Staging and Evaluating Public Performances as an Approach to CVE Research

Steve Benford, Mike Fraser, Gail Reynard, Boriana Koleva and Adam Drozd
The Mixed Reality Laboratory
The University of Nottingham
Nottingham NG7 2RD, UK
{sdb, mcf, gtr, bnk, asd}@cs.nott.ac.uk

Abstract
Staging public performances can be a fruitful approach to CVE research. We describe four recent experiences: Out of This World, a live gameshow; Avatar Farm, a (3D) recorded participatory drama; Desert Rain, a mixed reality performance for six players; and Can You See Me Now?, a game that mixed on-line players with players on the streets. For each, we describe how a combination of ethnography, audience feedback and analysis of system logs led to new design insights, especially in the areas of orchestration and making activity available to viewers. We propose enhancing this approach with new tools for manipulating, analysing and sharing 3D recordings of CVEs.

INTRODUCTION

We have been using collaborative virtual environments (CVEs) to stage public performances since 1996. This has involved working with artists, television companies, poets and theatre groups to create real-time participatory experiences that involve members of the public alongside actors. Examples include the NOW'96 poetry performance [2], the Out of This World [7] and Avatar Farm [5] inhabited television shows, Desert Rain [11] and most recently, a citywide mixed reality game called Can You See Me Now? [1]. These have been deployed in a wide variety of settings including theatres, galleries, warehouses, over the Internet, in our laboratory and on city streets.

In this paper we reflect on the general approach of staging performances as a way of conducting CVE research. We begin by clarifying our motivations. We then summarise four key examples from previous work. Finally, we draw out some common CVE design issues that have emerged and propose ways in which this approach could be enhanced in the future. Our aim is to inspire others to adopt this style of research and, if they do, to be aware of some of the lessons that we have learned over the past six years.

THE APPROACH, ITS BENEFITS AND COSTS

There has been a long and rich history of collaboration between artists and technologists dating from the 1960s to create innovative and interactive public art works. On the arts side, one thinks of organisations such as Ars Electronic [12], the International Symposium of Electronic Arts [21] and institutions such as the ZKM (Germany) [24], The ICA (UK) [19], Banff (Canada) [14] and many others. On the technology side, one thinks of research laboratories such as the MIT Media Lab [22], Xerox PARC's RED group [23] and European projects such as eRENA and eSCAPE under the i^3 initiative [18].

Endeavours such as these have produced some notable examples of interactive VR art works (see for example, Osmose by Char Davies' [20]). At the same time, the entertainment industry, operating in the commercial arena, has become increasingly focused on interactive 3D games, and recently on on-line (multi-player) games and now massively multi-player games.

Against this broad backdrop of activity, the focus of our research (and hence of this paper) is defined by two particular concerns:

- Using CVEs to create engaging collaborative experiences for the public, where the primary content is provided by dialogue, typically through real-time audio. This is in contrast to a focus on gameplay or single user interaction.
- To evaluate these experiences in order to feedback into the technical design of CVE platforms and interfaces. In other words, public deployment or demonstration isn't enough; it is necessary to learn from public experiences.

Why stage public performances?

There are many valid ways of conducting research into new technologies: theory backed up with mathematical proof, implementation as proof of concept, controlled experiments in the laboratory, and "demo or die" to name a few. The approach of staging public performances involves taking emerging technology out of the laboratory and working with professionals to create an event that can be placed before the public. This often requires organisational and financial support from arts festivals and arts commissioning bodies in addition to more conventional R&D funding.

Staging a public performance can be a time consuming and expensive process: the technology has to work and large volumes of equipment may have to be moved, rigged and de-rigged, requiring the support of a production 'crew'. Why go to the lengths of staging a public performance? We see several distinct advantages to this approach.

The discipline of detail – in order to produce a successful public performance it is necessary to focus on the details. Big ideas that seemed feasible (and even demonstrable) in the lab need to be trimmed down, and important new issues that weren't originally envisaged emerge. It is only in full detail that a concept or technology is fully understood.

Situatedness – one only witnesses the true behaviour of a technology (and its users) when it is used in a real situation. A public performance can provide a more realistic setting than a laboratory.

