Chapter 4

Application

This chapter describes an example Collaborative Virtual Environment in detail. It shows how all the issues mentioned in earlier sections of chapter 3 are used for selecting the most appropriate representation components, metaphors, operations and interaction techniques. In order to depict the User+Need Space as well as the Application+Interaction Space the same representations as in section 3.8 are used. The CVE presented in this chapter, with slight modifications is the basis for the description of the hardware setup in chapter 5 and the evaluation in chapter 6 assessing usability and collaborative awareness. However, the description of this decent CVE and its user scenario stands exemplarily for other rear projection based CVEs developed within this thesis.

4.1 CVE with two Responsive Workbenches

4.1.1 User Task Description

In order to perform a User Task Analysis (UTA) a detailed User Task description (UTD) needs to be provided. Due to its importance to the scientific community as well as to the novel ways education is carried out the following UTD describes a collaborative education scenario using an anatomical content.

Two users, an anatomy professor and a medical student work together on a virtual human data set. They stand opposite each other on either side of a table. They are able to walk around the table and to have a look from the other side onto the virtual human data set. The data set consists of human body skin and an underlying skeleton and heart model. Both users are able to cut the skin in order to see the underlying bones and inner organs, to pick bones, to drag and query extra information about them. The data set is used for anatomical education. Names of all bones can be queried as well as their

affiliation to the body's right or the left hand side. Additionally, test (exam) scenarios can be uploaded where different bones have to be compared with each other and inserted into the skeleton according to their functionality. The professor as well as the student have possibilities to verify the correct position of the bones inside the skeleton. In addition, both are equal in their possibilities while working on the data set.

The User Task Analysis leads to the following application design according to all items that have been introduced in chapter 3.

4.1.2 Input Devices - Output Device Combination

- stylus (practical)
  - reason : Easy to handle, suitable for both hands, the professor can pass it over to another student if the session is extend to three or more users for example.
- three button tool (practical)
  - reason : Easy to handle, suitable for both hands. Due to the buttons more high-order functions available like changing the viewpoint, changing the test scenario etc.
- pinch or data glove (practical)
  - reason : Good representation of the using hand and thus direct manipulation is possible. But it can only be used with one hand. Further it is uncomfortable to use when trying to pass it to the partner. Within the described application they are not used, which is the first design decision.
- video camera as the remote partner representation is a video texture.
- microphone for communication.
- Responsive Workbench (practical)
  - reason : Handling the data set and working with the tools can be displayed excellently. For this kind of scenario the RWB is the optimal display system especially as the virtual human data fits within its viewing frustum almost without scaling.
- CAVE (not practical)

  - reason : The CAVE is too oversized for the education session. Handling the data set does not require such a huge virtual interaction space as the CAVE offers. In addition using a CAVE at one or even both sites implies more rendering power.

- Wall (not practical)
  - reason : according to the fact that the data is needs to be viewed as on a table the Wall display system is not very practical since it does not provide this working metaphor.

- cylindrical projection (not practical)
  - reason : see argumentation for the CAVE

- headphones (practical), speakers (practical)
  - reason : The recommendation for using headphones instead of speakers is due to the reduction of acoustical feedback loops. As the scenario is designed to have one person on either site headphones are recommendable. However, headphones are not very comfortable to use, especially in combination with stereo glasses. A three or more user CVE with at least two users at the same site would need to have speakers in order to support natural communication at this site.

4.1.3 Generic Operations

- **select/grasp** - (either the bones or the whole body or the tools)

  Action
  * the user points with the virtual pick ray to the data set and presses a button of the stylus or three button tool
  * the user points with the finger to the data set and snips with the thumb and the middle finger when using pinch gloves

- **translate** - (e.g. in order to position a bone inside the skeleton or to obtain a better view of an object)

  Action
  * the user 'selects'/'grasps' the bone or the body and moves the hand together with the selected object (this action is restricted because of the limited interaction space in front of the RWB)

  * the user selects the group drag tool or the selective drag tool and applies it to either a bone or the whole body.

