Towards a Citywide Mixed Reality Performance

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ABSTRACT
We are exploring the use of mobile mixed reality technologies to create citywide performances. We introduce six approaches to overlaying a virtual world on the city streets that emerged from early brainstorming workshops. We describe how one of these was refined and used to create an initial public performance called Can You See Me Now? in which up to twenty on-line players were chased across a map of Sheffield by three performers running through the streets. We discuss key issues raised by these experiences: combining diverse interfaces to create a single experience; supporting orchestration; and the critical role of real-time audio.

AN INTRODUCTION TO THE CITYWIDE PROJECT
The Citywide project is exploring the potential of mobile mixed reality technologies to create performances across a city. Participants on the city streets will experience events that are taking place in a parallel virtual world that is connected to and overlaid on the city in a variety of ways. At the same-time, online participants who are accessing this virtual world over the Internet will experience events that are taking place on the city streets.

Citywide is exploring the city as a culturally charged area that holds great creative potential. Artistically, the project aims to articulate the spaces between mundane realities (such as traveling on a bus or train) and fantastical projections (most commonly derived from film and television) of drama and action, in which the city is inscribed with untold possibilities. Technically, the project aims to create new mobile mixed reality interfaces that are able to support rich and dynamic interaction between physical and virtual worlds, both indoors and outdoors, on the scale of a physical city. In the long term, we are driven by the following broad research questions:

- In what ways will the emergence of mobile mixed reality technologies combined with changes in modes of cultural reception create opportunities for new cultural forms?
- In what ways is the city inscribed by fictional narratives, particularly film, and how can this be used to develop interactive experiences across a city?
- How should mobile mixed reality experiences be structured and how should the technologies involved be further developed to support this?
- What role can artists have in shaping the development of emerging mobile technologies?

The project involves collaboration between the EPSRC-funded Equator Interdisciplinary Research Collaboration and the artists group Blast Theory. Equator is a six-year research programme investigating the 'interweaving of physical and digital interaction' [15]. It began in 2001 and involves researchers from computer science, electronics, social science, psychology and art and design, spread across eight academic organisations in the UK. Blast Theory is a group of artists based in London who make live events for theatres, clubs, galleries and the street [13]. The four members of Blast Theory have developed cross platform projects since 1991 and have a history of creating performances that involve computing and video technologies. Their previous works include 10 Backwards, Kidnap and Something American.

Citywide builds on a previous collaboration between Blast Theory and researchers at Nottingham called Desert Rain, a mixed reality performance in which six participants at a time interacted within a collaborative virtual environment that was projected on a 'rain curtain', a screen of water spray through which they and the performers could pass (more conceptually, an example of a 'traversable interface'). Ethnographic studies of Desert Rain as it toured Europe yielded insights into the process of orchestration – how performers and crew shaped participants' experiences and how the technologies involved helped and hindered this process [9].

The new Citywide project has been active since early 2001. The first phase of the project (February 2001 – October 2001) involved a series of intensive weeklong workshops to propose and rapidly prototype different techniques and technologies for overlaying a virtual environment on a city. The second phase of the project involved a first public performance called 'Can You See me Now?' [14]. This was staged in Sheffield on November 30th and December 1st 2001 as part of 'Shooting Live Artists', a new strategic initiative from by The Arts Council of England, the BBC, Yorkshire Media Production Agency's Studio of the North and b.tv.

In this paper, we summarise progress on Citywide to date. We present the technologies that emerged from the early workshops and then provide an overview of Can You See Me Now? We then discuss some of the lessons and design issues that have emerged from these experiences.

PROTOTYPING INTERFACES FOR THE CITY

We began with the challenging problem of accessing a virtual environment as if it were overlaid on the city; in other words, supporting augmented reality (AR) on the city streets. The archetypal approach to AR uses a wearable or handheld device to supplement a participant's experience of a physical environment. For example, they may don a wearable computer with tracking and specialized IO devices (such as a see-through head mounted display). This allows them to receive or recall additional context-relevant information superimposed on their normal experience of physical spaces and/or artifacts. Alternatively they may carry a handheld device. A typical application for this kind of system has been in the production of electronic guides, where visitors are presented with information about their current location. This class of system ranges from museum based systems [2] to broader town and city guides [4].