A creative playground – art and entertainment provides a creative and relatively safe playground for developing new ideas. Anything goes.

Engaging the public – public performances provide a good way of directly involving the public in the research process, a necessary step when developing technologies for the public. They also promote public understanding of the likely impact of new technologies.

Drawing on the skills of artists – artists are often highly skilled technology developers. It is useful for mainstream research to draw on this skill base.

Potentially important markets – ideas first tested in art and performance can lead to potentially marketable spin-offs in areas such as entertainment and education.

Publicity – staging public performances provides many opportunities for raising the public profile of research.

However, there are drawbacks with this approach.

The expense – as noted earlier, there can be significant additional 'production' costs, particularly where performances involve large numbers of participants.

Bucks traditional research planning (and funding) models – it is hard to predict in advance what equipment will be required, there are frequently unexpected costs, and it is often necessary to hire large teams of people to work on a project for a short intense burst. All of these cut against the grain of traditional research project planning in which a few researchers work on a problem for an extended period of time and where equipment funding is fairly predictable.

Making good art and good computer science – in our experience, it is difficult to make something that is both artistically and technically groundbreaking. Indeed, interdisciplinary researchers often suffer from the expectation that they will be excellent at two or more disciplines.

Reception – as a technologist, one has to be prepared for strong and immediate reactions. Public audiences and art critics are not afraid to voice negative opinions in a forthright way that is relatively rare in science and engineering. Researchers need to steel themselves.

How to evaluate public performances

How can one evaluate a public performance? Our own attempts have combined three techniques, each of which offers a different perspective.

Audience feedback and discussion – this involves both face-to-face and offline discussions with participants in order to solicit their feedback and to get their own reflections. Various mechanisms can be employed including discussion sessions with live audiences after a show, interviews with selected participants, debriefing meetings and feedback via email and the web. This kind of feedback can give an initial sense of an event and can frame key issues for further investigation.

Ethnography – is a natural observational method that seeks to provide rich descriptions of human activity. It is one of the oldest methods in the social research toolbox [4] and has been widely used in the design of interactive technologies. This follows from the recognition by designers that successful research and development increasingly relies upon an appreciation of the social circumstances in which systems are deployed and used. The method is particularly good at identifying and conveying to designers the orderly ways in which interaction is coordinated, thereby elaborating the social demands that may be placed on new technologies in their use. Ethnography has been extensively used to study CVEs, often focusing on the behind-the-scenes work required to make an experience work [3].

System instrumentation and analysis of logs – developers instrument the underlying CVE platform to log (and timestamp) as much data as possible at participants' machines and as it passes across the network. This data might include all avatar movements, interactions with virtual objects, audio packets and text messages. These logs can then be analysed statistically in order to uncover significant patterns of user activity (e.g., frequencies, distributions and correlation of movements and communication). The results can support or contradict other observations (participants' own reflections and ethnography), can inform models of system and network performance, and can suggest new technical designs and optimisations.

EXAMPLES OF PUBLIC PERFORMANCES IN CVES

We now introduce four examples of staging public performances using CVEs from our previous work. We describe the goals and structure of each, and also discuss how the combination of evaluation methods introduced above yielded new design insights.

Example 1: Out of This World

The concept of inhabited television combines collaborative virtual environments (CVEs) with broadcast TV to create a new medium for entertainment and social communication. The defining feature of this medium is that an on-line audience can participate in a TV show that is staged within a shared virtual world. A broadcast stream is then mixed from the action in the virtual world and transmitted to a conventional viewing audience.

Out of this World (OOTW) was a public experiment with inhabited TV that was staged in front of a live theatre audience [7]. Our aim was to see whether we could produce an experience that was coherent and engaging for both participants and viewers. The event was staged as part of ISEA: Revolution, a programme of exhibitions and cultural events that ran alongside the 9th International Symposium on Electronic Art (ISEA'98) that was held in Manchester in the UK in September 1998. There were four public performances of OOTW in the Green Room theatre over the weekend of the 5th and 6th of September. These were preceded by two days of construction, testing and rehearsal.

