Using VR Technology to Support e-Learning: The 3D Virtual Radiopharmacy Laboratory[1]

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Abstract

In this paper, we present a virtual laboratory, which is designed and implemented in the framework of the VirRAD European project. This laboratory represents a 3D simulation of a radio-pharmacy laboratory, where learners, represented by 3D avatars, can experiment on radio-pharmacy equipment by carrying out specific learning scenarios. This paper describes the functionality provided by this laboratory, the motivation factors which led to its formation, the technological decisions that were made for the optimization of the system as well as the envisioned steps to be carried out.

Keywords: Distance learning, Virtual reality, Multi-user virtual environments, Virtual Laboratory, Multimedia applications

1. Introduction

The wide expansion of the World Wide Web (WWW) and the Internet has formed all the necessary preconditions for adopting this powerful means–for purposes such as delivery of e-learning content, collaboration and distance learning both in the industrial and the educational field. This trend has been proven beneficial for small communities of people, working in highly specialized areas and facing communication and collaboration difficulties due to spatial limitations [4]. The community of Radiopharmacy stands as an example for this kind of specialized communities.

In the technological field, Virtual Reality (VR) technology has been widely proposed and recognised as a major technological advance for supporting life-long education to individuals along with a flexible workforce. One of the unique capabilities of the VR technology is the successful translation of abstract concepts into visualized events and the interaction of students with them, that in real life can be limited due to distance, time and safety factors [6]. Furthermore, by exploiting 3D multi-user virtual environments the user can interact with other users of the virtual environment, thus achieving a great sense of realism. Therefore, VR technology has a high potential for supporting not only Resource-Based Learning (RBL) but also collaborative e-learning processes. However, current user interfaces fail to enable the user to be fully creative. In most cases the emphasis is given on the technology rather than the fact that they should be designed for the content to be accessed. For example, in general, voice or gestures from the user are not utilized [3].

In recent years, communities and educational collaborative virtual environments, in general, drew academic and research attention and a great number of educational institutions and organizations focused on the development of virtual collaboration environments. Among these efforts, a distributed virtual reality environment for simulation-based learning is C-VISions [7]. C-VISions is a research project, which focuses on the implementation of a multi-user 3D environment for educational purposes. In order the learning process to be realized, users are represented by avatars in a 3D environment. Furthermore, the system provides collaboration and communication tools such as enhanced text chat and a global audio chat system. Another example of a virtual environment for educational purposes is The Virtual Labs Series produced by the Howard Hughes Medical Institute [8]. This work is a collection of virtual laboratory exercises, fully interactive, created for the diffusion of biomedical know-how, with 3D modeled laboratory equipment covering different modern biological topics. The Virtual Lab Series begins to address the need to educate the public at large about the rapidly emerging fields of bioinformatics, genomics, and applied Internet-based research.

The above environments focus either on the technical implementation and representation of 3D world as C-

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VISions or on the standard operation process as Virtual Lab Series. Consequently, research has not yet presented an integrated educational 3D environment, which could provide a powerful 3D world with enhanced communication tools (avatars' gestures, voice and text chat) and intelligent learner modeling functionality along with the ability to focus on the training procedure. This notation led to the implementation of the VR Laboratory, which will be described in detail in the remaining of this paper.

On the whole, this paper presents a 3D Virtual Radiopharmacy Laboratory that exploits the benefits of VR technology, and tries to overcome the above problems in order to provide a simulation of a radio-pharmacy laboratory, where learners can experiment on radio-pharmacy equipment by carrying out specific learning scenarios as well as interact with other learners and mentors. This laboratory has been implemented in the framework of the VirRAD European project, which has as main goal to support the Radiopharmacists' community worldwide.

The remainder of this paper is structured as follows. In section 2 the VirRAD project is briefly described while in section 3 the motivation factors and main design issues are presented. Section 4 is dedicated to the system implementation and architecture. Following this, the functionality provided by the VR Laboratory is presented. Finally, some concluding remarks and planned next steps are briefly described.

2. The VirRAD project

VirRAD (Virtual Radiopharmacy, http://www.virrad.eu.org/) project is concerned with section III.2 of the IST 2001 work program "Education and Training". It started on February 2002, and it will run for almost 3 years.

