Collaborative Virtual Environments : When Real World Is Not Enough, We GLOW

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Abstract

I set out to find research question for my M.Sc. thesis from Virtual Reality, going its through history and concepts ending up to Collaborative Virtual Environments (CVE). User embodiment is fairly complex subject in the CVEs. A specific taxonomy to evaluate user embodiment is introduced and presence in a CVE is evaluated further, only to found out that it is a wile beast. After that, a couple of projects is introduced to indicate the subtle differences between CVEs, proceeding to the intital concept of the netWork Oasis GLOW project, which is a new type of environment for people to work and learn. I explain my contribution to the project to be designing and implementing a 3D engine and briefly go throught the few initial ideas for the visualization schemes and implementation details behind them. In the analysis I conclude my part to be the technical implementation of the engine. In the end I argue that 3D engine will have an important role in bringing about presence, but that it is only a part of the greater whole. In addition to 3D engine design and implementation I see my further study to involve a review of 3D modeling and animation packages to be utilizes in the GLOW project.

List of Abbreviations

AR	Augmented Reality
CAVE	CAVE Automatic Virtual Environment
CVE	Collaborative Virtual Environment
HMD	Head-Mounted Display
RFID	Radio Frequency IDentification
VR	Virtual Reality

Contents

1 Introduction

The need for a collaborative tool for creative professionals has received attention in recent times (Shneiderman, 2002). The fundamental change in trends and driving forces, aspects of creativity and paradigm shifts in modern working have forced people to form networks, where they can achieve their full potential. The technologies which enable collaborative working are under development and have not yet fully matured for everyday use.

In this document I set the basis for further research, by going through the concepts related to Virtual Reality and Collaborative Virtual Environments. NetWork Oasis, located in Joensuu Science Park, is a project to create a new type of working environment to support playful approach to working, learning and problem solving. As a case study I describe the purpose behind netWork Oasis GLOW project, which is an implementation of the new environment – an effort to construct an unique mixture of the virtual and real for creative professionals to work where and when they want. After analyzing the implementation challenges I set out a research question, to which my M.Sc. thesis will provide an answer. The document structure is illustrated in Figure 1.

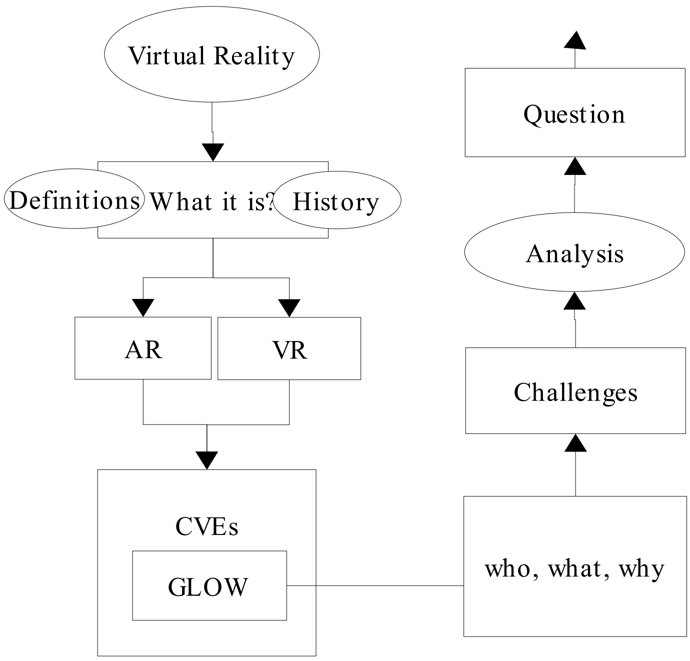

Figure 1. The thesis structure.

2 The Rise of the Virtual Reality

Virtual reality (VR) has been around for quite a long time, one could argue it was born in the advent of computers themselves. In this chapter I explain where almost every piece of VR-related technology has risen from. I have selected the following concepts due to the fact that the initial ideas behind them are still widely used today.

The babysteps of the virtual environments were taken in 1961 in the form of a new movie theater, called Sensorama, constructed by Morton Heilig (Figure 2). According to ACCAD (2005) the device was a single-person movie theater which had video, audio and odors to enhance the movie experience. The attempt was to make the viewer think he was inside the movie. The movies, however, were recorded beforehand and the device could not allow interaction with the movie content.

Heilig also developed the idea of the *Head-Mounted Display* (HMD) (Figure 3) in 1961, which essentially would have been Sensorama in a more compact, wearable form. Heilig also proposed an idea of a full-experience theater, which would remove the need for the HMD unit (ACCAD, 2005). Over 40 years later, the idea still remains to be realized.