- **rotate** - (e.g. in order to position a bone inside the skeleton or to obtain a better view)

  Action

  * the user 'selects'/'grasps' the bone or the body and moves the hand together with the selected object (this action is restricted because of the limited interaction space in front of the RWB)

- **zoom** - (e.g. in order to get a closer and better view on the data set)

  Action

  * the user 'selects' and 'translates' the data set and moves the hand closer to the eyes
  * the user changes its position (goes closer to the data set)
  * the user selects the zoom tool and applies this to the data set

4.1.4 Content Specific Operations

- **change the geometric form when cutting the body skin**

  Action

  * the user calls the ring menu, 'selects' the knife icon through rotation of the wrist from the disc segment, gets a 3D frame attached to the left hand and moves the hand to cut the body skin.

- **change the visualization mode from solid into wireframe rendering**

  Action

  * the user calls the ring menu, 'selects' the 3D grid icon through rotation of the wrist from the disc segment that switches the body into wireframe mode and vice versa. The already selected tools remain in the user's hand during this operation.

- **change the visualization mode from opaque to transparent**

  Action

  * the user calls the ring menu, 'selects' the color lookup icon through rotating the wrist from the disc segment, gets a 3D slider, moves the slider with the selective drag tool attached to one of the input devices in the hands and thus changes the transparency.

- **change of the view point** - (for verification purposes and in order to get a better view.)

  Action

  * the user moves the head physically and looks from a different position.
  * the user presses a button on the stylus or three button tool and 'rotates' the viewpoint as long as the button is pressed.

- **query information** - (in order to query the name of the bone or to find out whether the bone belongs to the right or the left hand side of the skeleton.)

  Action

  * the user selects the special information tool from the toolbar through 'selecting' the 3D "i" letter icon, touches the desired bone and clicks the stylus button.

- **undo function** - (in order to remove the bones from wrong positions, to snap the bones into the destined positions or to verify the bone's position.)

  Action

  * the user selects the special snap back tool from the toolbar through 'selecting' the 3D hook icon, touches the desired bone and clicks the stylus button.

4.1.5 Metaphors

- for the position of the partners:
  - *eye-to-eye contact, data set between the partners*
- sharing viewpoint:
  - *look through the other's eyes or over the other's shoulder* : this metaphor enables the users to slip into the partners position and to have a look from the other side onto the data set. This metaphor is especially useful working opposite each other within a limited virtual work space or for teacher/student scenarios.
- for the communication and collaboration between the partners:
  - *ring-up and join session*
  - *turn-taking conversation*

- for the rotation operation:
  - *rotate the data set(s)*
  - *walk around the data set(s)*
- for the zoom operation:
  - *change user's position (go closer to the object)*
  - *scale the data set itself*
- for the collaborative manipulation of the data sets:
  - *tug-of-war* : This metaphor allows both users to apply operations on the data set at the same time. No locking mechanism is implemented. The advantage is that the first user can hold the skin cutter with one hand and position the bone inside the skeleton whereas the second user controls the body's position and size. The drawback is that both users have to know exactly what the other one is doing as uncoordinated interaction will result in a real tug-of-war situation.

4.1.6 Interaction Techniques

- menus : for the generic and content specific operations: zoom, rotate/translate, snap back, query, change geometric shape and visualization mode
- virtual pick ray : for the selection with the stylus input device and in order to apply the operation

4.1.7 Types of Feedback

- *highlight*: bones which are manipulated by the local user are highlighted in red, the ones manipulated by the remote partner are not highlighted. Respectively, for the remote user the bones manipulated by himself/herself are highlighted in red as well. The idea behind is that although a user needs to be aware of the remote partner's actions local own actions have higher priority.
- *pick ray and tool representation colors*: The tool pick rays and tool representations used locally are red and yellow for the ones of the remote user. Menu pick rays are represented locally in green and blue for the remote user.

- *textual feedback about remote viewpoint*: as the remote partner can change the viewpoint independently, the local user needs a feedback about this change. Therefore a text in the upper left corner of the RWB's back face reads "Student/Professor stands opposite you" or "Student/Professor stands beside you".

- *disappearing texture representation as local viewpoint feedback*: If the local user changes the viewpoint from eye-to-eye contact into the sharing viewpoint position the video representation of the remote partner disappears.

4.1.8 User Representation

- no representation

  - reason: When using rear-projection systems like the Responsive Workbench no representation form for the user itself is necessary in contrast to using HMDs.

- video image of the partner

  - reason: Using the video texture in rear-projection systems is a useful representation form for the remote partner. Additionally as the display systems are two Responsive Workbenches, the video image is mapped on the vertical face of the Responsive Workbench. This supports face-to-face communication and the perception of the remote user standing on the opposite side of the table.

