X3D Multi-user Virtual Environment Platform for Collaborative Spatial Design

Ch. Bouras
Computer Engineering and Informatics Dept. (CEID), Univ. of Patras, Greece, and Research Academic Computer Technology Institute (CTI), Greece
bouras@cti.gr

Ch. Tegos
Computer Engineering and Informatics Dept. (CEID), Univ. of Patras, Greece
tegos@ceid.upatras.gr

V. Triglianos
Computer Engineering and Informatics Dept. (CEID), Univ. of Patras, Greece
triglian@ceid.upatras.gr

Th. Tsiatsos
Department of Informatics, Aristotle University of Thessaloniki, and Research Academic Computer Technology Institute (CTI), Greece
tsiatsos@csd.auth.gr

Abstract

It is well known that both space and the spatial organization play an important role in our work and learning environments as well as in everyday life. There is a definite need for many persons to design their space along with an expert and to preview it in order to test its functionality. Many times there is a need for the inhabitants and workers to collaborate in order to co-design their space from distance.

Multi-user 3D virtual environments are a powerful form of collaborative telecommunication applications, enabling the users to share a common three dimensional space and interact with each other as well as with the environment surrounding them, in order to collaboratively solve problems or aid learning processes. This paper presents the work done for extending a multi-user virtual environments platform, to support collaborative spatial design applications. Furthermore, a usage scenario is presented concerning the collaborative design of a classroom for educational purposes.

1. Introduction

The maturation of the Internet and the need for electronic communication formed the basis for the research and development of collaborative telecommunication applications. Collaborative Virtual Environments (CVE) is a promising form of this type of applications. More specifically, a CVE can actively supports human-human communication in addition to human-machine communication and it uses a Virtual Environment. The central concept of CVEs is the one of a multi-user virtual world, i.e. a computer generated space where participants can meet and interact. CVEs might vary in their representational richness from three dimensional 3D graphical spaces, 2.5D and 2D environments to text-based environments [9]. CVEs can enable the users to share a common 3D space and interact with each other as well as with the environment surrounding them, in order to collaboratively solve problems or aid learning processes. This is an exciting field with much potential for inter-disciplinary collaboration particularly in the fields of computer science, psychology, sociology, architecture and urban planning, cultural and media studies as well as artificial intelligence.

Collaborative virtual environments using desktop PCs are particularly useful for spatial activities when the participants are distributed [8]. This implies that they could be used in order to support spatial collaboration. According to [8], spatial collaboration is an everyday activity in which people work together to solve a spatial problem (for example, a group of people will often arrange furniture together or exchange directions with one another).

The work presented in this paper inspired from two different cases. The first one is to help people with disabilities to re-organize their personal or work space in a more functional manner. The second one is to help teachers to create more effective learning spaces according to special characteristics of their classroom and audience. A usage scenario concerning the second of the above–referred cases is presented in this paper.

This paper presents, also, a networked virtual environments platform that could be used to support distributed and collaborative spatial activities. This platform is an extension of an X3D enabled NVE platform called EVE (http://ouranos.ceid.upatras.gr/vr, [6], [7]). This technical platform has been selected due to a number of reasons such as cost-effectiveness, interoperability, as well as conformance with open standards (i.e. X3D) and technologies (i.e. Java).

This paper is structured as follows: The next section presents an overview on the related work done on spatial collaboration with the use of 3D CVEs as well as on the advances of X3D platforms. Following this (in section 3) the design characteristics and requirements of an application for spatial collaboration are presented. After that the technological solution and the issues faced during the implementation are presented (in section 4 and 5 respectively). Section 6 presents a usage scenario concerning collaborative design of a classroom for educational purposes as well as a prototype application.

Finally, some concluding remarks and planned next steps are briefly described.

2. Related work

This section presents an overview on the related work done on spatial collaboration with the use of 3D CVEs as well as on the advances of CVE multi-user platforms.