OOTW involved eleven participants: eight members of the public who were selected from the paying audience for each show, divided into two teams and who used desktop PCs; two team-leaders, played by actors who used immersive interfaces; and a host, who was represented as a live video texture. There was an open audio channel between all of these participants. The teams played a series of five games involving interactions with virtual objects and quizzes. Figure 1 shows a scene in which a member of the 'robot' team is lifting their leader into the air to 'harvest fish from the sky' (the opposing 'alien' team is in the background).

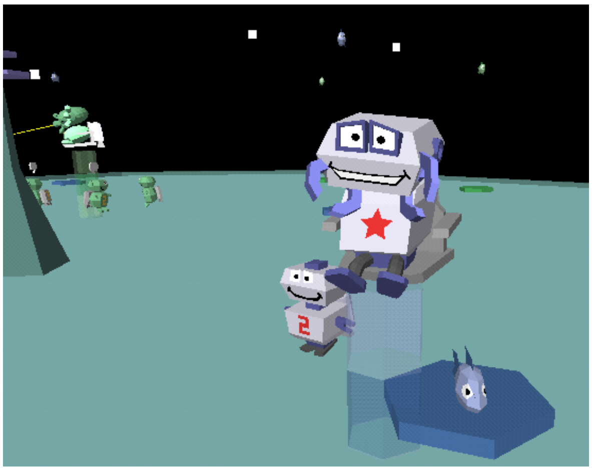

Figure 1: harvesting fish from the sky in OOTW

OOTW was implemented using the MASSIVE-2 system. Behind the scenes, four virtual camera operators captured views of the action that were then mixed by a professional TV director (see figure 2) before being shown to a live theatre audience. One crewmember, the 'world manager', was able to dynamically introduce movement constraints (invisible and potentially moving bounding boxes that limited participants' movements) in order to take participants to set locations at key moments.

Figure 2: the TV director and assistant in OOTW

Evaluation of OOTW involved discussions with theatre audiences, ethnographic studies of behind the scenes activities, and statistical analysis of system logs. The main findings were as follows.

Coherence and engagement – discussions with participants suggested that OOTW was coherent for both players and viewers. The combination of movement constraints and virtual cameras enabled the crew to keep the action moving and to produce a TV-like rendition of it. However, viewers did not engage emotionally with the characters and roundly criticised us for adopting a clichéd linear gameshow format.

Camerawork – ethnographic studies of coordination between camera operators and the TV director led to new proposals for semi-automated virtual cameras [7].

Simultaneous speaking – The analysis of system logs revealed significant correlation of activity, especially talking. For example, there would typically be nearly ten minutes of a forty-minute show during which all participants were speaking (or shouting) at the same time [8]. This observation contradicts a commonly held view among network engineers that there are typically only one or maybe two simultaneous speakers in a real-time audio application [10]. In turn, this led to new proposals for audio mixing architectures that could cope with the high volumes of network traffic generated by many simultaneous speakers.

Example 2: Avatar Farm

Avatar Farm was a second experiment in inhabited television that attempted to address some of issues raised by OOTW, especially the feedback from viewers criticising its format and content.

The overall goal of Avatar Farm was to create a more sophisticated non-linear drama in a virtual world, based upon improvised dialogue between members of the public and professional actors. We recreated four virtual worlds from an online community called The Ages of Avatar in the MASSIVE-3 system. We then invited four active members of the community and seven professional actors to join us in our laboratory for a weekend to create and record an inhabited television show. The resulting drama was staged as four chapters, each of between twenty and thirty minutes duration.

In chapter one, the four members of the public – the players – were reawakened in the familiar worlds to find that their original creators, the feuding gods Virbius, Egeria and Attis, were back in residence, along with their various sidekicks. The players were split up, taken to different worlds, and were recruited or forced into the service of the gods. Chapter two involved the players learning about the nature of the worlds, especially how to gain special powers such as flying, changing appearance, and becoming invisible. They also learned how to trigger a "time rift" – a ghostlike playback of a scene from the past (part of a backstory that had been recorded by the actors on previous days). In chapter three, the players' loyalties to one another were tested and they began to rebel. Further time-rifts revealed more of the history of the feud between the gods. Finally, in chapter four the players overthrew the villains of the piece.