Early experiments with augmented reality outdoors have identified a number of difficult design challenges. For example, Azuma [1] discusses displays being hard to read in sunlight, tracking having variable accuracy, and portability being limited, especially as a function of power requirements.

Our early Citywide workshops explored how a performance could work within such constraints. They also brainstormed and prototyped alternative approaches to augmenting the city streets that might be particularly suited to artistic applications. We now briefly describe six interfaces that emerged from these initial workshops:

- The use of fixed and public telephones to create audio tunnels between physical and virtual worlds;
- The extension of these to mobile phones;
- The combination of a PDA, GPS device and wireless networking to create a digital activity meter, an interface for locating hotspots of activity in a parallel virtual world and displaying these on a radar display;
- A second digital activity meter that produces an audio sonification rather than a visual display;
- A portable tripod-mounted display called an augurscope through which users may view virtual activity when outdoors;
- The projection of a virtual world into public space as virtual shadows;

Each interface establishes a different kind of relationship between a physical environment and an overlaid virtual world. Each also responds differently to a range of underling design issues as we shall discuss later on.

Audio tunnels using fixed or public telephones

In our first prototype interface, an on-line user moving through a virtual world approaches a virtual payphone. This automatically triggers a phone call to the corresponding physical payphone, establishing an audio channel to it from the corresponding part of the parallel virtual world. Figure 1 shows an avatar approaching a phone in the virtual world in order to place a phone call.

Figure 1: A virtual user approaches to payphone to establish an audio tunnel to the physical world

This example shows that augmented reality can exploit devices that are already embedded in the physical world as a means of augmentation. Payphones are an established component of many urban landscapes, providing a potential bridge between physical and virtual space. The locations of public payphones can be determined in advance of an experience and these can then be used to allow activities within the virtual world to be heard from corresponding locations within the physical. This communication can also be two-way, with the audio information from the payphone link made available to the virtual users. The result is to create an audio tunnel between the digital and physical world.

Audio tunnels using mobile phones

Mobile phones are carried and used in vast numbers, especially in Europe, North America and the Pacific Rim. As with fixed phones, they are an established pre-existing technology that can be appropriated to support augmented reality, rather than a completely new device. In our second prototype a mobile phone was accessed from the virtual world as above – i.e., a virtual participant could trigger a call to a mobile phone by bumping into it. In addition, supplementing the mobile phone with a tracking technology enabled changes in its location to be reflected in the virtual world. As a result, the mobile phone user moving through the city streets could bump into virtual objects or participants and receive a call from them.

There is ongoing work on positioning of phones using just the phone network radio strength, for example to support emergency services in locating callers, however this information is not generally available (for reasons of security and privacy). Instead, the approach that we have prototyped is to use a GPS receiver and a PDA (a Palm Pilot) connected to the mobile phone, that notifies the virtual world via an SMS message when the mobile phone is moved physically. Figure 2 shows the hardware carried by the mobile user (left) and a corresponding image of their avatar in a virtual environment (right) in which an audio tunnel is active (shown by the presence of the yellow pyramid above their head).