2.1 Work related to spatial collaboration.

There is some research work done on spatial collaboration using CVE. The main example is the work done in [8], which investigates how to support distributed spatial collaboration activities and presents a novel prototype that integrates both two-dimensional and three-dimensional representations. Our work differs from these project in terms of technological solution as well as from the communication channels included. Our scope is to rely on the use of the combined representations and the findings of [8] which highlight the usefulness of multiple representations and the need for additional features to support collaboration across representations. Another example is the prototype CALVIN. This system explores using different virtual reality hardware configurations, such as CAVE and Immersadesk technology, for collaboration. Although our scope is to design and develop a system for desktop CVE using only keyboard and mouse as input devices, the findings of this work are useful concerning the viewpoints usage [10], [11]. Another interesting work concerns VSculpt, which is a collaborative virtual sculpting system that

enables geographically separated designers to participate in the design process of engineering tools and sculptures. Although this work aims at supporting collaborative virtual sculpting, its findings concerning intuitiveness and real-time interaction are very useful for the extension of our platform [12].

2.2 State of the art in collaborative virtual environments platforms

According to the previous sections, collaborative virtual environments could support spatial collaboration applications. However, in order to provide an open solution that could be used by many users the collaborative virtual environments should be supported by platforms that are open and/or standards compatible. The current standard in this area is X3D [1]. Other requirements would be a web-based system, accessible by a typical web browser using a free plug-in.

This section presents an overview of the state of the art on X3D enabled networked virtual environment platforms.

Generally speaking there are many networked virtual environment platforms either commercial products or research platforms. The most significant commercial networked virtual environment platforms are the following: blaxxun platform (www.blaxxun.com), Bitmanagement solution (www.bitmanagement.de), Active Worlds (www.activeworlds.com), Octaga (www.octaga.com), and ParallelGraphics (www.parallelgraphics.com). The most significant research platforms are the following: DIVE: Distributed Interactive Virtual Environments (http://www.sics.se/dive, [3]), SPLINE: Scalable Platform for Large Interactive Environments (http://www.merl.com/projects/spline), VLNET: Virtual Life Network [4], [5], SmallTool [2] and EVE (http://ouranos.ceid.upatras.gr/vr, [6], [7]).

However, some of the above platforms are not supporting X3D standard at all and some of them are supporting X3D standard partially [7]. The most promising X3D enabled CVE platforms today are Blaxxun, Bitmanagement, Octaga and EVE solutions. Almost all these platforms partially support X3D standard, and offer good rendering functionality. However, the first three (i.e. Blaxxun, Bitmanagement, and Octaga) solutions are commercial and any extension and or programming, that requires additional technical implementation, cost additionally due to the additional cost of the respective SDKs. Furthermore, a commercial solution may have the risk of a closed solution due to each company's extensions to the standards.

IEEE
COMPUTER
SOCIETY

Therefore, it is obvious that in order to support X3D collaborative virtual environments the most mature solutions are the commercial platforms. However, the cost in this case is high. Thus, a promising technical solution could be EVE platform.

3. Design characteristics of an online environment for spatial collaboration

This section presents briefly the design characteristics of an online environment for spatial collaboration.

First of all, such an environment, as a CVE should include the general characteristics of a collaborative system. These characteristics are the follows:

- **Communication channels:** The environment should support communication among the collaborators in order to facilitate the interactions among them by supporting multiple communication channels such as avatar gestures, voice chat and text chat.
- **General collaboration characteristics:** The environment should allow the users to collaborate by distance by offering tools such as manipulation of shared 3D objects, locking /unlocking shared objects, as well as user handling. Furthermore, it should support at least two different roles of the users (i.e. trainer and trainee) in order to support not only collaboration but also training scenarios requiring users who have different roles and rights when visiting the environment.
- **Spatial collaboration characteristics:** According to [8], it is useful to represent the same space from nultiple representations (e.g. 3D viewpoint along 2D ground plan of the same environment). Furthermore, the users should be provided by tools for picking and moving furniture as well as tools and predefined models for designing their real space in the virtual environment.
- **Presence, awareness and support of users' representation:** 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. The environment could be populated by concurrent users, who could be represented in the environment. The use of avatars (3D or 2D) for user representation in virtual environment is a key feature for supporting e-collaboration. Therefore, it might be useful to represent the users by avatars that can support mimics and gestures, in order to support virtual and social presence as well as to enhance the ways of communication among the users with non-verbal communication.