Our four players used standard desktop PCs, as did five of the seven actors. The remaining two actors used immersive interfaces with head-mounted displays (HMDs) so as to give them more expressive avatars. Members of a production crew were also present in the worlds, although invisible. Each player was followed by an invisible stagehand who could invoke special effects and grant them powers. A storywriter and dramatic director, assisted by an artistic director, were provided with an interface to monitor the action in the worlds and to pass instructions to the actors and production crew. In this way, they could adapt the story on the fly, sending the actors into the world with appropriate instructions.

In contrast to OOTW, Avatar Farm had a highly non-linear form. The core of the story was based upon the four players' experiences. For much of the time they were separated and involved in parallel scenes, often taking place in different worlds (see figure 9 below).

The key technical innovation behind Avatar Farm was a technique called temporal links that enables us to make 3D recordings of sessions in CVEs and then replay them back in a live CVE at a later time [9]. The result is that live avatars can experience scenes from the past, can move around to view them from any angle, and can discuss them while on-line. There were several uses of temporal links in Avatar Farm. First, the story involved several flashbacks in which the players and actors triggered the replay of backstory scenes that had been recorded on previous days and that appeared as ghostly time-rifts (see figure 3). Second, Avatar Farm was itself saved as a series of 3D recordings so that it could be reviewed at a later time. We then developed a series of interfaces that would allow viewers to explore the recordings in different ways. These included an on-line 'promenade performance'' in which live avatars entered the recordings and followed different characters; projecting multiple simultaneous viewpoints into an immersive dome interface; and a table-top projection system in which a virtual camera could be moved across a map of a virtual world (an orthogonal projection) in order to control a more detailed in-world viewpoint (see figure 4).

Figure 3: live avatars watch a ghostly 3D flashback

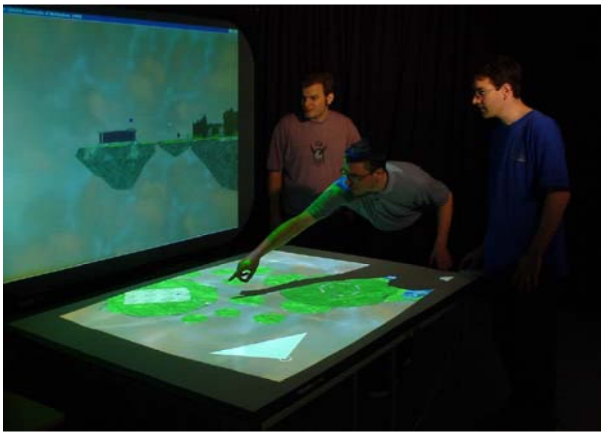

Figure 4: reviewing recordings on the table

The 3D recordings and the table-top projection system also supported ethnographic analysis of Avatar Farm. Whereas previous ethnographic studies of CVEs had relied on capturing the viewpoints of different characters on video (meaning that only one or two viewpoints could be examined), we were able to review the whole experience at leisure, adopting any viewpoint that we required. We were also able to alter the recordings to reveal more information. For example, we made the invisible stage-hands visible and then replayed the recordings to see how they had worked together. This revealed a number of problems, mostly arising from the fact that the stage hands could not see one another and so could not easily coordinate their actions. In turn, this led to proposals for making greater use of subjectivity in CVEs [6]. This provides a powerful example of staging a public event, capturing it in detail, and then drilling into the data in order to explore different issues that were not known or predicted in advance.

Example 3: Desert Rain

The focus of our third example, Desert Rain [11], was different again. This time, our aim was to explore issues surrounding the design of mixed reality performances that blur the boundaries between the virtual and physical.

Desert Rain was developed as joint venture with the performance art group Blast Theory [15]. It is a combination of performance, installation and computer game. Six players are sent on a mission into a virtual world to find six human targets. They explore motels, deserts and underground bunkers, communicating with each other through a live audio link. Once in the virtual world, they have twenty minutes to find their allocated targets, complete the mission, and get to the final room, where the identities of the targets are revealed.