Figure 2. Heilig's Sensorama (ACCAD, 2005)

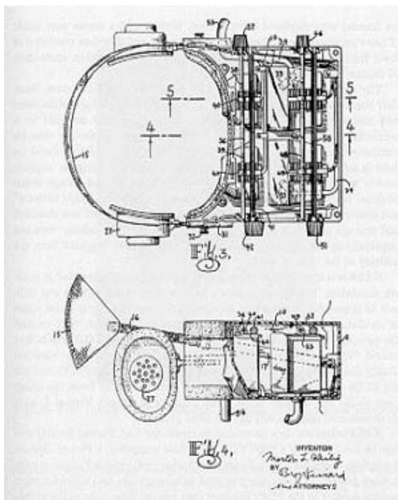

Figure 3. Concept of HMD by Morton Heilig (ACCAD, 2005)

Apart from HMDs, the first interactive hypermedia system, called Aspen Movie Map, was developed in MIT labs in 1978 by Andy Lippman, Michael Naimark and Scott Fisher. The system allowed the user to travel in the streets of the city of Aspen, Colorado, and even enter into some buildings. The city had been filmed using a truck with four mounted cameras, each pointing to different directions. These images were then displayed according to user position in the virtual city. The system also included a virtual map which could be used to jump to different locations directly by pointing them (ACCAD, 2005).

Another form of system which did not require a user to wear the traditional HMD was developed in 1992 in Electronic Visualization Laboratory of the University of Illinois at Chicago, USA. The Cave Automatic Virtual Environment (CAVE) consisted of three walls and a floor, where images were projected (Figure 4). The user wore special 3D glasses to feel the VR effect. Each of the projection screens was driven by Silicon Graphics Workstation and the system could handle 12 simultaneous users. The system was found to provide a very convincing VR experience, thanks to its large angle of view, high-resolution color images and the uncumbered use (Cruz-Neira et al., 1993).

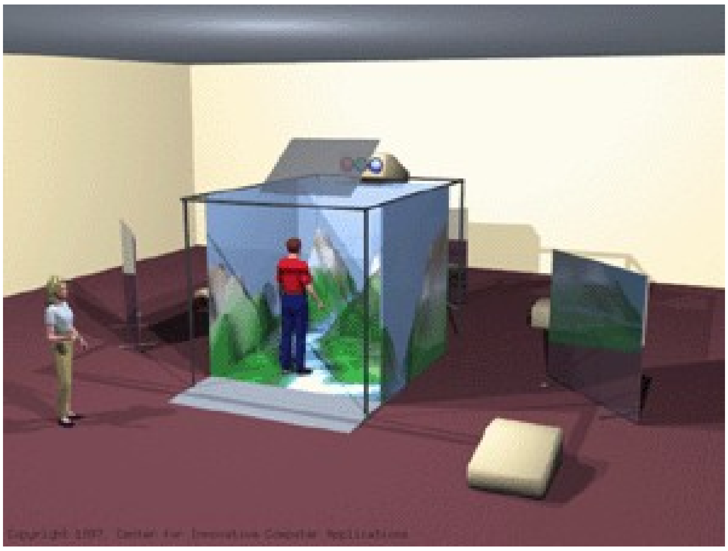

Figure 4. The CAVE system setup (ACCAD, 2005).

In the 90's Mackay (1998) presented a different approach to the virtual reality: instead of sinking a user totally into the computer-generated world she suggested a method of augmenting the user, real objects or surrounding environment with a computer, referring this as the *Augmented Reality* (AR). The fundamental difference between VR and AR is that AR seeks to bring virtual objects to our real world by overlaying images over the user's view of physical world (Avery et al., 2005), where VR simply keeps everything in the computer-generated space (Figure 5).The user was required to wear some sort of augmentation device, which he used to interact with the virtual components, just like in normal VR. An example of such a device is a data glove, which enables a user to point and grab virtual objects. Object augmentation was defined to be embedding sensors or other devices into real objects – an example of this are building blocks with embedded proximity, sound, light or touch sensors. Augmenting the surrounding environment was defined as "enhancing physical environments to support various human activities", which was realized with a screen where an *avatar*, an embodiment of the user's digital self, was displayed according to the user position (Benford et al. 2001; Mackay, 1998). The initial idea behind avatars was a simple embodiment, but later on more information has been added to them so they can express user state more precisely.

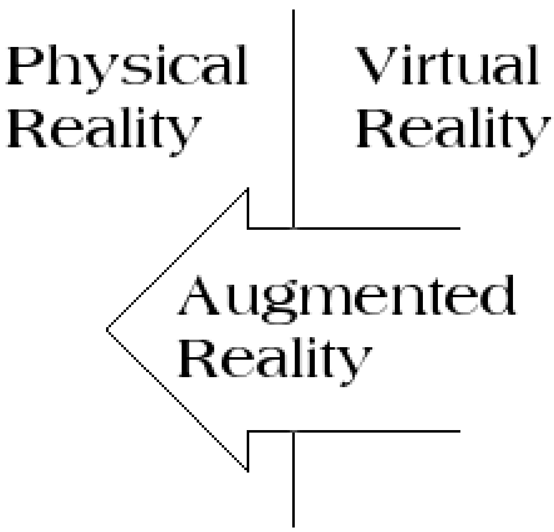

Figure 5. Relationships between physical, virtual and augmented reality.

