; (b) The integration of comprehensive general as well as e-learning content search facility indicated by 70% of users; (c) The integration of navigational aids as well as a facility for Frequently Asked Questions (FAQs) indicated by 60% of users; (d) The enhancement of the e-learning content manipulation tool in order to be more usable and to support import and export of standardized e-learning content indicated by 70% of users; (e) The integration of an online tool for creating e-learning content indicated by 40% of users.

Concerning the Training Area, 50% of the users suggested the integration of a facility for supporting real-time video presentation, in order to present hard copy documents

using a document camera. Furthermore, 60% of the users proposed to support freehand drawing on the whiteboard tool. The 60% of the users also suggested that the avatars should have a context menu in order to manipulate them as well as that the avatars should support facial expressions, at the same time with a gesture, in order to express feelings in a better way. In order to upgrade the usability of the Training Area, the 50% of the users proposed to add tool tips in every clickable area. The provision of intelligent help to the users concerning e-learning scenarios and the usage of the tools has been rated as a very useful feature by the 70% of the users.

6 Conclusions

This paper presented EVE, which is a platform for NVEs. This platform supports multi-user 3D spaces along with chat and voice over IP communication. It is based on an open and flexible architecture exploiting well-known and open technologies and standards such as VRML, Java and H.323.

EVE is a platform which tries to overcome the limitations of the current platforms for on-line virtual communities concerning the support of both Educational Virtual Environments and VCSs. More specifically EVE take advantage of the theoretical potentials of 3D multi-user communication platforms concerning the support of collaborative e-learning by supporting humanoid avatars and avatars' gestures, audio and text-chat interactions enhanced by bubble-chat, collaborative manipulated objects (such as brainstorming board, video presentation and 3D shared whiteboard) in a 3D-unified user interface.

Furthermore, this paper describes an educational community, which was based on VCSs. EVE Community Prototype aims to provide an integrated learning environment, giving emphasis on both pedagogical as well as technological texture of the educational place. Furthermore, this Community is identified by the fact that it is comprised of well-distinguished roles and rights, which simulate in an efficient manner the learning process. The variety of learning tools, both in the asynchronous and synchronous mode, creates the sense to the students and participants of the environment that are members of a community. These tools form the basis for the realization of the virtual courses, by providing all the functionalities of a real classroom. Thus, through a friendly to use and navigate environment, the members of EVE Community Prototype have the capability to maintain their personal profile and a private space with all their personal holdings and interests, have the potentiality to communicate and interact with other members of the community and participate in virtual courses, either as students or tutors, in order to obtain rich knowledge.

From a pedagogical scope, EVE has defined mindfully the roles and rights of the involved users, providing the capability to all of the users to become equally transmitters as well as receivers of knowledge. These roles and the rights that each of them implies, form the basis for a learning environment which relies in the communication and interaction of its members, the mutual respect and their active participation on the way to collaboration and knowledge.

From the technological scope, EVE manages to provide all the functionalities necessary for the asynchronous communication and support of its members as well as for the simulation of a real training area. Therefore, EVE used the technologies and standards available, for the implementation and integration of the necessary 2D and 3D tools, and created a platform, which is characterized by operability and scalability. Furthermore, EVE supports easy creation of a multi-user space from a standalone one, through the integration of the VRML parser.

Concerning the acceptance and usability of EVE Community Prototype, the overall the range of data gathered in the evaluation phase gives a largely consistent picture: that whilst there is still work to do the EVE Community Prototype software is regarded as largely usable and acceptable on a number of different parameters, and shows every sign of being able to support a thriving virtual learning community

7 Future work

In its current form, EVE Community Prototype manages to create an Educational Virtual Environment, which can offer necessary tools for the communication, interaction between the members involved as well as the prerequisites for the simulation of a real classroom, providing the "material" features that could be found in a real classroom, i.e. whiteboard, library, brainstorming, chat, etc. However, EVE has the potentiality to be enriched with new features and tools, which will exploit the capabilities of Virtual Reality's technologies and standards. Therefore, the graphical representation of the 3D virtual worlds could be enhanced in order to provide a more friendly and efficient for knowledge environment. Furthermore, concerning the pedagogical aspect of the community, some emphasis should be given on the composition and organization of the learning material, in order to correspond and deal with multiple learning scenarios. This could be done by supporting standardized learning content following well known standards for learning objects. An available standard in this area is SCORM (Sharable Content Object Reference Model) and a next step for the improvement of EVE Community Prototype will be the integration of SCORM standard for importing and exploring standardized learning content.

Finally, the integration of intelligent agents in EVE will be a major enhancement of the functionality offered. Intelligent agents can support educational process and they can offer intelligent help to the users for the usage of the system. They can also support the collaboration of virtual community members through profiles matching. Therefore,

there are many types of intelligent agents such as collaborative agents, interface agents, mobile agents, information agents, reactive agents, hybrid agents and smart agents. In addition, recently have been developed new types of intelligent agents for specific functions, such as pedagogical agents. Pedagogical agents can inhabit in Collaborative Virtual Environments and be represented by a character (avatar) or a special object (e.g. a book). Their role is to interact with the users (students and teachers) within the CVEs. The pedagogical agents can further monitor student's interactions as well as guide and advice the users. The main advantage of the pedagogical agents over conventional intelligent learning is that they enable closer and more natural interactions between students and intelligent courseware. This provides more useful and friendly user interface and helps the users to find easily the desired information.

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