The central artistic concern of Desert Rain is virtual warfare, the blurring of the boundaries between real and virtual events, especially with regard to the portrayal of warfare on television news, in Hollywood's films and in computer games. Both the content and the form of Desert Rain are designed to provoke participants to reevaluate the boundaries between reality and fiction, and between the real and the virtual.

The key feature of Desert Rain is the way in which the virtual world is integrated into an extensive physical set. The experience begins in an antechamber where the players don special clothing and are briefed as to the nature of their mission. A player's access the virtual world by being zipped into an individual fabric cubicle (see figure 5), where they shift their weight on a pressure sensitive footpad in order to control a viewpoint that is projected onto a rain curtain, a two meter square curtain of water spray (figure 6). The rain curtain further blurs the boundary between physical and virtual as it allows performers and players to physically step through it, establishing the illusion of crossing into and out of the virtual world. Finally, at the end of the experience, the players move on to a physical room that is a facsimile of one of the rooms in the virtual world.

Figure 5: players zipped into their fabric cubicles

Figure 6: a virtual world seen on the rain curtain

Of all the experiences described in this paper, Desert Rain was the one that most successfully lived as a professional work. It emerged from a long period of development that began in the summer of 1997 to begin touring as a polished product in October 1999. It has since toured venues throughout the world including Nottingham, Karlsruhe, London Bristol, Glasgow, Rotterdam, Prague, Stockholm and Sydney. This extensive touring schedule provided a unique opportunity for study.

Evaluation of Desert Rain included critical and audience feedback. On the whole, the critics were highly favourable, suggesting that we had managed to create an experience that functioned successfully both as an art-work and as an example of emerging technology:

> "… is possibly the most technologically ambitious art installation ever made" and "Sombre as its aims may be, Desert Rain is exhilarating to experience first hand." [The Times (UK), May 10th 2000]

> "… the experience does recreate some of the fear and disorientation that those on the ground during the Gulf War must have felt" and "part of a growing trend in performance and installation to blur the line between spectator and participant" [The Guardian, UK, May 18th 2000]

We also carried out ethnographic studies of Desert Rain as it toured, focusing on the issue of orchestration; the process of shaping on-going experience from behind the scenes in order to ensure that a participant's engagement with content is not fractured [13]. Our studies shed light on two key aspects of orchestration [11]. First, was the way in which performers and crew monitor activity in both virtual and physical spaces. This was achieved through the use of displays that tracked different players' viewpoints, listening in to the audio channel, and by exploiting the asymmetric nature of the rain curtain (it is transparent from behind, providing an opportunity to observe users without being observed). Second, were the different ways in which performers intervened in physical and virtual spaces in order to shape a player's experience and to resolve problems. Off-face interventions involved carefully weaving instructions to the players into the performance (e.g., using the audio channel). Virtual interventions involved carefully steering the players through the world (ideally) without them knowing. Finally, face-to-face interventions were a last resort in which a performer would have to directly engage a player directly in order to resolve a problem.

Example 4: Can You See Me Now?

Our final example, Can You See Me Now?, extended our work with mixed reality performances by moving outdoors onto the city streets. Can You See Me Now? was a game in which up to twenty on-line players were chased across a map of a city by three performers who were running through its streets. Our motivation was to explore issues in the deployment of mixed reality technologies outdoors, and to understand the kinds of collaborative relationships that are possible between online participants and those on the streets.

Can You See Me Now? was created in collaboration with Blast Theory, and was staged in the city of Sheffield as part Shooting Live Artists 2001, a series of new media events supported by the Arts Council of England, BBC Online and b.tv, the media company.

Central to Can You See Me Now? was a relationship between up to twenty on-line *players* (members of the public using the Internet) who were moving across a map of Sheffield, and three *runners* (members of Blast Theory) who were moving through the streets of Sheffield. The runners chased the players. The players avoided being 'seen'. Everyone, runners and players, saw the position of everyone else on a shared map. Players sent text messages to each other, which were also received by the runners. In turn, runners talked to one another over a shared radio channel, which was also overheard by the players.

Figure 7 shows an example of the player interface. A simple white icon showed the player's current position according to their local client. Other players were represented as blue icons. The runners were shown as orange icons.