3 Collaborative Virtual Environments

As VR technology developed, new types of applications were created to assist in learning and work. *Collaborative Virtual Environments* (CVEs) are navigable, populated 3D virtual worlds, which support cooperative work and social play. Each user in the virtual world is represented by an avatar. Although name might relate more to the VR, the term also encapsulates AR systems - which becomes apparent in following sections in this document.

The United States Defense Forces has pioneered in the field of creating CVEs. Benford et al. (2001) mention a system called NPSNET, which was developed in the Computer Science Department of the U.S. Naval Postgraduate School. The system was designed to assist in large-scale military training simulations and computers could be configured to view the world with the eyes of a trooper, or alternatively, driver of a military vehicle.

In one sense, CVEs exist all around us - for instance, simple first-person shooters which are played over network. They fall into the category of CVE especially if the type of the game allows team play, where each of the participants has the common goal within his/her team and must coordinate his/her efforts to achieve it. Persons who kill their own team members in the game or hamper the game play in other ways are removed by vote.

CVEs have also been used in an attempt to create interactive television. The MASSIVE environment, originally developed to experiment wide-area network teleconferencing, led to an idea of "inhabited television". The concept is a new form of entertainment, where people can enter to a shared virtual stage, which is recorded with virtual cameras and displayed through them to other viewers (Benford et al., 2001).

3.1 User embodiment in CVE

Benford et al. (1995) define *user embodiment* as the set of appropriate body images, which represent the user in collaborative situations. They also suggest the following classification (Table 1) for user embodiment in CVE, from which classes can be selected to evaluate the system at hand.

Table 1. Classification for evaluating user embodiment in CVEs (Benford et al. 1995).

Class	**Description**
Presence	How the system creates clues of the persons currently logged in.
Location	How the system indicates the location and direction of the user in the virtual world.
Identity	How different users are presented (with body images or other type of objects) and how well they could be identified.
Activity, viewpoints and actionpoints	How current activity, type of it and the type of virtual limb he is doing it with, are presented.
Availability and degree of presence	How system indicates the presence level of the user, is he busy or idle, how he would react to interruption at that time.
Gestures and facial expressions	How well system records and transmits the unconscious gestures and expressions to other viewers.
History of activity	How the system represents the past actions of the user, what he was doing and where.
Manipulating one's view of other people	How well the owners and observers of the avatar can alter the representation details to match their preferences.
Representation across multiple media	How the system converts the representation of the world, users and their actions into different formats, such as audio, graphics, video and text.
Autonomous and distributed body parts	How the system represents users who are participating with several instances or doing multiple things at once.
Efficiency	How the system scales to different display hardware (Does it reduce the level of detail for low-grade hardware and increase it if more powerful system is detected)
Truthfulness	How the embodiment displayed by the system corresponds to user qualities in the real world.

3.2 About the presence in CVE

Nunez (2004) argued that presence is possible in non-realistic virtual environments, but only if the environment matches the expectations of the user. The background of each user will have impact on the interpretation of the information given by the environment in the beginning, but after the user gets acquainted with it, the level of presence will increase. From this can be concluded that a 'story' is needed to help users adjust themselves to the system. Using a metaphore familiar to users, they probably can feel presence better.

In their game immersion study, Brown & Cairns (2004) conclude that immersion has three levels among gamers: engagement, engrossment and total immersion. According to Brown & Cairns, engagement refers to the first contact to the game environment and the gamer must be willing to learn the controls and possibilities in the game. They also state that engrossment is the stage in which the game has a direct emotional effect to the gamer. An example of this could be a feeling of frustration when enemies kill your beloved family member in the game. The total immersion was described as the gamer being completely cut off from the reality and game was the only thing affecting him. Or as they put it : “Total immersion is presence.” The same levels should apply to different types of CVEs also.

Presence can occur many ways in user embodiment. For instance, sounds of steps would quite clearly indicate that somebody is close by. Although usage of sounds would serve a certain purpose, it could only apply to users in movement – remote users are unlikely to move their virtual presence around the room very often just to create audible clues of their presence. In addition, constantly audible sounds might not be very useful, after all a human mind seems to filter out normal environment sounds, and extraordinary sounds could be irritating, especially if the person is exposed to them for a long period of time.
The most obvious choise, visible avatar, is probably the safest to start with when effect of presence is needed.

