A Toolbox Supporting Collaboration in Networked Virtual Environments

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Abstract. A growing interest in Collaborative Virtual Environments (CVEs) can be observed over the last few years. Geographically dislocated users share a common virtual space as if they were at the same physical location. Although Virtual Reality (VR) is heading more and more in the direction of creating lifelike environments and stimulating all of the users senses the technology does not yet allow communication and interaction as it is in the real world. A more abstract representation is sufficient in most CVEs. This paper provides an overview on tools which can be used to enhance communication and interaction in CVEs by visualising behaviour. Not only is a set of tools presented and classified, an implementation approach on how to use these tools in a structured way in form of a framework is also given.

1 Introduction

CVEs have emerged in various forms in the recent years. Interaction and communication in these environments are realised in many different ways. The users can send text messages, use audio and video communication; they can change attributes of the simulation, can share data and might even be able to collaboratively manipulate this data. Our research concentrates on environments using desktop VR or immersive VR systems such as Head Mounted Displays (HMDs) or CAVEs [4]. In these environments the users can manipulate objects with natural interaction techniques and experience the feeling of co-presence.

Performing collaborative tasks in Networked Virtual Environments (NVEs) is more difficult than performing them in a real world environment through the limitations of the interfaces. Different factors such as latencies, abstract graphical representation, limited field of view (FOV) and precision of input devices make natural interaction a challenging task. VR technology on the other hand provides many possibilities to enhance or even to completely change the users perception of the Virtual Environment (VE). Collaboration to the level that two users can manipulate the same object simultaneously [3] combined with natural interaction offers new challenges in the area of computer supported cooperative work (CSCW).

Although some systems support this collaboration on a technical level, i.e. they provide networking, allow for concurrent object manipulation or provide

audio communication. However no tools exist so far which allow a rich enhancement of the VE to support collaboration on a more abstract level by visualising additional information about the users and the interaction. Worlds can be shared and manipulated, but an abstract toolset visualising collaboration is not available yet. This paper presents a set of tools which can be used to support collaborative work in immersive NVEs. The tools are described in their functionality as well as their benefit for collaboration. All of these tools augment the environment in a way which is only available through VR technology. Communication and interaction could be improved through the use of these tools. This approach tries not to overcome technical issues such as lag or limited FOV, it rather enhances the VE with additional information which is not available in a real world environment. The toolbox is integrated into a CVE framework, which provides support for collaboration on a technical level.

This section has given an introduction on the topic of NVEs and collaboration. The following section shows an insight into the area of related work. Section three presents different tools which have been identified as supportive for collaborative tasks. The fourth section will give an overview on the architecture of the collaborative toolbox. The last section concludes the paper and shows some future work in the area.

2 Related Work

Numerous research has been done in the area of NVEs and CVEs. Good overviews on these topics are given in [8], [9] and [11] on a technical level. They describe how VEs have to be designed to be scalable and interactive. Psychological aspects of collaborative tasks in NVEs have been examined [16]. Users perform placing tasks to build up cube, while their behaviour is analysed. Aspects of collaboration have been researched in a medical visualisation in [6]. Audio and video communication are used in this scenario with several different projection VR systems. Advantages and disadvantages of different VE systems and different communication methods are analysed.

Cooperative object manipulation has been researched by many authors. Good examples are given in [14] where different attributes of single objects can be changed simultaneously. In other scenarios such as the piano carriers [15] the users are able to manipulate the same object simultaneously in a way that they manipulate the same attribute concurrently. In these examples the position of the manipulated object results from a transformation based on both user inputs. This is concurrent object manipulation in a three dimensional environment is described in [10] as the highest level of collaboration. All these scenarios incorporate complex communication and interaction, but none of them provides abstract tools in form visualisation of collaborative activities.

Many NVEs exist but none exploits the support of collaboration the level desired. CAVERNSoft G2 [5] provides a collaborative geometry viewer. The users have the possibility to share a scene in a VE. While discussing the scene

they are able to manipulate it sequentially or they can indicate areas of the shared world using a virtual pointing device.

CVEs usually have avatar representations which represent an embodiment of the user. One example approach using avatars is given in [13]. There is full anatomically based body articulation possible which allows the use of postures and gestures in a CVE. Avatars allow dislocated users in a VE the feeling of co-presence. Good overviews on the design of avatars are given in [1].