Figure 7: An on-line player's Interface

The runners also saw the map of Sheffield showing their positions as well as the players' positions and text messages. This was delivered to them on a Compaq iPAQ from a server in a nearby building over a 802.11b local area network. A GPS receiver plugged into the iPAQ registered the runner's position as they moved through the streets and this was sent back to the server over the wireless network via an armband antenna. The runners also used walkie-talkies with earpieces and a head-mounted microphone (see figure 8).

The performance was orchestrated from a control room in Sheffield. This hosted the game server, the connection to the 802.11b network (via a high-power omni-directional antenna on an eight meter mast on the roof), the connection to the Internet, and interfaces for monitoring GPS and 802.11b signals from the players.

Can You See Me Now? was live for 6.5 hours during the weekend of Friday 30th November and Saturday 1st December 2001. 214 players took part over the Internet. 135 of these were caught, 76 logged off and 3 were never caught. The best 'score' (time without being caught) was 50 minutes. The worst was 13 seconds.

Figure 8: A runner ready to go

Evaluation based upon audience feedback, ethnographic studies and analysis of system logs (including statistical analysis of players' movements and manual analysis of logs of text messages), raised a number of issues, grouped around the themes of gameplay and orchestration. Gameplay issues focus on participants' experiences of the game, their tactics, and ways in which the game could be improved.

Runners' tactics – the runners changed their tactics to great effect between the two days, slowing down, luring the players in, exploiting areas of good GPS coverage and collaborating more closely.

Local knowledge – players would have benefited from better knowledge of the local environment on the streets, including labels for local references, indications of hills and traffic conditions.

The role of audio – the streamed walkie-talkie communication was an important part of generating excitement for the players, especially when their names were mentioned by the runners.

As with Desert Rain, studying the process of orchestration also raised several design issues.

Interfaces for monitoring – the monitoring interfaces were too fragmented, detailed and expert specific. A shared higher level interface that provided an overview of the state of the game with possible drilling down into greater detail would have been an improvement.

Intervening outside the control room – one crewmember had to be dedicated to servicing the runners on the streets (e.g., frequently changing batteries). This would have been much harder if the performance had taken place over a larger physical area, suggesting the use of mobile support units in future experiences.

REFLECTIONS AND IMPROVEMENTS

Our four examples show how the approach of staging public performances, combined with a strong evaluative focus that utilises ethnography, audience feedback and analysis of system logs, can help identify new design issues for CVEs. Two issues are worthy of particular note as they arise as a direct result of focusing on public performance.

Orchestration and capturing activity for viewers

The first is orchestration. As noted above, this is an ongoing process where performers and members of the production crew shape a participant's experience from behind the scenes. This can be contrasted to the traditional view of software deployment where the user installs some software, runs it and is then on their own (unless here is a major problem in which case they call a help desk). Orchestration is an important issue for CVEs in general. Early ethnographic studies of CVE teleconferencing highlighted the activities required by participants to establish and maintain a virtual meeting – the "work to make it work" [3]. However, orchestration is a far more acute issue for public performance, and so this is a good driving application for an in depth exploration.

Our experiences have shown how orchestration involves monitoring both physical and virtual spaces and then intervening in them in different ways. Interventions have included the use of predefined movement constraints (OOTW), invisible stagehands (Avatar Farm) and off-face and virtual interventions that are more subtly woven into the experience (Desert Rain). They have also raised issues for further research, especially the need to support future experiences in which participants and both distributed and mobile.

Our second key issue is capturing action in a CVE so that it can be shown to third party viewers. In OOTW this involved deploying human controlled virtual cameras so that a television director could create a live broadcast for a viewing audience. In Avatar Farm it involved making 3D recordings of CVEs and then developing new interfaces to allow viewers to explore them at a later time. Again, although obviously relevant to performances, we argue that this issue (and hence these techniques) is relevant to other applications. As an example, training and simulation applications may require exercises to be managed and presented to reviewers, either live or during subsequent debriefings.

Improving the method – new techniques for data capture, analysis and sharing

While the approach of staging and evaluating public performances can lead to new design insights for CVEs, our experience shows that there are ways in which it can be improved. A key bottleneck concerns the capture, manipulation, analysis and sharing of data.