The above aspects will be the basis for the final selection of the CVE platform.

4. Technological solution

This section presents the technological platform selected for supporting our spatial collaboration application. As described before the main goal of this paper is to present a networked virtual environments platform that could be used for supporting collaborative spatial design. The results of the related technical work dictate us that there are some commercial stable platforms that could be used for satisfying this goal. In addition, some of these platforms support X3D standard. However, the cost in this case is high. For that reason the authors of this paper have decided to use and extend an X3D enabled NVE platform called EVE. As a result, the EVE platform currently supports the following characteristics [7]:

- Flexibility and good rendering quality, since the large set of all X3D nodes can be used to create worlds that are visually more appealing, as well as better defined compared to a VRML world.
- A consistent shared 3d virtual environment for all users connected to the platform, which is highly interactive and allows for all possible functionality of an X3D world to be reliably shared among all connected clients. In other words EVE is stable in terms of network and multi-user behavior.
- An efficient physics system functioning locally on each client's machine, which is provided by the Xj3D library and based on the ODE open-source physics engine, as well as an efficient sound system.
- Text chat and audio communication, using H.323 for audio and chat bubbles for text chat.
- User roles and user management.
- Support for avatar gestures and body language
- A flexible, fully customizable and open client-multiserver architecture.

EVE platform is based on a client-multiserver architecture, which allows a simple sharing of the computational load among multiple servers. The main servers used by the platform are the connection server, 3D data server and a set of application servers, which add specific functionality such as audio and text chat to the platform. The architecture of the EVE platform is displayed in Figure 1. Modifying the EVE platform to support spatial collaboration applications requires the integration of another server called "2D Data Server" both on the server and the client side. These changes and the rationale behind them will be discussed in more detail in the next section.
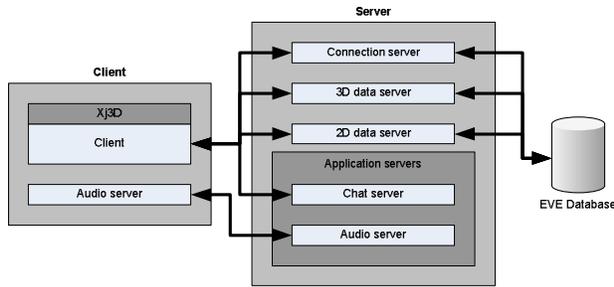
Figure 1: Architecture of EVE

5. Implementation issues

This section presents in technical terms the implementation issues faced in order to extend EVE platform.

5.1 Rationale of the EVE platform extension

Collaborative spatial design requires a flexible way for dynamic world manipulation such as the ability to dynamically load virtual environments and shared objects. This functionality was partially implemented in the previous version of the platform. However, a more stable and overall solution has been implemented in the extended version of EVE platform in order to accomplish the demand for dynamic node loading.

The previous version of EVE has integrated an X3D event-handling mechanism responsible for serving events related to the virtual world. This mechanism overrides SAI and EAI in away that events are sent to all users connected to the platform. In order to create dynamically nodes a specific event is sent to the 3D data server, containing the node to be added and the parent (default is root) to make this node its child. This event is then broadcasted to online users and is added to an X3D representation of the world it belongs. This representation is kept in the server and it is broadcasted to new users that sign in. It should be pointed out the fact that users that are already online and connected to the platform receive only the newly added node thus networking load is significantly reduced. Once online clients receive one node it locally adds it to its VRML-X3D Scene.