3 Tools

Different categories or classes of tools can be identified for the support of collaboration in immersive VEs. They range from visual to audio support. The field of haptics becomes more and more important in the area of collaboration but is not researched in this project. The tools presented are categorized into 5 different areas. Gaze visualisation enhances the local users information about the remote users perception of the world. Object highlighting allows users to clearly show interest on certain objects in the VE to remote users. An overview of the whole VE is shown to the users by the map tool and complex movements can be stressed by the use of the movement visualisation tool. Sonification is another aspect which is important especially when feedback is needed and textual messages would decrease the feeling of immersion.

3.1 Gaze Visualisation

Gaze visualisation helps the collaborating partners to see of what the dislocated users are possibly aware of. This tool is especially useful, when the FOV of the users is limited, which is the case when HMDs or desktop VR systems are used.

Since most VR systems do not analyse the actual gaze of the user a rough approximation is used. It is based on the gaze vector of the avatar. On desktop systems the centre of the screen is assumed as the centre of interest of the user. In immersive environments, where head tracking is available the gaze vector is based on orientation and position of the head sensor. On a desktop system the centre of the screen is used for approximation of the users gaze. Locally the gaze centre can be displayed by a crosshair.

Frustum Visualisation. This type of gaze visualisation enables other participants in the environment to see what parts of the scene the remote user could see. The frustum is displayed with a very high transparency value not to irritate the observing users or to hide objects from them. In the case of desktop VR or HMDs one frustum is displayed. If several camera orientations are used for the different display walls as in the case of CAVEs or multiple screen installations the setup data of the display walls is transferred to the remote users and several frustums, one for each used screen, are displayed. Using stereo display the frustums of the left and the right eye are merged together.

Gaze Vector Visualisation. The gaze vector indicates not only the direction the user is looking; it indicates as well the distance of the far clipping plane

from the viewing frustum. A line is displayed from the avatars gaze centre in the direction of the gaze. The line stops at the far clipping plane.

Parameters of the gaze visualisation are color, opacity and color range which will allow different frustum or vector visualisations for different remote users.

3.2 Object Highlighting

The possibility to highlight objects in a NVE allows users more easily to show to each other about which object they are discussing or with what they intend to interact. In [12] several interaction techniques were suggested for object selection. These interaction techniques could easily be used for displaying an interest in certain objects. CVEs could profit from the use of two particular ways for highlighting of objects.

At-a-Distance by Pointing. The user points at a certain object with his input device. The position and orientation of the wand are measured, a ray is cast in the scene and the first object of which the bounding volume is hit is highlighted. On a desktop VR environment either a picking algorithm is applied to check where the user points with the mouse or the avatars hand movement is implemented by emulating a tracked users hand.

Gaze Directed. The user looks at a certain object which will be highlighted. For this the gaze vector calculated by the mechanisms described in the previous section are be used. The first bounding volume which is hit by the gaze vector is highlighted.

These selection techniques can be used continuously during the whole simulation or they can be toggled by input signals from a wand, a mouse or a keyboard. Several possibilities arise as well in the way how the highlighting is done. The whole object or it's bounding volume can be highlighted by a colour change or a change of the objects opacity. Instead of color change flashing of the color can be applied to get more attention. If flashing of an object is enabled, the color change is activated after a the object is selected for certain amount of time.

Parameters of the object highlighting are similar to the ones given in gaze visualisation. Color, opacity and color range highlight the objects geometry or the objects bounding volume. The time to activate flashing after selection has to be set as well.

3.3 Movement Visualisation

Complex movements can be visualised in many ways. In the area of cartoons which represent their own reality in a more abstract way complex motion is visualised by the use of motion lines. The support of this framework is given by motion lines and shadow objects. Considering two dimensional CSCW applications the use of motion lines has been suggested by [7].

Two different types of motion visualisation are given by the framework. Lines at object vertices can be drawn as well as shadow objects can be displayed.

Motion Lines. Motion Lines are drawn between two positions in the time line. A point taken into account for representation of a motion line is a vertex from a moved object. Using the motion lines it is not only possible to display the area where the object was moved. By changing color, opacity or length of the motion line it is possible to display the speed as well.

Shadow Objects. A shadow object is a copy of the geometry of the actual object with a higher transparency value. Options in this tool allow the amount of shadow objects displayed in a set timeframe with constant transparency or increasing transparency over the time. Shadow objects can be connected with motion lines from one time frame to another.