The aim of the VirRAD environment, in general, is to provide a sustainable, user-driven web-based interface, which supports communication between all members of the worldwide Radiopharmaceutical community. It will help them to expand their horizons, share their ideas, disseminate best practice and develop innovative solutions to universal radiopharmaceutical problems in order to promote the ongoing contribution of the specialty to science and health-care. VirRAD aims at the integration of current RBL concepts with collaborative e-learning strategies [4]. Part of this environment will address the particular needs of trainee radiopharmacists by providing distance-learning material for supporting RBL [5]. The development of multimedia learning material will be closely coupled with the pedagogical theory of Mindful Learning [1]. Furthermore, as group-learning processes are highly efficient, especially in problem solving, the virtual environment will support collaborative processes

enabling the communication and collaboration among individuals both in a synchronous and an asynchronous manner.

To meet the aforementioned objectives, VirRAD system has been divided into the following main areas: Community, 3D VR Laboratory and Courseware [2]. The Community site provides a series of tools for the communication, collaboration and information exchange among the radio-pharmacist's community members. These tools offer functionality such as personal card, library, text chat rooms, virtual conference rooms, forum, news, links, events, adverse reactions reporting system and glossary of terms. The Courseware aims to support and facilitate the access to non-VR learning material. Regarding the 3D VR Laboratory, it simulates a radiopharmacy laboratory in order to make radiopharmacy learners familiar with the execution of standard operation processes as well as to encourage and facilitate interactions among learners and mentors. Both Courseware and 3D VR Laboratory are supported by an intelligent learner modeling system for creating an integrated Instructional Component of the VirRAD system. The first prototype of the VirRAD system is available at http://community.virrad.eu.org.

The remaining of this paper is dedicated to the description of the 3D VR Laboratory.

3. Motivation and design

This section presents the main motivation factors that inspired the design and the implementation of the VR Laboratory. The goal that should be achieved by this work is threefold:
1. To provide an e-learning environment for radiopharmacists students as well as to overcome communication difficulties among them
2. To overcome limitations of current e-learning applications
3. To avoid limitations met in most VR applications so far
These goals are described in the following paragraphs.
At a first level we plan to support the community of Radiopharmacists as follows:
- To overcome the problem of interaction and communication among them
- To support the radiopharmacy students to construct their knowledge in radiopharmacy in a "learning by doing" situation
- To provide remote support to radiopharmacy students by radiopharmacy mentors
In order to achieve the above goals the VR Laboratory simulates a set of standard operation processes that take place in a real radiopharmacy laboratory. Furthermore, it offers various communication channels such as avatars' gestures, voice and text chat, for achieving a greater sense of realism.

At a second level, having in mind that the VR Laboratory is targeted to provide e-learning services to the users, the limitations of current e-learning applications should be overcome. Currently, it is noticed the need for a paradigm change in e-learning, which has not yet taken place [4]. In the past, Information and Communication Technologies (ICT) have been developed in a technology-centered way, but we are currently undergoing a change towards more human-centered concepts of using information technology for business, learning and communicating with each other. However, RBL, which focuses on the interaction between human and computer, still prevails. Although, this approach has several advantages for supporting individual learning by providing interactive, media-rich resources for learning, several disadvantages have been identified. Some of these disadvantages involve the lack of peer contact and interaction of students working alone and the need for flexible, available tutorial support. In order to exploit the advantages of RBL and, in parallel, overcome its disadvantages, the VR Laboratory offers the ability to be accessed in two ways: the study mode, which supports RBL and multi-user mode which supports collaboration and interaction among learners and mentors.

At a third level the main effort is focused on designing an environment that could be characterized as a "place" of interaction and not a simple, plain space. As mentioned before, current user interfaces have been proven insufficient to enable the user to be fully creative. Furthermore, the theoretical advantages of multi-user VR technology 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. In order to overcome the above limitations, the design of the VR Laboratory is based on the concepts introduced by Dourish and Harrison [9] about space and place: "A space is always what it is, but a place is how it's used". In addition, according to [9] we have to deal with some aspects of the "real world" which can be exploited as part of a VR spatial model for collaboration and learning. The real-world value of the features listed below is that they provide critical cues, which allow individuals to organize their behavior accordingly (such as moving towards people to talk to them, or referring to objects so that others can find them). VR Laboratory, presented in this paper, exploits aspects of space and spatial mechanisms, such as providing identity, orientation, a locus for activity, and a mode of control, which can be considered as powerful tools for the design. These aspects are:

- Relational orientation and reciprocity: The spatial organization of the VR Laboratory should be the same for all participants. Since people know that the world is physically structured for others in just the same way as it is for them, they can use this understanding to orient their own behavior for other people's use.
- Proximity and activity: People act, more or less, where they are. They pick up objects that are near them, not at a distance; they carry things with them; and they get closer to things to view them clearly. Understandings of proximity help relating people to activities and to each other. Similar properties are exploited in the VR Laboratory.
- Partitioning: Following on from the notion of proximity and activity is a notion of partitioning. Since actions and interactions fall off with distance, this distance can be used to partition activities and the extent of interaction. VR Laboratory uses rooms or locations to partition activity. For that reason it provides different rooms for high radioactive areas and for clean, sterilized areas.
- Presence and awareness: The sense of other people's presence and the ongoing awareness of activity allow them to structure their own activity, integrating communication and collaboration seamlessly, progressively and easily. Similarly, the VR Laboratory presents views of other people through 3D human like avatars, their role and their actions within the same environment.