The role of EVE serving as a collaborative spatial design platform increased the demand for effective non-X3D event handling. There is a need to handle events such as database queries to retrieve objects and 3D environments from the virtual worlds and shared objects database, as well as swing events for the 2D Java Swing representation of the virtual world. Thus an additional server called "2D data server" has been developed.

The choice not to embody the new functionality to already existing servers is due to two reasons. First, the data nature of the "application events" (i.e. non-X3D events) is different from data types handled by the rest of the servers. The second reason is load-sharing.

5.2 "Application events" structure

This paragraph explains how "application events" are structured. First of all, an effective class that would allow the abstraction of the characteristics of an event was needed, in order to manipulate the events effectively.

A new class was created called AppEvent.class. Each appEvent has a type variable which describes the type of the event e.g. Java Swing component or SQL query. These variable accept certain values corresponding to predefined types of events. Five types of events are currently supported:

- SQL Database query (which is a string representing an SQL query)
- JDBC ResultSet (a JDBC ResultSet class)
- Swing Component (such as labels, shapes, etc.)
- Swing Events (such as altering the location of a Swing Component)
- Ping: Used to verify that the connection between the server and the clients is available.

A value variable contains the actual data that we want the event to carry. When handling Swing events a target variable relatively to the type of the event (Swing Component or Swing Event) indicates the parent of the component to be added or the component of which we want to alter one of its fields.

AppEvent class has also methods for streaming itself.

5.3 Server modifications: Integration of the "2D Data Server"

EVE, as already mentioned, consists of several servers. As described before, the current set of servers is not managing 2D events (such as swing events and database queries). For that reason an additional server called "2D data server" has been integrated in EVE platform.

The server is responsible for handling "application events. This operation is described as follows:

Firstly a client establishes a connection to the server by using a ClientConnection class. This class deals with connection related issues such as sockets server ports etc. Once a connection has been established two threads, one responsible for sending and one for receiving AppEvent instances, are created for each client. On the client side a thread responsible for AppEvent handling and server Communication is

created. Each ClientConnection instance features A First-In-First-Out (FIFO) queue for storing unhandled events. The receiving thread examines if the event is to be executed in the server(e.g. Database query). In that case it executes it and if necessary creates another event (e.g. ResultSet). Otherwise it enqueues the event in the ClientConnection FIFO queue. After that the sending thread takes the first pending event and sends it to all clients.

At the client side, the thread receives the events and handles them accordingly.

5.4 Client modifications

The original EVE client is a java applet, which handles all communication with the servers. The java applet includes a plug-in based on Xj3D toolkit in order to do the rendering of the virtual world.

This plug-in is extended by a 2D interface. This interface contains a number of panels providing different functions. Besides the already existing panels (i.e. gesture, chat and lock panels), a set of two new panels is introduced:

- The "2D Top View Panel": This panel was embedded to the UI as tool for re-arranging worlds in collaborative spatial designs. It illustrates the floor plan of the world and its objects. A user can move an object inside the limits of the world thus the limits of the panel and then watch the corresponding X3D object moving in the virtual X3D world. The introduction of this panel is of great importance. Not only does it give a better inspection of the object arrangement in the world, making it easier for the user to choose the modifications to be applied, but it also functions as lightweight object transporter. The events occurring on that panel are shared with the rest of the online users.

- The "Options Panel": When dealing with collaborative spatial design options such as object lists and classroom information are a necessity. For that reason the option panel features options depending on the application. For example in our usage scenario study, which is presented later on, this panel features options such as an object chooser list, a classroom object list, number of copies of certain objects to be inserted etc. The option panel must be well organized because the appropriate visualization of the information will make it easier for the user to interact with the platform.