- no Avatar

  - reason: Both users need to see each other like they would do in real exam situation. So the CVE programmers and designers need to create an extremely realistic avatar including muscles and body movements. As this requires much more additional computing and rendering power and network bandwidth a further design decision is formulated against using avatars.

4.1.9 Representation and Functionality of the Data Sets

- virtual models of the body skin, skeleton and heart.

  - the skin can be rendered in wireframe and in transparency mode.

- the heart does not need to beat since this is an anatomy session. It lies statically inside the body and only supports orientation. This implies no additional animation and rendering.
- the bones of the skeleton can be moved separately. Assigned to each bone is its name and the side of the skeleton it belongs to. This information can be queried by both users.

4.1.10 Representation of the Environment

- a virtual model of the environment is not recommended as the student user has to focus on the anatomical task. Although the aim of the virtual session is to transfer the learned to real world situations there is no need for rendering the inventory of a pathologic laboratory for example.

4.1.11 Representation of the Tools

- virtual models for the representation of the tools when they are in use:
  - group drag tool (3D cross with three orthogonal axes)
  - selective drag tool (pick ray with 3D arrow)
  - scale tool (magnifying glasses)
  - information tool (pick ray with 3D "i" letter)
  - snap back tool (pick ray with 3D hook)
  - skin cutting tool (3D frame)
  - transparency tool (3D slider)
  - wireframe tool (switch button)
- virtual models for the representation of the tool icons on the menus:
  - fixed 3D toolbar with 3D buttons and 3D tool icons
  - half transparent 3D ring menu disk consisting of 12 disc ("cake") segments
  - group drag tool (3D three cross with two axes on the fixed 3D toolbar button)
  - selective drag tool (3D arrow on the fixed 3D toolbar button)
  - scale tool (magnifying glasses on the fixed 3D toolbar button)
  - information tool (3D "i" letter on the fixed 3D toolbar button)
  - snap back tool (3D hook on the fixed 3D toolbar button)

- skin cutting tool (3D knife on the ring menu disc segment)
- transparency tool (3D colored lookup icon on the ring menu disc segment)
- wireframe tool (3D grid button on the ring menu disc segment)

4.1.12 Representation of the Input Devices

- virtual pick rays
  - reason: useful when using a stylus and three button tool. Some of the tool representations use pick rays in addition to their 3D icon (see above). The functionality of the pick rays is distinguished by their color. So, the pick ray for calling the ring menu is green (blue for the remote user) whereas pick rays connected to tools are red (yellow for the remote user).

4.1.13 Work Mode

- distributed, collaboratively and data sets are provided by one of the sites, or by a remote (external) data server.

The representation components as well as the operations, metaphors and interaction techniques are put into practise designing and implementing a Collaborative Virtual Environment for education purposes. Two snapshots of a real session in this CVE are shown in Figure 4.1.
The images show the two users working together (collaboratively) on an anatomical virtual human data set. Each snapshot is made from either site of the collaborative scenario. In the upper left and right corner the information about the partners viewpoint is displayed. This provides the feedback necessary for communication purposes. In the middle of the back face of each RWB the small finger sized cameras are visible. They are mounted this way to minimize the viewing angle onto the remote partner. If the camera would have been placed outside the viewing frustum, algorithms for image reconstruction of the front view were necessary. With these CPU intensive reconstructions the real-time requirement of CVEs would not be fulfilled.

4.2 CVE design using other display systems

4.2.1 CAVE-RWB

Many more applications using different display combinations are implemented within this thesis. The same application provided above is implemented using