Measuring presence and/or immersion is not a trivial task. An example of such an attempt is the experiment conducted by Murayama and Takamizawa (2004) : transferring video image from wearable camera. Their purpose was to broadcast university graduation ceremony over the Internet by giving one student a wearable camera. Remote users could then see the ceremony like they actually would have been there. They received over 4000 requests from different people willing to see the ceremony, but they were able to provide this experience only to 76 of them due to the hardware constraints. The measurement itself was conducted by asking the opinion of those involved in the experiment. The remote users reported that in overall, they experienced more presence than expected. They also mentioned that voice and image synchronization did not always work well, following the event was difficult when camera was in movement and the camera did not point to the same direction the cameraman was looking at, which reduced the feeling of presence. Apparently some form of questionnaire was used to gather this information. It represents the subjective views of the users which are difficult to compare.

From this can be concluded that presence is wile beast to tame. There exists many ways to create it, however, the final result depends on the users and measuring it can be painstaking if you wish to compare results.

3.3 Examples of different CVEs

Since CVE as a concept is quite wide and encapsulates several types of systems, I present the following examples to demonstrate which kind of CVEs exist at the moment. Although all of them are designed as collaborative tools, there are slight differences in the approach they use.

The Croquet project

According to the Croquetproject.org (2005), “Croquet project is an effort to develop a new type of computer operating system to enable deep collaboration between users.” At the moment, the project is a conferencing system utilizing broadband connections, 3D user interface and peer-to-peer network architecture.

The approach of Croquet resembles the concept of World Wide Web, where everyone can create their own web page and create links to other pages. In Croquet, users are able to create their own virtual world and create links to other worlds via "portals". The main difference to WWW is that everything in Croquet is a collaborative object, which is shared among the users via a special protocol called TeaTime. The system renderer engine, TeaPot, is built upon OpenGL.

The system allows to use standard desktop applications within the Croquet space (Figure 6), and the project www-pages claim that eventually Croquet will be backwards compatible with everything installed on user's computer. The system also allows the remote users to interact with applications executed in the local workstation (Croquetproject.org, 2005).

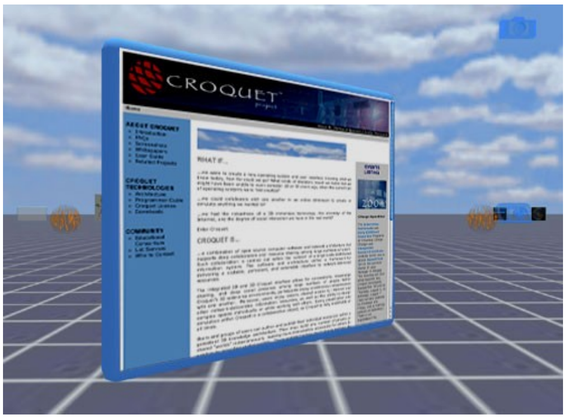

Figure 6. Croquet can embed normal desktop applications into the virtual space.

The idea of embedding standard desktop applications in the virtual world and allowing remote users access them using avatars (Figure 7) is quite interesting. In this manner, Croquet creates a 3D workspace where teams can collaborate. I was unable to find information how the application sharing was implemented, but I suspect it would be turn-based – which means each user can reserve the application for his use and then release it when task is done. This would imply that the applications cannot be used simultaneously for input from several users. However, the information created with the application can be viewed simultaneously.

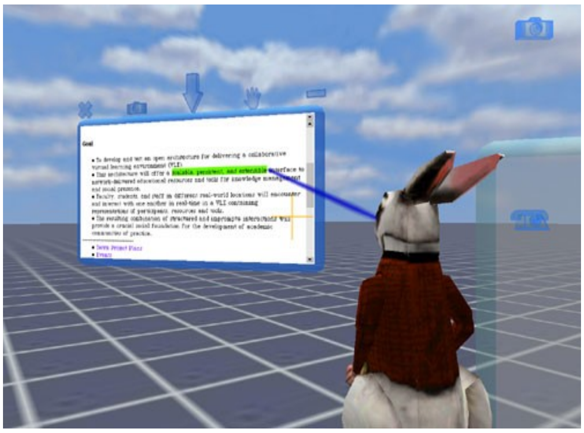

Figure 7. Remote users can access the application of an another user.

MPGSketch

Tang et al. (2004) implemented a program called MPGSketch, which allows several remote teams to collaborate through a drawing program. Previous implementations embodied remote parties with a mouse pointer, which reduced effect of presence quite a bit. The team developed the concept of "digital arm shadows", which enhances the effect of presence (Figures 8 and 9).

Figure 8. Real world example which inspired MPGSketch arm shadows (Tang et al., 2004)

The approach differs from other CVEs, which seek to transfer the entire working environment into the virtual world. In the application described by Tang et al., users are very much in the real world and share only the collaborative tool in virtual world. Embodiment of other users is done in a simple manner, by transparent lines, which represent the user's arm on the virtual table – an approach which simulates real-world situation when several persons are working a schematic draft on the same paper.