VR Laboratory based on the above aspects, tries to simulate not only the spatial model of a real Radiopharmacy laboratory but also the actions that take place in such an environment. Implementing and simulating the usage of equipment located in a radiopharmacy laboratory the execution of standard operation enable processes taken place in a real radiopharmacy laboratory. The users can catch, carry, use, destroy objects etc. Furthermore by exploiting avatars, and avatar's gestures we try to satisfy crucial functions such as perception, localization, identification and visualization of the others' actions [10].

4. System implementation and architecture

This section is dedicated to describing the structure of the system that supports the VR Laboratory. The term structure is used for referring to the logical view of the static structure of the architecture in terms of its components, their interconnections, and the interfaces and operations offered by these components.

The step that follows the definition of the main design principles of the VR Laboratory is the assessment of the technologies that will facilitate the implementation of the system. VirRAD system should be an easily accessible web-based system, used by a worldwide community, taking into account bandwidth and client-side system constraints. Therefore one of the major targets apart from

implementing the VR Laboratory with the appropriate functionality is to satisfy the following prerequisites.

Firstly, there is a need to minimize the client-side system requirements and the cost of client-side system set-up. This means that the end-user should be able to access the laboratory using a typical personal computer (PC) without excessive requirements either in hardware or in software. Secondly, the system should have the ability to support a maximum number of simultaneous users. This requirement should in particular be considered in the multi-user applications. Finally, using technologies, which do not require excessive hardware requirements, should also minimize the cost of the server side set-up.

According to the above criteria, the system architecture is defined by some basic principles: The system should be based on a variety of communication protocols, should be scalable, as much as possible, platform independent and based on well-known standards.

The system architecture (Figure 1) is based on several components that provide the needed functionality as follows: the database, the multi-user (MU) server, the web server and the client. These components are described below in details.

The database of the system stores the majority of the information about users such as profiles, roles, and avatars. VirRAD exploits the MySQL database management system.

The multi-user server offers to the users a consistent and shared view of the Virtual Laboratory along with the support of the collaboration and communication among them. VirRAD exploits the Macromedia Flash Communication Server MX as a multi-user server due to the fact that this server could support not only multi-user 3D environments (i.e. VR Laboratory) but also the necessary communication channels such as text and voice chat. However the text and voice chat functionality have been implemented by using Macromedia Flash MX, and by exploiting specific communication components offered by Macromedia Flash Communication Server MX. Flash movies have small size, can be accessible over the WWW by a free plug-in (Flash player), and their quality of service is satisfactory over the Internet. The communication between the multi-user server and the respective clients (Shockwave and Flash player) is achieved using the Macromedia Real-Time Messaging Protocol (RTMP). The 3D functionality of the VR Laboratory has been implemented by using Macromedia Director MX, due to the fact that Director movies could be accessible over the WWW by a free plug-in (Shockwave player), they can include a variety of media such as sound, text, animation and digital video. Furthermore, Director movies are compact and relatively small for web delivery.

As far as it concerns the web server, it is used for storing the client-side files of the VR Laboratory, voice chat and text chat. Furthermore, the web server stores and executes the PHP scripts in order to obtain the users' data from the database. The web server that satisfies the above prerequisites is the Apache web server, which is free of charge, runs on almost all operating systems; supports PHP scripts; can host Director and Flash movies; and can interoperate with MySQL and Macromedia Flash Communication Server MX.

