

Coping with uncertainty in a location-based game

Steve Benford, Rob Anastasi, Martin Flintham, Adam Drozd,
Andy Crabtree, Chris Greenhalgh
The Mixed Reality Laboratory, The University of Nottingham, UK

Nick Tandavanitj, Matt Adams, Ju Row-Farr
Blast Theory, London, UK

Introduction

Location-based games are a new form of entertainment that is played out on the city streets. Players equipped with handheld or wearable interfaces move through the city. Sensors capture information about their current context, including their location, and this is used to deliver a gaming experience that changes according to where they are, what they are doing and potentially how they are feeling. In collaborative games, this information is also transmitted to other players who may also be on the streets or on-line. The net result is a gaming experience that is interwoven with the player's everyday experience of the city.

Location-based games are an exciting commercial prospect. They build directly on current wireless (but usually disconnected and location independent) games for mobile phones, the market for which is predicted to reach billions of dollars in the new few years, and represent a potentially significant income stream for 3G mobile telephony. There are also already a few early examples of location-based wireless games including *Bot Fighters!* from Its Alive! [9] and *Battlemachine* from UnwiredFactory [10].

Such games also provide an interesting focus for research as they offer an open space in which it is possible to create a wide variety of experiences – both collaborative and competitive – and are also relatively easy and safe to deploy in public. There have been several examples of research projects that mix online and mobile players to different extents. These include *Pirates!* From the Interactive Institute in Sweden [1], the AR Quake project [4] and *Border Guards* from the Mixed Reality Systems Laboratory in Japan [3].

This paper describes our experience of publicly deploying an experimental mobile mixed reality game called *Can You See Me Now?* (CYSMN) in two different cities. Analysis of more than one thousand plays over more than twenty-five hours provides insights into the effects of uncertainty in location sensing (in this case using GPS) and networking on the players' experiences, shows how we adopted different strategies to deal with these, reflects on how successful these were, and finally leads to some general recommendations for developing similar location-based experiences.

Can You See Me Now?

CYSMN is a chase game. Up to fifteen *online players* at a time, logged in over the Internet, are chased through a virtual model of a city by three *runners*, professional performers, who are running through the actual city streets equipped with handheld computers, wireless network connections (using 802.11b) and GPS receivers. The online players can move through the model with a fixed maximum speed, can access a map view of the city, can see the positions of the other players and the runners, and can exchange text messages with them. The runners run through the streets, can see the positions of the online players and other runners on a handheld map, can see the players' text messages and can communicate with one another using walkie-talkies. A key feature of the game is that the runners' walkie-talkie communication is streamed to the players over the Internet, providing them with ongoing description of the runners' actions, tactics and experience of the city streets, including reports of traffic conditions, descriptions of local topology and the sound of them being out of breath.

CYMSN is a joint development between the Equator project in the UK [8] and the artists group Blast Theory [5]. At the time of writing it has been staged in two different cities: Sheffield in December 2001, where it ran for six hours over two days and received over two hundred on-line plays; and Rotterdam in February 2003, where it ran for twenty hours over five days and received over one thousand on-line plays. The following description of the CYMSN experience is based on the version deployed in Rotterdam (there were some significant developments after Sheffield, including moving from a 2D to a 3D online interface), although our later analysis draws on both.

The online player's experience

An online player's experience begins at the CYSMN webpage where they can explore background information about the game, including instructions. They enter a name for themselves, followed by the name of someone that they haven't seen for a long time – a person that they are looking for. They then join the queue to play (we restricted the number of simultaneous players). When it is their turn to play, they are dropped into a 3D model of Rotterdam. This model is highly abstract, it shows the layout of the streets and outline models of key buildings, including two wire-frame representations of planned buildings that have yet to be constructed, but does not feature textures and misses details of dynamic objects such as cars and of course most of the population. The online player uses the arrow keys to run around this model. They cannot enter solid buildings, move out of the game zone or cross several fences. They need to avoid the runners who chase them. Specifically, if a runner gets to within five virtual meters of an online player, the player is 'seen' and is out of the game (their score is the time elapsed since joining the game).

Online players see themselves represented as running avatars, as are other players and the three runners. Avatars are labelled with players' names and the runners are further highlighted with a red sphere that makes them highly visible, even from a distance. Online players can also select a zoomed out map view of the model which shows the positions of more distant players and runners as well as text labels giving the names of key locations. Finally, they can view and enter text messages and hear the runners'

audio. Figure 1 presents an example of an online player's interface, with the player's avatar in the foreground and a runner close by in the background. Figure 2 shows the interface in map mode.