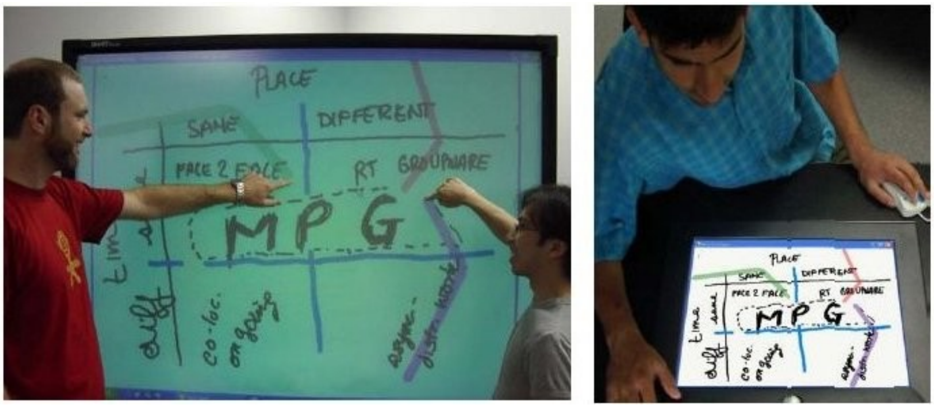

Figure 9. Digital arm shadows in MPGSketch. (Tang et al., 2004)

Virtual Round Table

The virtual round table project uses AR technology to create a collaboration environment. The concept is a table, on which virtual objects are created with placeholder objects in the real world (Figure 10). Each placeholder object has its own counterpart in virtual environment and they are used by the participants to move and rotate virtual objects (Broll et al., 2000). A placeholder object can be anything from a coffee mug to a pencil, and represent anything in the virtual world. The name suggests a completely virtual environment where a table exists, but the table and the objects which are handled are very real. A more descriptive name for the project would be Augmented Round Table.

This tool can be described as a collaborative virtual environment, although the presented approach is suitable only for people located around the same physical table. Remote users, in this case, would be reduced only to observe the collaborative task and possibly to comment on the actions taken.

Figure 10. Virtual Round Table setup (Broll et al., 2000).

Summary

The examples show that collaboration can occur in different ways. Each of the systems solve a different type of problem in collaborative work and are not general-purpose solutions for every situation. The Croquet project attempts to send the user with his/her desktop to the VR, so collaboration can occur with already existing desktop programs, of which functionality is extended through VR. The MPGSketch shares the drawing board though VR, allowing more users to participate in the design process. This is achieved by distributing participants to smaller teams which use separate devices to work together. And finally, the virtual round table lays virtual objects on the physical table which enables multiple users to communicate normally while interacting with the objects in the VR.

4 The netWork Oasis GLOW Project

The GLOW project driven by netWork Oasis in Finland is an attempt to create a new type of environment for people to work and learn. Ilari (2004) states that the goal is to combine the best parts of the virtual and real worlds to provide an environment where ideas can flow freely and every possibility is in reach. But a simple combination of virtual and real is not enough, users must possess the proper mindset, the glue, which enables the connection between virtual and real. Chernenko et al. (2004) state that GLOW is for supporting knowledge community, so people around the world can work together if they choose to – whenever and where ever.

The GLOW itself is an user interface for virtual and real worlds, which assists people to work and contribute freely. In a way, it could be described as a window to the Oasis community, which can be accessed anywhere. Instead of creating teleconferences with different parties, the communication takes place within the system transparently.

The "Oasis Way" of working is best described using the Scharmer U-curve (Figure 11). The curve itself describes the process of "getting creative" by relaxing and questioning the purpose and methods of the work, and afterwards crystallizing the image of the goal, finally pursuing it with extreme enthusiasm and understanding – hence the sentence "calming down without slowing down" fits in nicely. The U-curve starts from "Paying attention" and pursuing to the "Connecting to source" and finally up to "Performing".

Figure 11. The Scharmer Curve (Ilari, 2004).

The Avatar Mirror will be one of the key interfaces in the Oasis GLOW. It will display the avatars and inform users in various ways. Persons located in the netWork Oasis workspace will have their avatars displayed as sort of mirror images of their own self. Every user can customize his avatar to match his own preference. Avatars are also used to represent the current mood of the user. By providing audiovisual, possibly even haptic clues to the user, we attempt to generate an illusion of the workers' presence in the room. In addition to visual representation, the plan is to use extremely directed audio streams which can be pointed so that only one person is able to hear them.

4.1 Sounds nice, but what makes it tick?

My contribution to the project will be a program, which will produce the graphical representation of the avatars. The whole system consists of two separate screens, which will present avatar for each user in the room with an inverted horizontal axis, so the user will have the impression of a virtual mirror. The system is expected to be mind-bogglingly beautiful[1] and set new standards to the graphics used in CVEs. The whole project will be eventually published as Open Source, using most likely the GNU Public License.