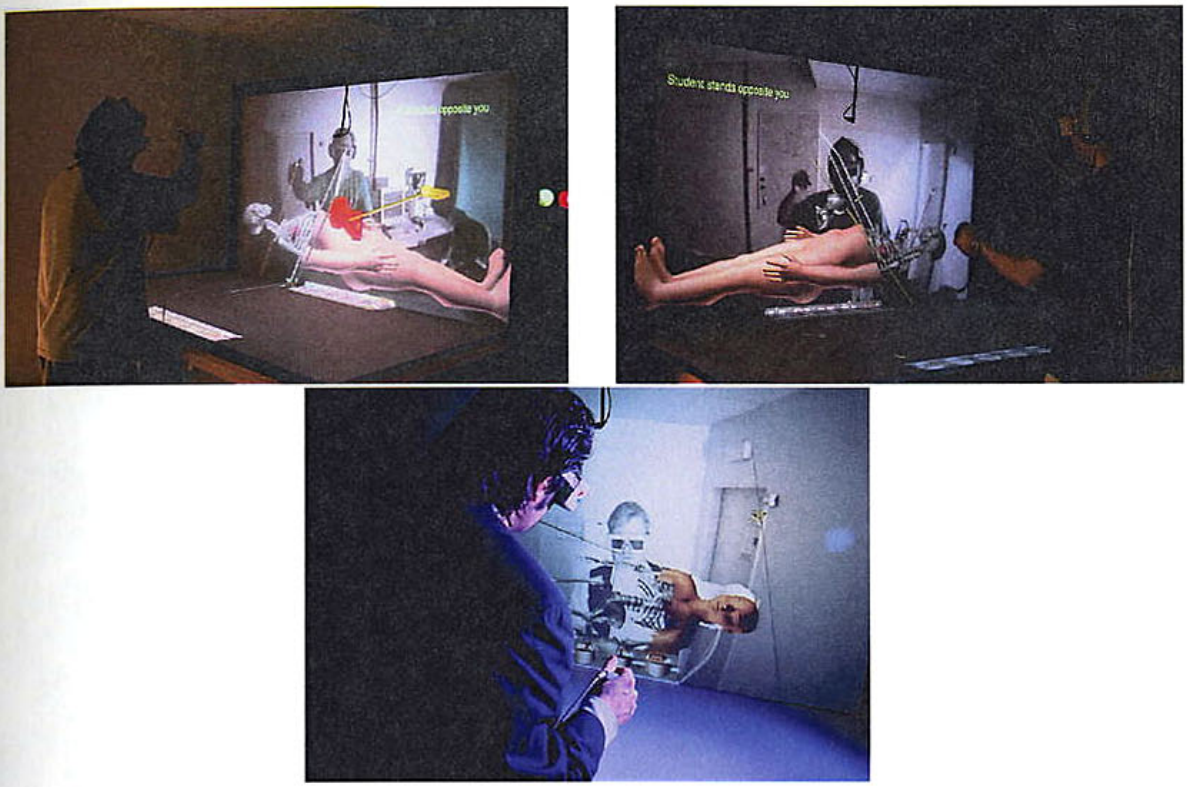

Figure 4.1: Snap shot taken from real sessions. For taking photos, the scene is rendered in monoscopic view. The upper left photo is taken from the remote RWB site than the upper right image.

a RWB-CAVE configuration. Images from the real application are shown in Figure 4.2.
Although the application is designed after the User Task Analysis of the User Task Description provided in section 4.1.1 some representation components are different when using a RWB-CAVE display combination instead of two RWBs. For increasing readability these differences are presented in the following rather than providing the whole User+Need Space and Application+Interaction Space again. Components that are not presented here do not change in the new display system combination.

Input Devices

- stylus (practical for RWB and CAVE)
  - reason : Easy to handle, suitable for both hands, the professor can pass it over to another student if the session is extend to three users or more.
- three button tool (practical for RWB and CAVE)