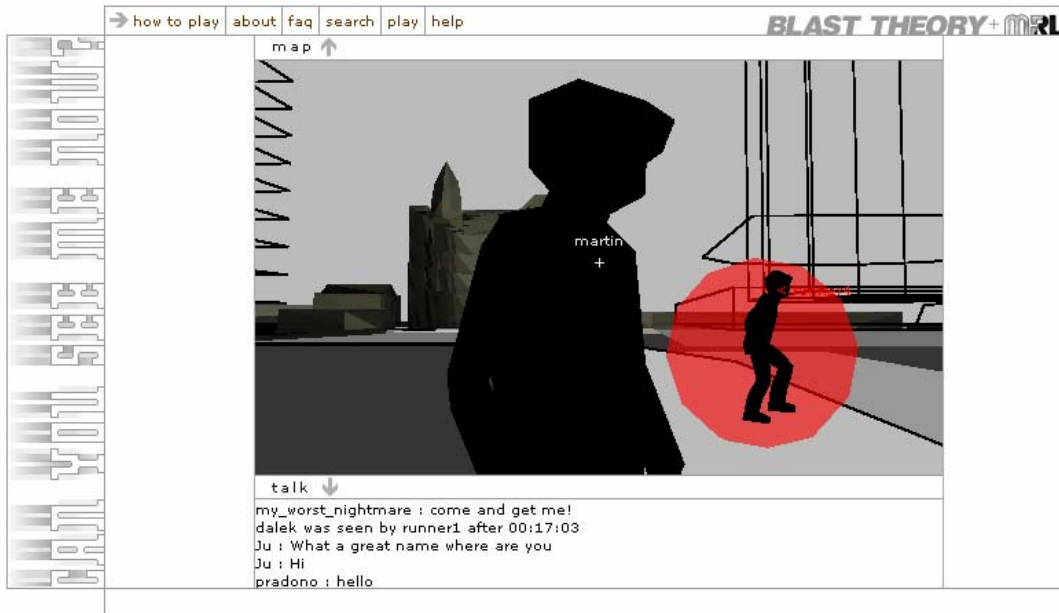


Figure 1: online player's interface – close up view

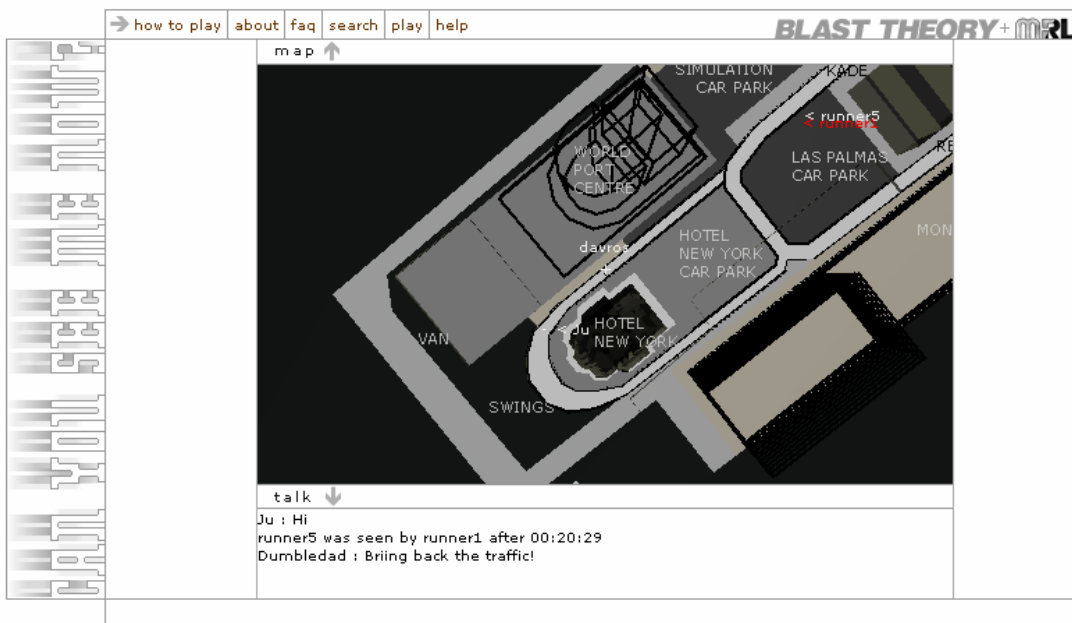


Figure 2: online player's interface – map view

The runner's experience

The runners' interface was delivered on a HP Jornada handheld computer from a server in a nearby building over a 802.11b wireless local area network.