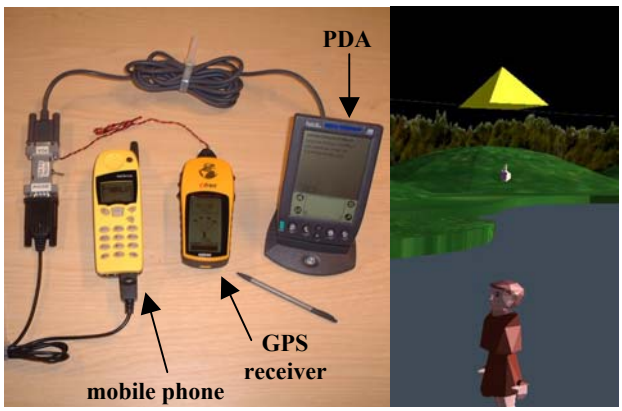

Figure 2: mobile phone with PDA and GPS receiver

A digital activity meter with a radar display

There are various devices in fiction and fact that are specifically tailored to locate objects, places and activities within the physical world. Geiger counters are used to locate sources of radioactivity; psycho-kinetic energy meters (PK-meters) are used by paranormal investigators to detect otherworldly presence and activity; and resistivity meters are used by archeologists to locate historical artifacts and buildings.

Inspired by these, we have created two handheld "digital activity meters". These alert the user to the presence of nearby digital activity, such as avatars or virtual objects in a parallel virtual world. These interfaces are designed to support the activity of searching – they allow a participant to home in on virtual content within a larger but less augmented space such as a city.

Our first prototype combines a PDA (a Compaq iPAQ), a GPS receiver to determine the user's physical position, and a wireless 802.11b network for communication with a remote virtual world server. It presents the user with a radar style display, indicating the relative positions of nearby artifacts and avatars in the virtual world. Figure 3 shows the radar indicating the presence of two nearby avatars as dots in the central circle.

Figure 3: Digital activity meter with virtual radar display showing nearby avatars.

A digital activity meter with a sonic display

Our second prototype employs an abstract audio presentation rather than 2D graphics to give the user proximity information about multiple nearby virtual objects. Each virtual object is associated with its own audio tone. As they move around the physical environment, the user hears a mix of tones that indicates the relative proximities of the objects (each tone increases in volume and frequency when the object is closer).

Searching is typically a single element of a guide-type or general-purpose AR system (e.g. [4]). In contrast, these interfaces support searching as an activity in itself, whereby searching may be as significant as finding. An early test application was based around a virtual archeology experience, in which users searched for "hidden" virtual artifacts, which they then "took back" to a fixed installation for detailed viewing [3]. Figure 4 shows two users in the physical world on the left who are searching for a virtual object (a fragment of a bowl) in the parallel virtual world on the right. The avatar on the right shows their current position in the virtual world according to the GPS tracking.

The Augurscope – a portable, tripod-mounted display

The augurscope (figure 5) is a portable augmented reality interface for use by small groups in open (indoor or outdoor) locations [12]. It is used to directly view parallel

virtual world, for example after particular content has been located using a digital activity meter.

Figure 4: Locating part of a virtual bowl.

Figure 5: The Augurscope in use.

The augurscope is based on a tripod-mounted laptop computer. A GPS receiver (for outdoor use) and electronic compass provide global location information. An onboard accelerometer and rotary encoder allow the virtual viewpoint to be interactively manipulated by panning and tilting the physical device on its tripod. As the scope is moved the laptop's display changes to show the corresponding view of the parallel virtual world, allowing users to view the virtual world alongside the corresponding part of the physical world. The augurscope is a public device designed to allow a small group of users to cluster around the view of the virtual world. Our first test application of the augurscope involved allowing members of the public to view a 3D model of Nottingham's medieval castle as they moved around the site of its 18th century replacement [12].

Virtual shadows as public projections

Our final prototype interface has been inspired by shadows in the everyday world. Shadows provide indirect projections of physical objects and activity onto public surfaces, typically outdoors, in a way that is at once familiar and distorted (and potentially aesthetically interesting). Various artists have previously incorporated shadows as secondary displays of activity in virtual reality installations (see for example, Char Davies' 1995 installation Osmose).

Our workshops experimented with *virtual shadows*, projections of a virtual world into a public space that are deliberately simplified and distorted (like a shadow) so as to convey a sense of virtual presence and activity without the need for accurate positioning or overlaid 3D graphics.