Ethnographic studies rely on a variety of data including field notes, photographs and video. As noted above, capturing social interaction in CVEs on video is a difficult task. Resources are often limited so that only one or two viewpoints can be captured, and current analysis tools do not handle multiple synchronized viewpoints at all well. Detailed analysis of sessions that involve tens of participants is even more difficlt. In short, it can be time consuming, expensive and frustrating work to analyse videos of sessions in CVEs. Analysis of system logs is also more problematic than it need be. At present, there is no agreed format for log data and no readily available suites of analysis tools.

We believe that techniques for making and replaying 3D recordings such as temporal links (see above) will form an important part of the solution to these problems. 3D recordings can be reviewed from any perspective, and so deal with one of the major limitations of capturing views from CVEs onto video; that the perspective needs to be determined at capture time. In addition to supporting ethnographic analysis, 3D recordings also support statistical analysis of activity, as the underlying data for a 3D recording includes detailed logs of system events (in fact, our work on temporal links emerged from techniques for logging activity for statistical analysis). As a result, a single data source can support both ethnography and statistical analysis. Finally, because they enable a session in a CVE to be completely recreated as if live, 3D recordings can support other aspects of the research process. For example, the same recording can be played back through different versions of a CVE system, enabling the technical performance of different architectures to be compared in the laboratory but under realistic conditions (i.e., as if a performance were actually happening). In fact, each new system can be tested against a collection of recorded performances.

However, some limitations need to be addressed if 3D recordings are to be used in these ways.

Flexible structure and manipulation – under our current implementation, a 3D recording is a large monolithic file that consists of an initial snapshot of system state followed by a log of updates to this state. It is difficult to cut up recordings into manageable chunks or to instantaneously jump to marked locations within a recording. 3D recordings need to be extended to make them easier to manipulate and view.

Indexing to other data – a CVE recording does not capture all of the data that an ethnographer requires. Previous studies of CVEs have shown that it is important to examine what is happening in the physical spaces of the participants as well as in the CVE [3]. Field notes and copies of participants' own documents may also be examined. As a result, it should be possible to index from CVE recordings into other media types. For example, to link recorded activity in a CVE to video recordings of the physical participants.

Analysis tools – reviewing CVE recordings in real-time (or even speeded up) is a painstaking process, especially where an experience involves many participants or takes a long time (Avatar Farm involved eleven different characters and lasted for over two hours). New tools are required to automatically analyse CVE recordings in order to provide researchers with guidance as to where potentially interesting events have taken place. We have therefore recently developed an scene extraction tool for automatically analyzing 3D recordings. Our current implementation determines interesting scenes based upon the proximity of participants (although it could be extended to account for other factors such as orientation, audio activity, or the identities of key characters). First, it uses a clustering algorithm to group participants on a moment-by-moment basis. It then looks at changes in clusters over time in order to determine on-going scenes. Figure 9 shows an example of its output. In this case, we are looking at a GANTT chart representation of the key scenes in chapter 1 of Avatar farm (determined with a proximity threshold of 15 meters – the cut-off point for audio communication). Time runs from left to right and the different colours distinguish scenes that were occurring in different virtual worlds. The tool allows the viewer to overlay the paths of different participants through the structure. We see two participants ('Role 2' and 'Role 3') in our example. We propose that tools such as this can assist researchers in analyzing activity in CVEs by enabling them to more easily home in on potentially interesting social encounters.

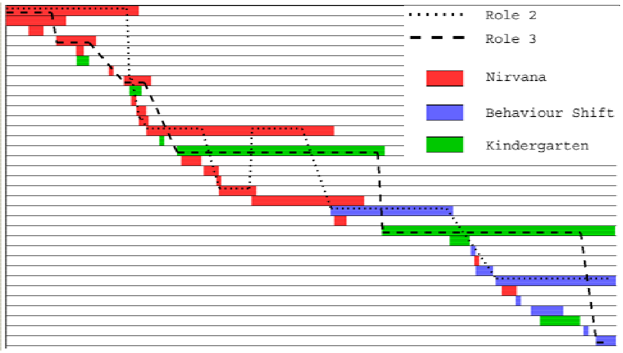

Figure 9: visualising scenes from Avatar farm

Sharing across the CVE community – our final observation concerns the sharing of data between researchers. In order to maximize the use of recordings, it will be necessary to share them between different researchers. As these techniques mature, the CVE community needs to agree on common formats for recordings so that we can establish shared repositories of recordings of different events in CVEs.