// a bit more about the network configuration

A GPS receiver plugged into the serial port of 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. This equipment was built into a robust outer jacket as shown in figure 3.

// needs updating – what kind of GPS

Given the small screen size of the iPAQ, the runners' map allowed them to zoom between a global view and a close-up local view centered on their current position as shown in figure 4. Blue arrows show runners, red ones online players and the area at the bottom of the screen shows the most recent text messages from the players. The runners used walkie-talkies with earpieces and a head-mounted microphone. Finally, they carried digital cameras so that they could take a picture of the physical location where each player was caught. These pictures appeared on an archive web site after the event [6,7].



Figure 3: a runner

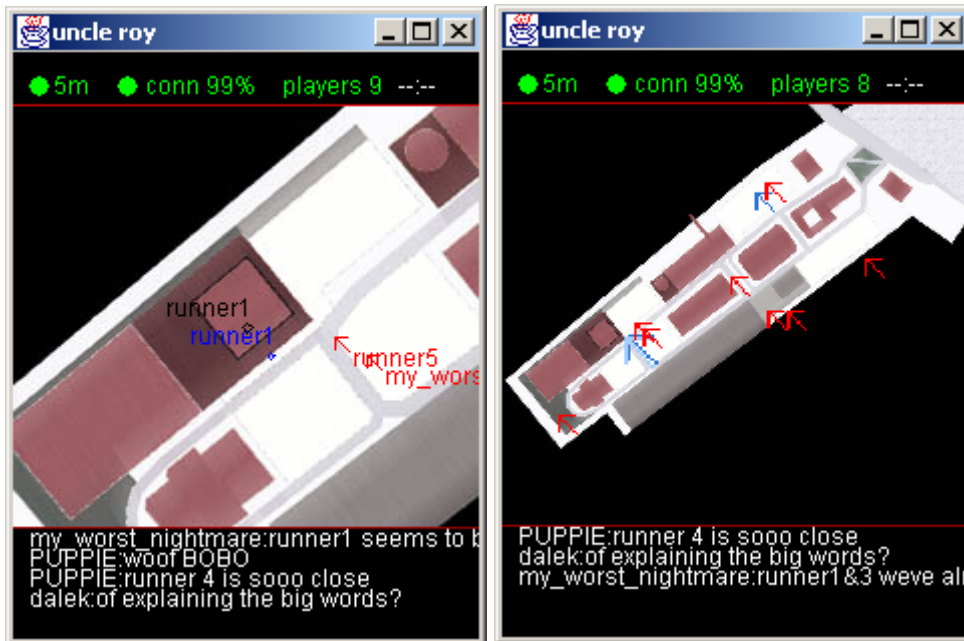


Figure 4: the runner's interface – close up (left) and map view (right)

Deploying CYSMN required the support of an extensive behind the scenes crew who were housed in one of the central buildings in the game zone (along with six public terminals for local online players). The control room was home to a technical crew of three who were responsible for running and managing the online server and supporting the runners. This team made use of a variety of monitoring and control interfaces including an overview of the game space, an interface for managing queuing players, an interface for monitoring the state of the wireless network, an interface displaying the status of the runners including current connection status and GPS status and an interface for playing the game. These monitoring interfaces were supplemented by the use of a separate walkie-talkie channel for communication between the control room and the runners. We return to the role of these different interfaces later in the paper.

Causes of uncertainty in CYSMN

We now consider the uncertainties that arose in the course of CYSMN, our strategies for dealing with them, and their ultimate impact on the experiences of online players, runners and technical crew. There were several sources of uncertainty in CYSMN.

The first and most significant was the uncertainty inherent in GPS. In Sheffield we used standard GPS with budget level Garmin etrex receivers and the game zone spanned a mixture of open urban spaces with a few narrow and built up narrow side streets. Analysis of system logs showed that GPS error ranged from 4m to 106m with a mean of 12.4m and a standard deviation of 5.8m. In Rotterdam, we upgraded to differential GPS and used **XXX** receivers, and the game zone contained a similar mix of open spaces several of which looked out over open water (i.e., with a good view of the sky to one side) and narrower built-up streets towards the centre of the game zone. **Similar statistics for GPS in Rotterdam.** GPS accuracy was therefore generally better in Rotterdam, although in part because the **XXX** receivers only

deliver readings when they see a larger number of satellites. As a result, it was often difficult to get a GPS fix. Indeed there were **XXX** minutes out of a total of **XXX** minutes of play (across all runners) where there was no GPS available. In both environments there were blackspots where multi-path reflections led to particularly high errors and therefore large jumps in reported position.