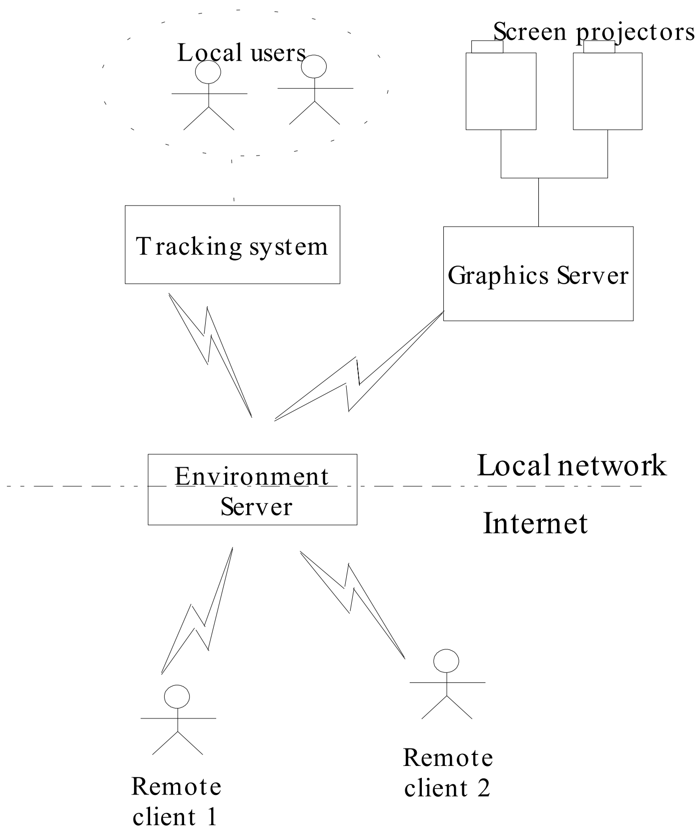

Figure 12. The initial design for GLOW architecture

The (initial) system architecture of the Oasis GLOW is relatively simple (Figure 12). The *Environment Server* will hold the information about users; for example those logged in, the current working mood and the physical location. The client software, operated by remote users, communicates with the server, sending the

information with some protocol, which is undefined at the time being. The local users will be equipped with a traceable identification key and the tracker system will notify the environment server about the changes in the physical location. Graphics server will

1 A subjective view of the author which might not relate to the views of the Oasis staff in general.

receive information from the environment server about the users. According to the received data, placement of the objects is changed to match the new location and the scene is re-rendered, giving the illusion of a mirror.

4.2 About the 3D Engine

A 3D Engine is an abstraction layer for 3D graphics application programming interface (API) operations and is used to render the world on a display device.The 3D APIs provide a set of functions which modify the view settings and 3D data on vertex level. Writing a complex 3D application would be laborous, not to mention painful, without ability to handle the world on object level. Therefore, an abstraction layer is required which encapsulates, for instance, drawing calls for a bunny rabbit behind a friendly draw()-function.

The engine responsible for the avatar mirror will be written with C++ and OpenGL. OpenGL is a 2D and 3D application program interface for interactive graphics applications. Since its debut in 1992, it has been widely adopted in the graphics industry and has been used to create various applications. OpenGL libraries are available for several platforms, which makes it an ideal tool to write portable graphics applications (OpenGL.org, 2005). C++ is an efficient, object-oriented programming language and is considered useful in large projects.

4.3 Planned visualization schemes

In the planning phase 2004, few initial ideas for the visualization of the avatars came up. These were to be used as core visualization schemes, however the engine would eventually support other types, which could be created by the users themselves if required. Different representations could be added dynamically to the system. In the following paragraphs I will go through the core representation methods and a rough sketch of them is in Figure 13.

The boy has metaballs of steel!

One suggested method for avatar representation was an amoeba, which is able to merge into other amoebas when they are close enough, and separate themselves again after moving further from each other. To realize this scene, the Marching Cubes algorithm (Lorensen & Cline, 1987) could be utilized to create a polygonal surface representation of an iso-surface through a 3D scalar field. The specific scientific term is not very descriptive, so to put jargon aside and provide a more understandable name, we refer to them as metaballs, which is also more commonly used among programmers in the demo scene. *Metaballs* are spherical mesh objects, which are able to have shared faces with each other. Their appearance depends on the densitity of cubes in a grid and the radius of each ball. Smaller cubes will yield a more precise approximation of the iso-surface, but in contrast, it will be more laborous to compute.The original algorithm (Lorensen & Cline, 1987) doesn't take optimizations into account and further study has revealed several points where optimizations can be made to reduce the number of triangles and to speed up the drawing process (Shekhar et al., 1996; Lakshmipathy et al., 2004).

Sandstorming

The second method for avatar representation is clouds of smoke or sand. Equal to their real-world counterparts, they will have swirls and they are affected by air flows. The main idea is to utilize a particle engine in this effect. Classic particles are textured quads or triangles always facing towards the camera. The amount of particles in a single scene might well elevate above 100k, which might require massive optimizations to keep frame rate sufficient. An alternative approach is to create a particle engine using vertex shaders. They provide at least one major advantage over classic particle engine implementation – performance. Every computation is performed on the graphics card itself, which has been optimized to do such calculations and will outperform any of the equally fast and even faster CPUs.