The primary goal is to create an ambient or impressionistic display, particularly aimed at bystanders and larger groups or crowds who are not typically addressed by current AR interfaces. A shadow projection can be realized as a viewpoint at a particular location within a virtual world that is then projected into a (public) place that normally corresponds to the virtual location. As users and objects in the virtual world move, the shadows projected into the physical world change accordingly. For example, as my avatar passes passes a specific location in a virtual street, its shadow appears in the corresponding location in the physical street. Virtual shadows could be supplemented with sound projections that broadcast the audio activity of virtual objects as they pass by.

Figure 6 shows an example of projecting digital shadows of avatars onto the side of a large building. These shadows were projected over a distance or approximately 200 meters using a projector with a long throw lens.

Unlike most of the interfaces described so far the devices that produce shadow projections are typically fixed and embedded within the environment, rather than being mobile. However, we have also experimented with an intermediate (semi-mobile) approach, running projectors and PCs from the back of a parked van, using a generator for power. Another possibility would be to use steerable projectors and cameras as described in [11].

Figure 6: virtual shadows projected onto a building

CAN YOU SEE ME NOW?

Following our initial exploratory workshops, the second phase of the Citywide project involved staging a first public performance called Can You See me Now? Our aim in so doing was to choose one approach to creating a

citywide mixed reality performance, refine and publicly test it in order to determine whether we could manage to create an exciting and engaging experience and also to explore issues surrounding public deployment.

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'.

A player's experience began at the Can You See Me Now? homepage [14], where they entered a name for themselves in response to the prompt "Who are you looking for?". They then joined the game queue, and from there were eventually dropped into the map of Sheffield. They used the arrow keys to move around this map. They could not move off of the map or enter solid buildings and other restricted areas.

A player was represented as a pair of icons on the map. A simple white icon showed their current position according to their local client, providing immediate feedback as to their movement. A blue icon showed their position according to the game server, and this would trail behind the white icon with a lag of a few seconds (due to the communication delay between the client and the server over the Internet and the time taken to process players' movements at the server). Other players were represented as blue icons. The runners were shown as orange icons.

Each player was able to exchange text messages with other players. In addition, audio from the runners' walkie-talkies was streamed to the players over the Internet so that they could listen in to their communications (which of course, were a deliberately staged dialogue created as part of the performance). The players continued to move and text until a runner got sufficiently close to them that they were 'viewed'. At this point they were removed from the game (although they were offered a chance to re-enter the queue). The players' interface was implemented as a shockwave movie connecting to a Fuselite server running at Nottingham. Figure 7 shows a screenshot of the player's interface from a Shockwave client.

The runners also saw the map of Sheffield showing their positions as well as the players' positions and text messages. Unlike the players, their map allowed them to zoom between a global view and a close-up local view centred on their current position. This interface was delivered to them on a Compaq iPAQ from a server in a nearby building over a 802.11b local area network. The performance took place over an area of Sheffield that was roughly half a mile square and that consisted of a mixture of open spaces and narrow streets lined with tall buildings. Establishing a wireless network with sufficient range and coverage required us to erect an eight-meter high-power omni mast on the roof of a building, and to supplement this with a smaller lower-power omni aerial to fill in coverage at street level. A GPS receiver plugged into the serial port of the iPAQ tracked the runner's position as they moved through the streets and this was sent back to the server over the wireless network. The iPAQ and GPS receiver combination was attached to a wooden board that could be placed in a plastic bag to improve ruggedness, ease of carrying and to provide some basic weatherproofing. The runners also used walkie-talkies with earpieces and a head-mounted microphone and carried digital cameras so that they could take a picture of the physical location where each player was caught. The resulting images are being used to built a final archive website for the performance. Figure 8 shows one of the runners kitted up and ready to go. Figure 9 shows a runner's map interface from an iPAQ.

The performance ran between 17:30 until 21:00 on Friday 30th November (a period of darkness in Sheffield at that time of year) and between 13:00 to 14:30 and 15:30 to 17:00 on Saturday 1st December (much of which was in the light, with darkness only falling towards the end). Overall there were therefore 6.5 hours of live performance time. During this time 214 players took part over the Internet. Of these, 135 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.