6. Usage cenario: Collaborative design of a multi-grade classroom

This section presents a usage scenario of the extended EVE platform. This scenario concerns the teachers of multi-grade schools and aims to support them to organize their classrooms spatially.

Multi-grade teaching occurs in primary education when a teacher has to teach two or more primary school student grades in the same class. In multi-grade schools a relatively small number oft teachers try to be effective in their educational work while dealing simultaneously with a number of pupils of different ages, educational levels and needs. In most of the cases the multi-grade school is the only viable school formation in rural environment and the effort should be focused on improving the teaching and learning conditions in this school formation. The following usage scenario shows how to support the teacher of a multi-grade classroom to organize spatially the classroom of its school in a collaborative way with an expert by utilizing EVE platform

The scenario has two main variants on how the classroom is organized. These two variants offer maximum flexibility on the classroom set up and they are the following:

- **Usage of predefined classroom models with classroom reorganization ability**: This variant offers quick classroom setup and the ability to move existing objects or add new. Its purpose is to approach the real school classroom through predefined classroom models. The procedure that a teacher has to follow is to choose one of the predefined classroom according to his/her criteria. Once the teacher selects a predefined classroom in which specific objects are placed has two options. The first is to select from an object list new objects to add. The second is to rearrange already added components. When a teacher loads a classroom a top view is created in a 2D panel next to the 3D world. Each 3D object has a 2D representation. The teacher can move an object in the 2D view. Accordingly the corresponding X3D object will be re-located in the virtual world. This scenario is preferred when the features and the customization needed for a classroom have to do mainly with objects' location and re-orientation. In that case the avoidance of having to select an empty classroom and fill it with object saves much time.

- **Creation and set up of a virtual classroom using object library**: Sometimes a teacher has increased and more complicated criteria concerning a classroom setup. For example, s/he may want to select the size or shape of the virtual classroom, add specific objects etc. If that is the case EVE

offers the ability to select from a variety of objects stored in a database library. Extended customization is offered by this model enhancing more precise customization. The teacher chooses from an empty virtual classrooms list according to his need. Then s/he adds the kind and number of objects s/he likes. Moving the 3D objects is supported as well in the same way supported in the first variant of the scenario. This variant may require a little more time for teacher to setup a classroom but its abilities are extended.

During the above scenarios the teacher (who is the trainee) could collaborate through chat with the expert (who is the trainer) in order to rearrange the classroom. Furthermore the expert can take the control to organize the classrooms. These scenarios are supported by an intuitive user interface (Figure 2), which gives the teachers the ability to select among a number of empty or already customized with objects classrooms.
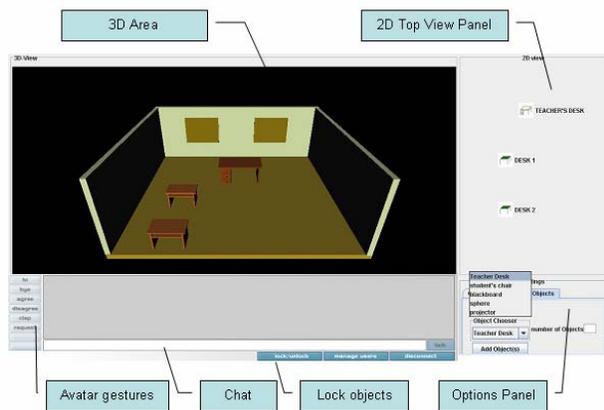
Figure 2: User Interface

A list of objects is available for the teachers to add in the virtual classrooms. Moreover, a teacher can move objects in the 2D floor plan. This plan contains a 2D representation of all the objects in the classroom. Dragging an object in the 2D view moves the corresponding object in the 3D world accordingly. A chat panel is responsible for the chat communication between teacher and the expert.