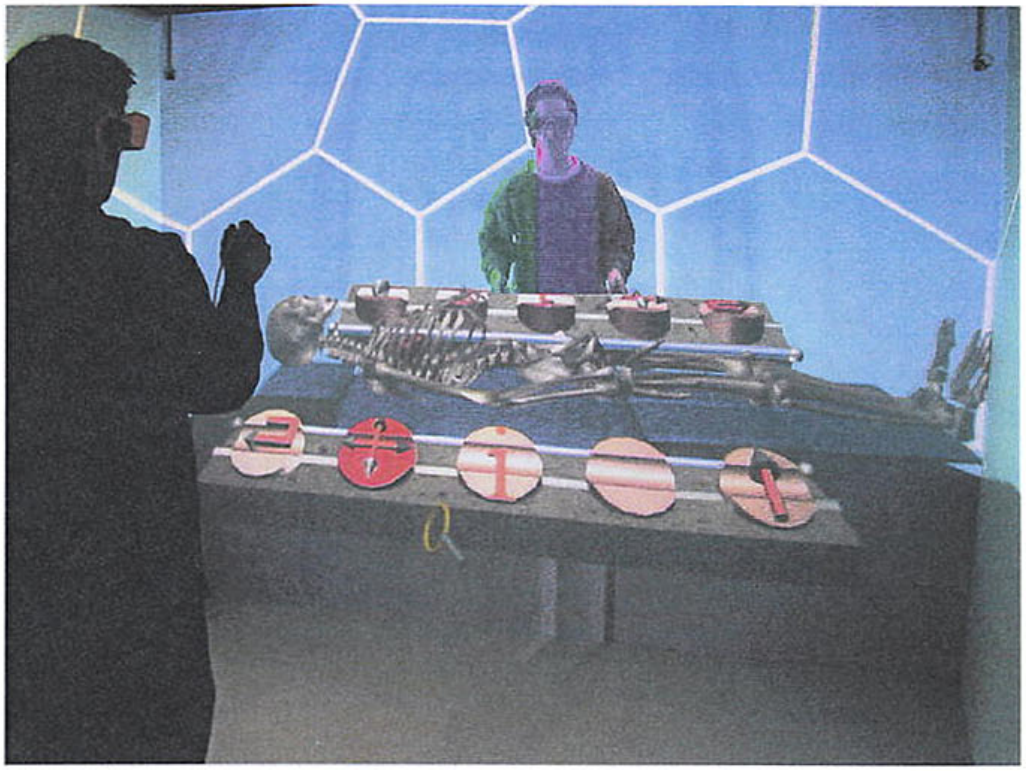

Figure 4.2: The snapshot shows two users collaborating in the CAVE. The desk with the data model represents the reference frame for the interacting user in the CAVE as the remote user works at the smaller display system.

  - reason : Easy to handle, suitable for both hands and usable in combination with both display systems. Due to the buttons more high-order functions are available like changing the viewpoint, changing the test scenario etc.. This is the reason why the three button tool instead of the stylus is used in the CAVE.

- joystick (practical for CAVE)

  - reason : As the CAVE display offers a much bigger viewing frustum and thus has a need for navigation, the users are provided with a special wand (joystick) for changing the viewpoint in this environment. The joystick is not usable at all in combination with a RWB. Here it is much better to ensure the model fits exactly into the CAVE boundaries and then walk within the display system environment.

Representation of the Environment

- In the CAVE display system a Virtual Environment representation is added to the data set and its functionality. This representations include

inventory, surroundings, floor etc. The reason is simply that the viewing frustum of the CAVE of approximately $27m^3$ has to be filled in a way that the application does not seem to soar in a black and empty space. This means that the environmental representation is not used in order to facilitate applying the learned in real world but rather to provide a reference frame for the application.

Metaphors

- for the handling of the toolbar grouping the generic operations:
  - *vendor's tray metaphor*: This metaphor is used for positioning the toolbar dynamically. This means that the CAVE user is carrying the toolbar like a vendor's tray. On the disposal of the RWB the toolbar grouping the generic operations is fixed. The handling of the ring menu grouping the content specific operations remains the same.

Types of Feedback

- *Representation of the smaller display system within the bigger*: Combining the RWB with the CAVE implies problems that might occur due to the different sizes of the viewing frustums. So it might occur that the CAVE user translates the data set within the bigger viewing frustum not knowing that the data set is clipped because it is outside the viewing frustum of the user at the RWB. This means that the user of the bigger display system needs to perceive the size of viewing frustum of the smaller display as a feedback. Here this problem is solved in providing a model of the smaller display system (Responsive Workbench) within the CVE of the bigger display system (CAVE). Therefore the RWB is represented by a normal table not showing the back face of the real RWB.

4.2.2 CAVE-RWB-Cylindrical Display

The last application example is a CVE for a combination of a Responsive Workbench, a CAVE and a cylindrical display (Cone) like the one shown in Figure 1.5. The idea behind this application is to provide three teams of players with tools to complete different tasks in an adventure game CVE. Depending on the display systems the teams have different abilities and functionalities within the game. The aim of the adventure game is to find three magic stones and to place them in a magic stone circle in order to discover the remaining secret. Thereby the teams are not playing against but with each other and the

game's stones can only be found and placed when they are working together being aware of the co-player's abilities and position. Figure 4.3 shows some preliminary results as this game is still under construction.

4.3 Conclusions

This chapter described the CVE application details for the combination of two RWBs and a RWB with a CAVE. Starting with a precise User Task Description (UTD) all necessary representation components, metaphors, operations and interaction techniques are determined. With this it is possible to create the User+Need as well as the Application+Interaction Space for the application. The remainder of this chapter provided information about a currently developed CVE combining a Responsive Workbench, a CAVE and a Cylindrical Display (Cone). The UTD for this application describes an adventure game based multi-user experience for practising team work. In chapter 5, it is shown how the former CVE application is implemented. It is evaluated according to usability and collaborative awareness assessments in chapter 6.