Since the use of shadow objects and motion lines can produce a high amount of geometry data displayed it is possible to display bounding volumes or draw lines between the different bounding volumes instead of using the whole geometries. Less computational power is required in that case especially if the original object consists of a high amount of polygons.

Movement visualisation is not only important for moved objects; it can be a powerful tool to display avatar movement as well. The movement of the whole avatar as a single object can be displayed, in the case of immersive VEs as the movement of its hand can be displayed as well.

The parameters for the movement visualisation describe how long a line or a shadow object shall be displayed. A fading factor specifies the opacity of the fading object.

3.4 Maps

Maps in NVEs can support spatial orientation and allow users to easily navigate to their desired location in the world [2]. Using landmarks in larger environments or floor plans in smaller environments allows users to discuss where they meet in the VE.

The map has different levels of detail depending on the current zoom factor. The smaller the displayed area is the more detail is given. An abstract representation of large geometries is given from a top perspective. This is realised by projecting the bounding volumes of large objects like buildings and landmarks on the map. The next level of detail shows the geometries of the large objects. Additionally it is possible to enhance the map with textual information. If the VE simulates a city, street names and names of buildings can be given.

Supporting collaboration an avatar radar is implemented which displays all surrounding avatars. If one avatar speaks to the client via voice connection the avatar can be highlighted on the map for a set period of time. The names of the avatars are displayed on the map as well. If a users avatar is interacting with objects in the scene a zoom on the map should automatically indicate an interaction. The focus on the map displays the interacting avatar from a top view with the object he is interacting with. Different states of the user in the environments can be visualised by different colours or textual output. Avatars can be highlighted in a different way when they are working with objects, when they are talking, when they are moving or when they are idle.

Parameters of the map include initial scale, level of detail, avatar visualisation and additional textual information.

3.5 Audio

Sonification of additional information can be useful in NVEs. If avatars are entering or leaving the environment the users should be notified. A voice notification that a user has entered the environment is given. In order to not to reduce the immersion, status messages can be given via audio rather than being displayed in a status window. If a collision with an object has happened or a user has picked up or selected an object audio feedback provides a useful addition to the visual cue. The volume of the audio can be set as a parameter. Different aspects of the sonification can be turned on and off, some of these values are user entry notification, interaction messages, system messages and collision messages.

4 Toolbox Architecture

The core of the toolbox is formed by the toolbox object which contains a list of available tools. Depending on the tool changes are performed once, like gaze visualisation where the frustum or the gaze vector are added to the scene graph, or several times like object highlighting, where it has to be constantly checked whether a new object has been selected or not. Each tool uses an update method which will be called once or every frame. This is defined by an update flag which can be set. Designing your own tools becomes a very easy task, by deriving from existing tool classes and overriding the update method. All tools in the framework can be activated or deactivated individually. The configuration file

Fig. 1. Toolbox Architecture

is stored locally in an XML format providing the initial setup. The different attributes of the tools can be changed dynamically during runtime. Additional tools can be activated or already active tools can be turned off. The users have to be able to choose which tools suit them best.

The tool setup can affect the VE in three different ways. The tools can be activated for the avatars representing the remote users locally, which allows enhancements of the perception of what the remote users are doing. Examples were discussed in section three. The second possibility allows the users to enable some of their tools locally, an example would be in the area of sonification if a user is notified if he picks up or uses an object in the VE. The last possibility allows the user to share his configuration file with other users. They could get information which tools the user has activated. Figure 1 gives a rough overview of the communication between the different components of the toolbox and other modules in the CVE.

5 Conclusions and Future Work

The paper has described a selection of tools which can be used to improve collaborative activities in a NVE by augmenting the VE. The users working with these tool are able to perceive the environment with additional information such as the gazing direction, viewing area, movement visualisation of the dislocated user. The tools represented were explained in functionality as well as in their meaning for collaboration. Modular design allows users to select the type of additional information they want to have displayed depending on their needs. The framework including this toolbox can be used as a testbed for the analysis of human behaviour in CVEs. Additional logging mechanisms which record tracking data and other user input can be used to replay the whole simulation after the collaborative task is completed. For analysis it can be helpful to enable the frustum visualisation afterwards for example.

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