Plain old mesh

The third avatar representation method is a mesh object. Each user will choose a special avatar from a vast pool of objects or even create one. Altering visual appearance of these objects is easier than with particle systems or metaballs, but some restrictions to the size and polygon count must be made in order to keep system running smoothly.

Information flow

Since the Oasis community is supposed to be global, the information about current connections to the Oasis facility are interesting to see. Therefore, a GLOW satellite view is included, where users can see the rotating globe with curves leading from various locations to the netWork Oasis in Joensuu. The satellite view can be moved by the user over any location on the globe, where it could be zoomed to view the details of cities and other places.

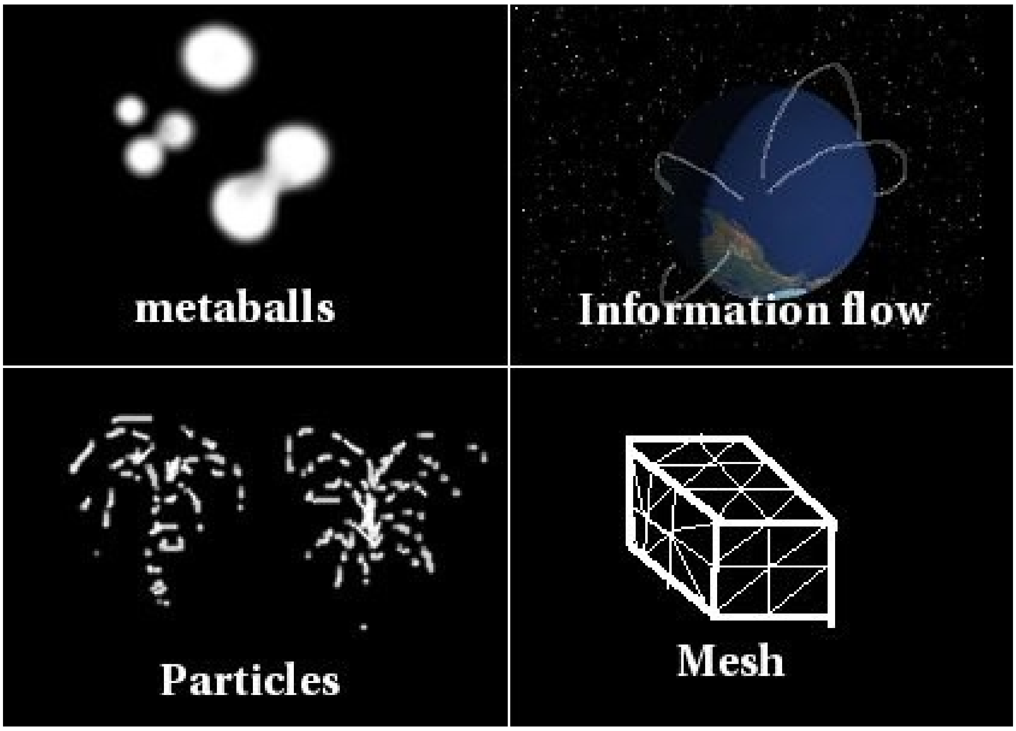

Figure 13. Sketch of the visualization schemes in GLOW

4.4 Implementation challenges

In this section, I present issues related to implementing the GLOW Avatar Mirror. I go through presence/user embodiment analysis using the classification presented in section 3.1 as basis, but modifying it to fit better to this situation. In addition, I analyze other challenges which are expected to occur.

Presence and immersion

The whole system will be quite complex when finished. The components must be integrated in a way which will create an effect of two-way presence, so to speak. The primary task is to create the presence of the GLOW remote users, so the people working in the Oasis facility will experience it. The another task is to generate an effect of presence to the remote users, who must feel that they are actually working in the Oasis facility. This raises interesting questions. How to create necessary clues which would almost immediately give a wide variety of users the impression of presence? Could it even be done with visual clues alone?

Location, orientation and identity

The location of the users in the room must be determined accurately and moreover, they must be identified so the avatar representation can be displayed correctly in the mirror. Because face recognition systems are not reliable and the required processing power for them is rather massive, users must be augmented by some means. The initial idea for this is to use individual Radio Frequency Identification (RFID) tags, which will identify and determine the location simultaneously.

The location can be represented in GLOW quite easily, at least by using the globe view mode. The remote users can be anywhere, so their avatars should not have specific location in the virtual world. Perhaps they could be presented as “ghosts”, who float freely in the virtual world among other avatars.