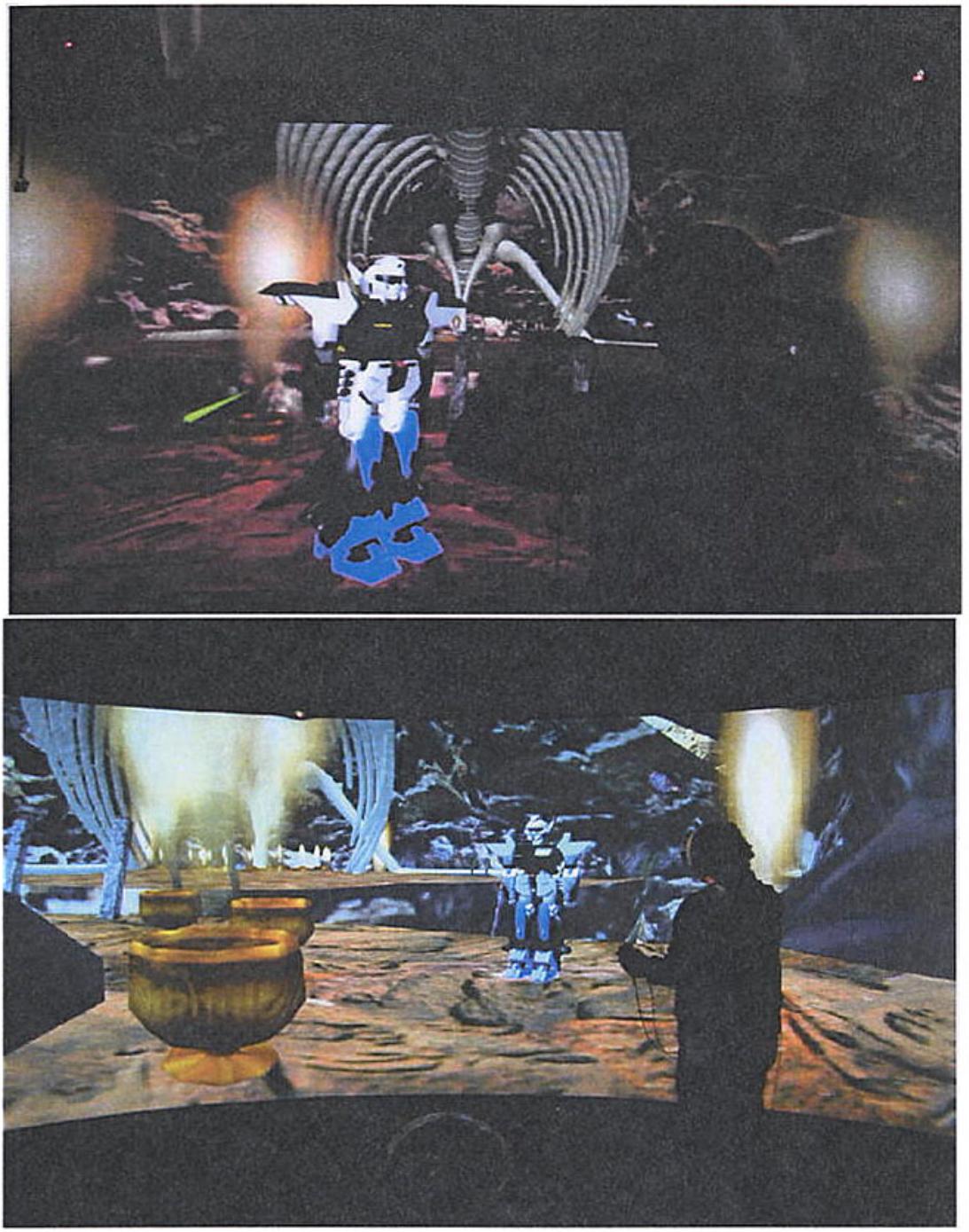

Figure 4.3: The images show some preliminary results of the collaborative game which is still under construction. The upper one shows the user interacting in GMD's cave-like CyberStage whereas in the lower one the user interacts in the CVE using the cylindrical display as output device.