7. Conclusions- Future work

This paper presents new additions and capabilities of the EVE platform and a case study of collaborative spatial design. The new embedded features address the problem of distributed virtual worlds' arrangement of objects. Our case study demonstrates this. EVE platform has two new characteristics that make her unique: the ability to dynamically alter any characteristic of a virtual world and an event-handling mechanism appropriate for any kind of event. These

characteristics combined with the previous functionality of the platform allows us to improve the platform in various ways. Furthermore, this paper has presented a usage scenario for collaborative spatial organization of a multi-grade classroom. Our next step has mainly to do with extended world setup abilities. Particularly, a user will have the abilities to add his/her custom X3D objects, change a classroom's dimensions, and visualize possible collisions. Collisions may occur due to the following reasons: (a) specific spatial setup models; (b) accessibility to emergency exits in case of an emergency situation; (c) routes a teacher follows during class time; and (d) students co-existence problems.

8. References

[1] Web3D Consortium, http://www.web3d.org/

[2] W. Broll, "SmallTool - a toolkit for realizing shared virtual environments on the Internet", *Distributed Systems Engineering Journal, Special Issue on Distributed Virtual Environments, Vol. 5.* The British Computer Society, The Institution of Electrical Engineers and IOP Publishing Ltd, 1998, pp. 118-128.

[3] C. Carlsson, and O. Hagsand, "DIVE: a Multi User Virtual Reality System", *in Proc. of IEEE 1993 Virtual Reality Annual International Symposium,* VRAIS '93, Piscataway, NJ: IEEE Service Center, 1993, pp. 394-400.

[4] I. Pandzic, T. Capin, N. Magnenat-Thalmann, and D. Thalman, "Towards Natural Communication in Networked Collaborative Virtual Environments", in Proc. of *FIVE '96*, Pisa, Italy, 1996.

[5] I. Pandzic, N. Magnenat-Thalmann, and D. Thalmann, "Realistic Avatars and Autonomous Virtual Humans in: VLNET Networked Virtual Environments", *Virtual Worlds in the Internet* (R. Earnshaw and J. Vince, eds) IEEE Computer Society Press, 1998.

[6] C. Bouras, E. Giannaka, A. Panagopoulos, T. Tsiatsos, "A Platform for Virtual Collaboration Spaces and Educational Communities: The case of EVE" *Multimedia Systems Journal, Special Issue on Multimedia System Technologies for Educational Tools*, Springer Verlang, , 2006, Vol. 11, No. 3, pp. 290 - 303

[7] C. Bouras, A. Panagopoulos, T. Tsiatsos, "Advances in X3D multi - user virtual environments", *IEEE International Symposium on Multimedia (ISM 2005)*, Irvine, California, USA, , 12 - 14 December 2005, pp. 136 – 142

[8] W. Schafer, D. Bowman, "Integrating 2D and 3D views for spatial collaboration", *Proceedings of the 2005 international ACM SIGGROUP conference on Supporting group work*, 2005, pp. 41 – 50

[9] D. Snowdon, E. Churchill, A. Munro. "Collaborative Virtual Environments: Digital Spaces and Places for CSCW: An Introduction", in "*Collaborative Virtual Environments: Digital Places and Spaces for Interaction* (Snowdon D., Churchill E, Munro eds.), ISBN 1-85233-244-1, Springer-Verlag, 2001.

[10] J. Leigh, A.E. Johnson. "Supporting Transcontinental Collaborative Work in Persistent Virtual Environments". *IEEE Computer Graphics and Applications*, 16(4), 1996, 47- 51.

[11] J. Leigh, A.E. Johnson, and T.A DeFanti. "CALVIN: an Immersimedia Design Environment Utilizing Heterogeneous Perspectives". In Proceedings of the *IEEE International Conference on Multimedia Computing and Systems*, 1996, 20-23.

[12] F. Li, R. Lau. "VSculpt: A Distributed Virtual Sculpting Environment for Collaborative Design", *IEEE Transactions on Multimedia*, Vol. 5, no. 4, December 2003