The client is the end-user's personal computer, with an Internet connection, the Flash Player, the Shockwave Player and a web browser (that can embed Flash Player and Shockwave Player) as described in Figure 1.
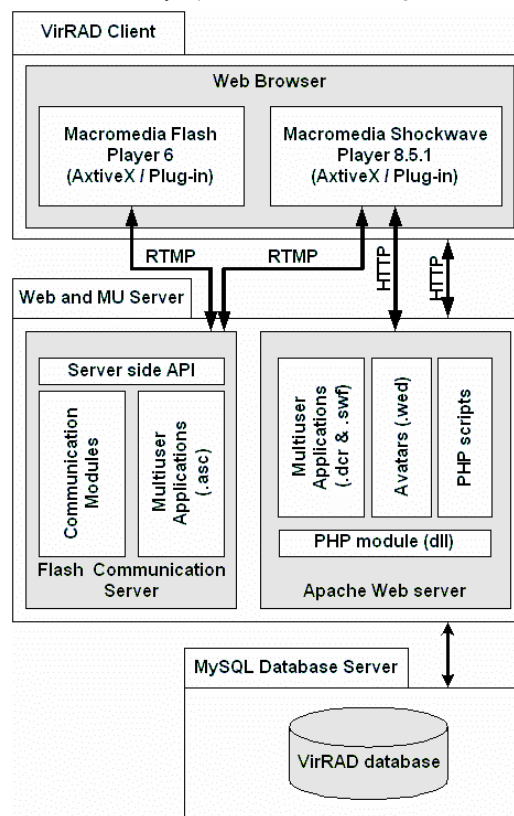

Figure 1: VR Laboratory architecture

5. VR Laboratory functionality

As mentioned above, the VR Laboratory is a 3D simulation of a radio-pharmacy laboratory, where learners, represented by 3D avatars, can experiment on radio-pharmacy equipment by carrying out specific learning scenarios. The user can access the VR Laboratory in two modes: (a) the study mode, and (b) the multi-user mode. In the study mode the user can interact with the environment without the presence of other users while in the multi-user mode the user can see other users that have also visited the VR Laboratory and interact with them, by gestures, text chat, audio chat, and the virtual environment. The functionality provided by the VR

Laboratory in these two modes is described in the following paragraphs.

5.1 Study mode

The interface of the VR Laboratory in the study mode includes the following areas/functionality (Figure 2).

- 3D area (Figure 2a):
- Viewpoints area (Figure 2c)
- Object description area (Figure 2d)
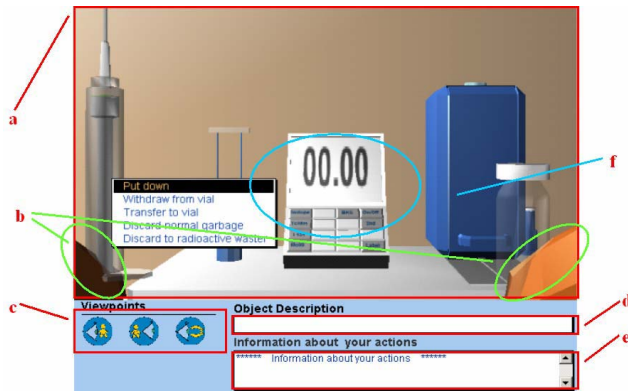- Area where the system feedback about user actions is displayed (Figure 2e):

Figure 2. Study mode of the VR Laboratory

Using the buttons of the "viewpoints area" the user can change his/her viewpoint in order to have a different view of the laboratory. The user can choose between four viewpoints: "View behind the avatar", "View in front of the avatar, "View avatar hands" (default viewpoint), "Stand Up" (this viewpoint takes effect only when the avatar is sitting on a seat).

In the "object description area" the user can see the name of the object, in which his/her mouse is up.

In the "information about user actions" area the user can see information and get system feedback after some specific functions. An example of such information is the result of an elution process.

In the "3D area" the user can navigate his/her avatar (the avatar's hands are displayed in Figure 2b) and manipulate active objects. The avatar navigation is achieved by using the arrow buttons of the keyboard. It is important to notice that the avatar has "collision detection" so as to recognize solid objects such as walls, other avatars etc. In order for the user to carry out specific radiopharmacy scenarios, active objects that can be manipulated by the user are located in the 3D area. Examples of active objects are displayed in Figure 2f. The way that the user manipulates the equipment differs from object to object. The right mouse click on an object creates a menu that contains a list with the possible actions that the user can realize with the object. This list is generated dynamically and depends on the object itself, the location of the object and other objects that it may contain and/or

may be attached to it (Figure 2) or in his/her other hand. In addition, some equipment devices in the VR Laboratory, which are static, such as the Calibrator Display and Laminar Airflow operate with left mouse click on the device' s buttons.

During the process of a specific radiopharmacy scenario, when the user realizes an action that is not in accordance with the specific scenario, a warning message appears in the screen. The learner's modeling assist to this point, could be proven beneficial for learners by providing them additional information about their mistakes and by indicating to them guidelines in order to successfully continue the learning process. This functionality indicates that the VR Laboratory environment could be characterized as a place of user-system interaction and not a native learning environment.