The primary mechanism for audience feedback was via the website. In addition, two ethnographers briefly observed the Saturday performance, making notes and recording video for subsequent analysis. We also instrumented our software to log all of the movements of the players and runners so that these could be statistically analysed later on. At the time of writing, ethnographic and statistical analysis is ongoing. However, our initial (and informal) feeling, backed up by some audience feedback, is that there were moments when the experience was genuinely exciting for the on-line players (it undoubtedly was for the runners!). In the words of two of the players:

"I played early doors and thought it was fantastic. I got a real adrenalin rush off it which surprised me."

"I only managed to get on to the map once for about 15 minutes. I can't remember the name I used, but it was pretty un-nerving first hearing my name said".

We will expand on some of the factors that contributed to this, as well as other design issues emerging from Can You See Me Now and the earlier workshops in the following section.

EMERGING ISSUES

Citywide is clearly a work in progress. This section reflects on some of the key lessons learned so far.

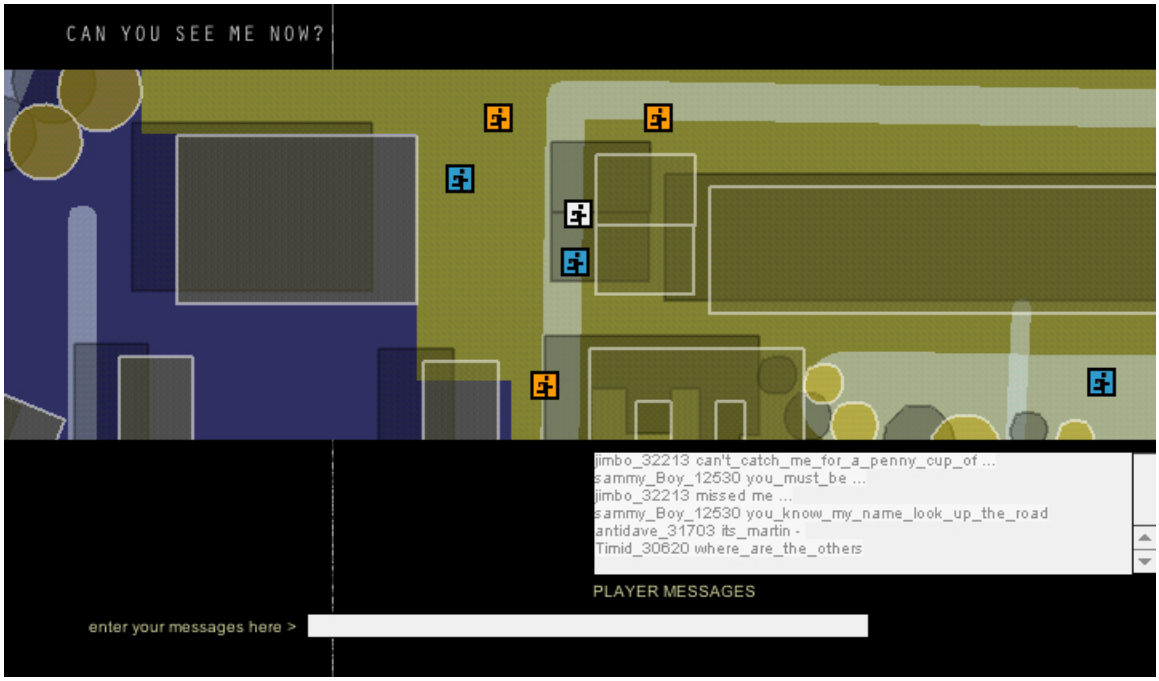

Figure 7: Screenshot from the player's interface

Figure 8: a runner

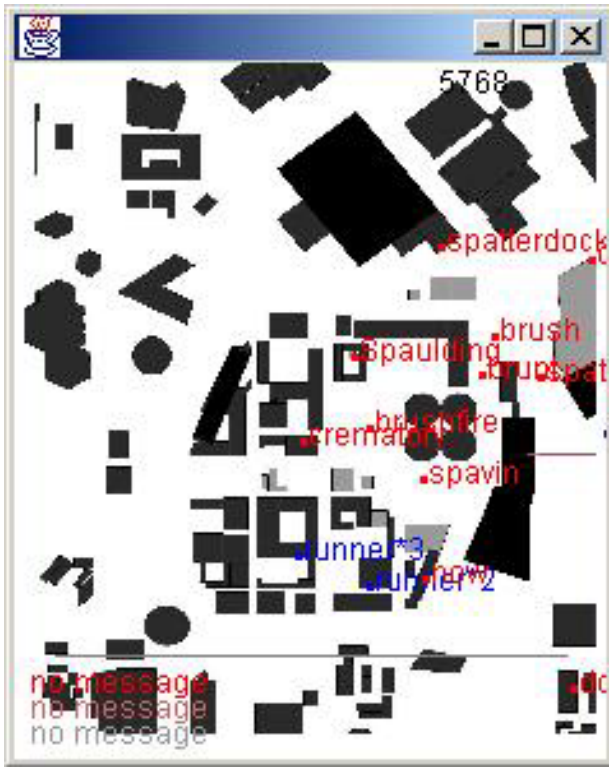

Figure 9: the runner's interface from an iPAQ

Combining diverse interfaces

We begin by reflecting on the potential roles of the various interfaces that we have prototyped to date in creating a citywide performance. Each interface addresses a set of underlying design questions in a different way:

- What kind of activity does this interface best support (e.g., alerting a participant to nearby virtual activity, searching for activity in a larger area, viewing this activity, or peripheral display for passersby)?
- How many users share the interface at one time (e.g., individual, small group or crowd)?
- Is this a commodity technology that participants can be expected to bring with them or that already exists in the environment, or a bespoke technology that will be provided by the producers?