We believe that such repositories could be extremely beneficial to CVE research. They would also enable researchers to get the maximum return from the high cost and effort involved in staging public performances and other large-scale events as discussed in this paper. Given developments such as these, we hope that staging public performances can become a more widely accepted approach in the CVE community and beyond.

ACKNOWLEDGEMENTS

This research has been supported by the EPSRC through the Equator Interdisciplinary Research Collaboration (www.equator.ac.uk).

REFERENCES

1. Anastasi, R, Tandavanitj, N., Flintham, M., et al., Can You See Me Now? A Citywide Mixed-Reality Gaming Experience, *submitted to Ubicomp 2002*.
2. Benford, S., Reynard, G and Greenhalgh, C., A Poetry Performance in a Collaborative Virtual Environment, *Computer Graphics and Applications*, 1999, IEEE Press.
3. Bowers, J., O'Brien, J. and Pycock, J., Practically Accomplishing Immersion: Cooperation in and for Virtual Environments, Proc. CSCW'96 (1996), ACM Press, 380-389.
4. Crabtree, A., Nichols, D.M., O'Brien, J., *at al*., M. (2000) "Ethnomethodologically informed ethnography in information systems design", *Journal of the American Society for Information Science*, vol. 51 (7), pp. 666-682.
5. Craven, M., Taylor, I., Drozd, A., *et al.,* Exploiting Interactivity, Influence, Space and Time to Explore Non-linear Drama in Virtual Worlds, *Proc. CHI'2001*, Seattle, April 2-6, 2001, ACM Press.
6. Drozd, A., Bowers' J., Benford' S., Greenhalgh, C. and Fraser, M., Collaboratively Improvising Magic: An Approach to Managing Participation in an On-Line Drama, Proc. ECSCW 2001, Bonn, 2001.
7. Greenhalgh, C. M., Benford, S. D., Taylor, I. M., Bowers, J. M., Walker, G. & Wyver, J., Creating a Live Broadcast from a Virtual Environment, *SIGGRAPH'99*, 375-384, Los Angeles, 1999.
8. Greenhalgh, C., Benford, S., Craven, M., Patterns of Network and User Activity in an Inhabited Television Event, In Proceedings of VRST'99, ACM, 58-65, London, Dec 20-22 1999.
9. Greenhalgh, C., Purbrick, J., Benford, S., Craven, M., Drozd, A. and Taylor, I., Temporal links: recording and replaying virtual environments, ACM Multimedia 2000, L.A. , October 2000.
10. H. Schulzrinne, S. Casner, R. Frederick, and V. Jacobson, RTP: A Transport Protocol for Real-Time Applications, IETF RFC 1889, January 1996.
11. Koleva, B., Taylor, I., Benford, S., Fraser, M., *et al*., Heath, C., Row-Farr, J. and Adams, M., "Orchestrating a Mixed Reality Performance", *Proc. CHI 2001*, Seattle, USA, pp. 38-45, ACM Press
12. kultur.aec.at (verified 3rd May, 2002)
13. Laurel, B., *Computers as Theatre*. Addison-Wesley 1992.
14. www.banffcentre.ab.ca (verified 3rd May, 2002)
15. www.blasttheory.co.uk (verified 3rd May, 2002)
16. www.canyouseemenow, verified 12 April, 2002
17. www.equator.ac.uk, verified 3rd May, 2002
18. www.i3net.org (verified 3rd May, 2002)
19. www.ica.org.uk (verified 3rd May, 2002)
20. www.immersense.com (verified 3rd May, 2002)
21. www.isea.qc.ca/maind.html (verified 3rd May, 2002)
22. www.media.mit.edu (verified 3rd May, 2002)
23. www.parc.xerox.com/red/ (verified 3rd May, 2002)
24. www.zkm.de (verified 3rd May, 2002)