5.2 Multi-user mode

The multi-user mode (Figure 3) of the VR Laboratory offers similar functionality with the study mode. The main difference is that in this mode the user can meet other learners and mentors who are also represented by an avatar and they can support him/her on the handling of the simulated equipment of the VR Laboratory as well as on the execution of the radiopharmacy scenarios, by using text and voice chat.

The interface of the multi-user mode of the VR Laboratory includes the following areas:

- 3D area (Figure 3a), which offers similar functionality to that of the study mode. Moreover the user can see the avatars of the other users who are on-line in the VR Laboratory at the same time (Figure 3k)
- Viewpoints (Figure 3c)
- Object description area (Figure 3d) and system feedback area (Figure 3e)
- Gestures area (Figure 3g), Online users area (Figure 3h), Text Chat area (Figure 3i), and Voice chat area (Figure 3j)

Using the buttons of the "gestures area" the user makes an avatar gesture, which is viewable by the other on-line users. This functionality is essential in a multi-user 3D environment because indicates the interactivity and friendliness of the environment. There are several ways that the user can communicate with other on line users by the use of gestures. These are: "I want to say something", "No", "Yes", "Good bye", and "View my hands".

In the "online users" area the user can see the names of the other users that are currently on-line in the VR Laboratory.

The functionality provided in the "text chat" area enables users to send text messages to other participants. Similarly the functionality provided in the "voice chat" area enables the users to discuss using voice.

The main advantage of the multi-user mode of the VR Laboratory is that it provides a virtual environment that allows learners to interact with other learners or with the equipment of the laboratory, exactly as it would happen in a real radiopharmacy laboratory. Thus, through his/her 3D representation, every participant has the ability to communicate, discuss and cooperate with other participants and together they have the ability to perform actions in the laboratory, having in mind that these actions must be in accordance with the specific learning scenario. Surely, it must be mentioned that as exactly it would happen in a real laboratory, the environment does not prevent a participant from doing an action that could possible cause the failure of the specific learning scenario.
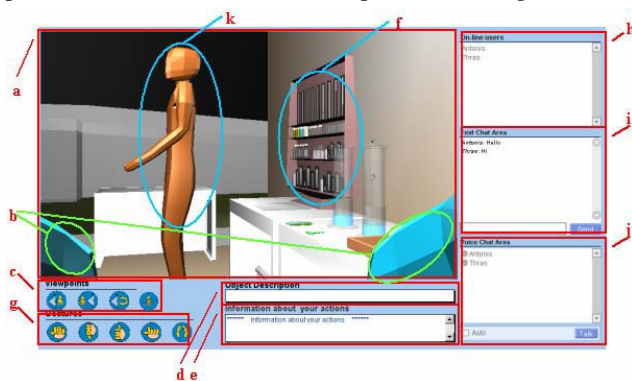

Figure 3: Multiuser mode of the VR Laboratory

6. Conclusions and Future work

In this paper we presented a first prototype of a 3D VR Laboratory. This laboratory tries to support both RBL and collaborative e-learning, by being accessed in two different modes, the study and multi-user mode, in order to enable radiopharmacy students to execute standard operation processes that take place in a real radiopharmacy laboratory as well as to support their communication and collaboration. Furthermore, it offers various communication channels such as gestures, voice and text chat.

The step that follows this first prototype is to conduct a user evaluation in order to fine-tune, and enhance the functionality integrated. Furthermore, we plan to integrate more simulations in the current prototype so as to enable the users to conduct more standard operation processes that could take place in a real radiopharmacy laboratory.

Moreover, we plan to enhance the study mode by integrating a learners' modeling system. Within the VR Laboratory, learners, will be learning on their own. Although peer group and mentor help are available through the communication channels of VR Laboratory, this help cannot be guaranteed, and hence some form of pedagogical assistance is likely to be required by the computer system itself. This need is emphasised by the requirement of the learner to be able to continue learning

at home and this potentially means needing assistance from mentors or peers at unsociable hours. This pedagogical assistance will be given on an individual level, based on the system's understanding of the learner's strengths and weaknesses both in his/her comprehension of radiopharmacy and of his/her ability to organise effective self-learning strategies.

Finally among the envisioned steps is to improve the user's representation by developing better avatars. The representation of a user is a delicate issue, because realism helps to understand processes, but graphics of avatars can take the view on what is happening at an apparatus. Therefore, there must be a lot of work in the direction of improvement avatar 's representation so as to be more functional and more attractive to the user.

7. Acknowledgements

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