- Is the interface embedded in the environment or mobile and therefore carried with the participants?
- What networking and tracking is used and how is the device powered?

	phone-box audio tunnel	mobile phone audio tunnel	augur-scope	visual activity meter	sonic activity meter	shadow
activity	alert/ hear	alert/ hear	view/ hear	search	search	periph.
no. users	indiv.	indiv.	group	indiv	group	crowd
commodity /bespoke	com	com	besp	besp	besp/ com	besp
embedded/ mobile	embed	mob	mob	mob	mob	embed
network	wired phone	phone /SMS	802.11 LAN	802.11 LAN	802.11 LAN	wired Internet
tracking	none	GPS	GPS+ accel. rotary	GPS	GPS	none
power	own supply	battery	battery	battery	battery	mains/ generate

We propose that a large-scale citywide performance will need to combine a diverse range of such devices into a single experience in order to integrate different kinds of participants and activities (e.g., attracting passersby to become involved versus supporting active participants who are searching for virtual content) and to meet local constraints in different parts of the city (does GPS work well? is this location in an island of 802.11b connectivity? is mains power available?). For example, shadow projections and phoneboxes may provide bystanders with some sense of the experience or draw them in, and interfaces based on mobile phones may then enable them to navigate to key locations in the city where bespoke interfaces then provide them with a richer experience of the virtual world. In turn, this approach requires the support of a software platform that is able to integrate different kinds of mobile and fixed interface with a virtual world. Equator is currently developing the Equip platform to meet this goal (see [15]).

Orchestration

In *Computers as Theatre*, Brenda Laurel proposed an approach to interaction where computers are considered as a form of theatre rather than as tools, and where the focus of design is on engaging users with content rather than with technology [10]. She then described how various behind-the-scenes activities are required to maintain engagement and to orchestrate users' experiences. Computer-mediated performances are of course quite literally computers as theatre and so have to tackle the issue of orchestration head on.