The direction each user is facing is more difficult to determine with RFID tag-based location system, since it only provides information about the placement. In this sense, the CyberCode concept, developed by Rekimoto & Ayatsuka (2000), would be useful. They used 2D barcodes, which were read by a environment camera to identify users. Applied to Oasis GLOW, each user could have different codes to be worn on their fronts and backs, which effectively would allow the system to give a rudimentary estimate of the direction each user is facing.

The augmentation hardware can be hidden into small tokens, which otherwise would have no meaning. In this manner, users are given 'hooks' which possibly can help in terms of immersion – for example, each user could have their own community jewel which would have the RFID tag hidden. In addition, if the jewel is combined with a exciting story, the immersion level could even be enhanced.

The activity, viewpoints and actionpoints

The current activity, viewpoint or actionpoint is impossible to determine using planned augmentation devices.

Availability and degree of presence

Availability and degree of presence is presented using specified color coding in avatars. Each avatar will be shaded accordingly to the state selected by the user. In this way, all users of the GLOW will be able to perceive the required information about the willingness of each user to cooperate or discuss.

Gestures and facial expressions

Gestures and facial expressions are not planned to be presented in the GLOW, since the type of the environment does not require it - communication is not planned to happen using avatars themselves.

History of activity

The history of activity is not planned to be displayed in Oasis GLOW. But due to the nature of the system, in should not impose problems – where somebody was a moment ago is irrelevant for collaborative work, more important is whether he can work now.

Manipulating one's view of other people

Manipulation of avatar representation is not currently planned to be included in the Oasis GLOW. This might bring about interesting cultural collisions among different users – also the color coding of the system might be different for people with different cultural backgrounds.

Representation across multiple media

The system has exactly two methods to represent avatars – the 3D objects in Oasis facility and the Flash-based with remote users. This effectively renders visually impared users unable to use the system. Some kind of text-based representation might be in order if blind people are taken into consideration.

Autonomous and distributed body parts

The system does not allow several logins from same the person and avatars are not required to present information about the current activity of the users.

Efficiency

The efficiency might be an issue with the remote users, for the local users sufficient hardware is available.

Truthfulness

Truthfulness is not considered to be an issue with Oasis GLOW. Avatars are allowed to appear in various forms.

Information Security

The system has to be flexible enough not to interfere with actions of the users, but in the same time extremely secure – if any major corporation wishes to get their masterminds together with virtual environment, it must be hack-proof. Otherwise their intellectual property will be at risk. Creating a hack-proof communications software will not be a trivial task – communications part must be careful designed.

Extendability

Graphics used in the avatar mirror must be impressive, due to the fact that games have influenced the user expectations of the computer-generated graphics. Hence, the system must support adding new visual representations of avatars dynamically. This issue must be taken into consideration while designing and implementing the 3D-engine framework.

Vast pool of techniques

Finding out the best techniques will take lot of time, not to mention to learn to use them effectively. For instance, vertex shaders could be used to achieve great effects, which have been seen from variety of computer games and demos, but at the moment the author has only a little knowledge about them.

5 Analysis

There are several advantages in using CVEs for work. Commuting workers, for instance, might be very interested in an approach which would reduce the time spent on travelling. Or even workers in a large city, where morning traffics are bad – each worker could go to a closest distance working center and have the same resources at his disposal as when going to the actual place.

One might argue that using CVEs will reduce social skills because they are just using computers instead of talking to real people. In my opinion, that statement could not be further from the truth – by using CVEs people actually have the opportunity to communicate more and with well-designed CVEs remote parties could experience the same non-verbal gestures as in real encounter.

The embodiment plays significant a role in the effect of creating presence. Without the presence, participants experience the other parties to be far away, and according to Bradner & Mark (2002), the willingness to cooperate decreases as the geographical distance increases. By creating the illusion of strong presence, the geographical distance could be diminished, although in the experiment conducted by Bradner and Mark the effect of geographical distance remained as it was.

My contribution to the GLOW project will mainly focus on making different visualization schemes possible. Various 3D models and scenes will be crafted by a selection of artists and the system must be able to produce their outcome on the screen. In order to achieve this a highly configurable and efficient 3D engine is needed.

6 Conclusion

So far I have explained what are Collaborative Virtual Environments and given examples of some of them. I've also introduced the Oasis GLOW system and outlined the implementation details. By analyzing the user embodiment in the Oasis GLOW using the taxonomy presented in section 3.1, I found that it is not suitable as such for direct comparison between arbitrary CVE systems due to the different purposes they are designed for.

The concept of presence has arisen as an important factor in the user embodiment. In order to achieve such an effect, several pieces of the GLOW puzzle must be fitted together – graphics from the artists, highly configurable and efficient 3D engine and a 'story' to bind them all. Graphics and story will vary with different users, but the engine should remain the same and provide an environment where two other components can roam freely.

A comprehensive study of the techniques behind 3D engines is required to create such a program which will be suitable for different visualization schemes. Also a review of popular 3D modeling and animation tools should be performed to gain information about suitable file formats and features in the programs, which might require additional functionality to be added into the engine.

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