Previous experiments with online drama and television shows in collaborative virtual environments developed orchestration tools that would allow production crew to monitor and intervene in activities in a virtual world [5,6]. Ethnographic studies of Desert Rain revealed how performers would *monitor* events, *intervene*, and *communicate* in both physical and virtual spaces in order to orchestrate a mixed reality performance [9]. These processes become more complex in Citywide performances due to distributed nature of participants and the spaces through which they move – physical participants can be spread a city and on-line participants can be anywhere on the Internet. Movement across a city takes a potentially long and unpredictable time, adding to the difficulty of coordinating actions.

To orchestrate Can You See Me Now? we established a dedicated control room in Sheffield from which the event was managed. This was home to several *monitoring* technologies:

- A dedicated game management interface that showed the positions of all players and runners on the map.
- A computer monitoring GPS data from the runners and a second monitoring their LAN signal strengths.
- A laptop running a standard player client so that people in the control room could join in the game.

The runners used a second walkie-talkie frequency for private *communication* with the control room. This was not streamed to the players. Mobile phones were used as a fallback and also for communication with the base at Nottingham. *Interventions* were possible through the game management interface (e.g., removing a player), through the streamed audio or by a member of the control team joining the game. A typical control team involved one person monitoring the game, a second monitoring the GPS and wireless LAN, and a third responsible for kitting out the runners as their entered the game and for regularly changing batteries on their wireless devices.

On reflection, this set-up could have been improved in several respects. There was probably not enough information available about the numbers of people queuing to join the game and their status (having this information might have revealed some problems with the server early on). Battery management for the runners was

a major headache and some telemetry data showing their power status would have helped.

Looking to the future, it would be interesting to explore more integrated orchestration interfaces (e.g., a shared projection in the control room that shows the status of runners and players in a more integrated way). Another possibility is to explore mobile orchestration interfaces that can cope with larger scale events where participants move across a large area of a city. We briefly experimented with one such interface in our early workshops where we deployed an 802.11b network from a van (a 'LAN in a Van') and monitored GPS tracked participants on the streets from a mobile laptop interface.

The importance of real-time audio

The previous online drama and television shows noted above also demonstrated the critical importance of real-time audio as arguably the primary medium through which performance is achieved and content is carried in on-line events [5]. This is perhaps due to the relatively impoverished nature of real-time 3D graphics when compared to the richness of film and video; avatars are still quite wooden, and so voice becomes the prime medium for expression. Studies of Desert Rain pointed to a second role for audio as a medium through which performers can issue instructions to participants embedded in a dramatic performance and so subtly orchestrate their experience.

Audio played two vital roles in Can You See me Now? First, it was the primary mechanism by which performers created suspension and excitement for players (see the second quote above as an example). Second, the performers used audio to paint a picture of conditions on the streets of Sheffield. Talk over the walkie-talkies was deliberately constructed to show for example, the presence of traffic, hills, fences and other real-world obstacles. Performers also chose to reveal aspects of the infrastructure such as inaccuracies in GPS tracking data or problems with batteries. Players who were sensitive to this performance would be able to tune in to these cues and adjust their tactics accordingly (e.g., crossing roads or moving uphill). In this case, the audio stream was compensating for the lack of detail on the map. However, all maps and 3D models no matter how detailed, are abstractions of reality and so the use of real-time audio in this way seems to offer an effective and dramatic way of communicating conditions on the ground for a range of performance applications.

SUMMARY AND FUTURE WORK

Our work to date has generated new mixed reality interfaces for outdoors; identified key issues to be addressed in staging a large-scale performance; and has convinced us that it is possible to create an exciting experience based around the relationship between on-line participants and those on the city streets. Future plans involve two further public performances. The first, Bystander, is planned for Duisberg, Germany, in June 2002 as part of Theater Der Welt. Current plans are to place the mobile interfaces in the hands of the public and to create a more nuanced experience based around a journey through a city. We then plan to move on to a full-scale Citywide performance in London in 2003.

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