Our second major uncertainty arose from the use of 802.11b networking. Although we invested considerable effort in deploying 802.11b in both game zones (using an eight meter mask on a roof top supplemented by two omni antennae in Sheffield and **XXX** in Rotterdam), coverage of each game zone was only partial. Consequently, runners would move in and out of connectivity, frequently leaving and rejoining the game. Analysis of system logs from Rotterdam revealed three broad categories of packet loss intervals: periods of short loss (less than 5 seconds) that account for 90.6% of loss intervals and were probably due to communication errors; 278 moderate periods of loss (between 5 seconds and 10 minutes) that were probably due to detours out of connectivity or interference; and finally two loss periods of about 15 minutes and one of about 40, probably resulting from major technical failures of one sort or another. It should also be noted that the runners speech was transmitted over a separate walkie-talkie channel which on the whole provided better coverage through the game zone although was sometimes subject to interference from other walkie-talkie and radio users.

A third source of uncertainty arose from frequent technical failures such as cables working loose and connectors being damaged (our runners were really running and consequently their equipment suffered a battering) as well as soft failures such as batteries running out of charge. These problems would add to GPS and connection failures in an unpredictable way.

Our fourth source of uncertainty was delay, arising from a combination of network delays across the Internet and the 802.11b network, and processing delays in the game server. Although variable, there was typically a delay of six seconds or more between one participant acting and another participant seeing that action.

Our final set of uncertainties arose from

a degree of fuzziness in the design of the game world, including only very limited information being available in the virtual model due to its sparseness and its static nature (i.e., not representing dynamic information such as traffic, people, weather and time of day) and also the relatively open and imprecise nature of the audio communication from the runners. Both of these required considerable interpretation by the online players in order to gain an impression of the runners' actions on the streets.

Our strategy for coping with uncertainty in CYSMN

Our initial experience in Sheffield suggested that combinations of these uncertainties could lead to a variety of problems. GPS inaccuracy and sudden jumps in GPS could cause players to appear in impossible places (e.g., inside virtual buildings), could result in noticeable unfeasible movements (e.g., sudden jumps) and could even result in false sightings, where a runner would suddenly jump close to a player, see them and then jump away again. The combination of variable connectivity, lack of a GPS

fix and technical failures could lead to runners disappearing from the game or being present but unable to move.

We formulated a double-edged strategy for dealing with these problems in Rotterdam. This involved generally hiding them from the online players, trying to give them a fluid game experience that was not unduly hampered by uncertainties in the technology, while at the same time deliberately revealing them to the runners and technical crew behind the scenes so that they could more effectively work the technologies in order to deliver this experience to the players. This strategy was supported by a number of mechanisms. Mechanisms for hiding the effects of uncertainties included:

- A GPS validation scheme to filter out some impossible positions, whereby GPS reports were first input into a ‘raw’ data space in the game server which would then compare them to a predetermined map of acceptable positions. Unacceptable positions would be corrected to the nearest acceptable position in the game zone before and then stored in a second ‘published’ data space. The net result was that runners would not appear in buildings, but would occasionally make additional sudden movements, for example when the algorithm would suddenly jump to a new ‘nearest safe position’.
- An animated viewing sequence where the virtual camera would zoom into a close up view of the player over several seconds and by showing a runner’s avatar nearby. A player would at least always end up seeing a runner, although if there had been a significant GPS jump, they may not have been in view before the moment of being seen.
- The runners would continue to talk over the walkie-talkies when disconnected from the game (in fact they would tend to talk more). As an online player was prevented from ever seeing an overview of the entire game zone, it was impossible for an individual player to determine that there weren’t any runners present in the game.
- We used a separate walkie-talkie backchannel for the runners to have private communication with the technical crew in order to resolve major technical problems without being heard by the online players.
- The game play deliberately used the term ‘seen’ rather than ‘caught’ to introduce a degree of fuzziness as to how close a runner had to get to a player.

Mechanisms for revealing uncertainties to the runners and crew included:

- Notifications on the handheld interface as to the current estimate of GPS error (taken from the receiver) and current connection strength (shown as a percentage), estimated from packet loss. These can be seen next to the two green dots in the top left of the screen shots in figure 4.
- A separate game management interface in the control room also showed the technical crew the GPS error and connection status associated with each runner.

The experience uncertainty in CYSMN

We now consider how the various uncertainties associated with CYSMN and our strategies for coping with them were experienced by the players, runners and

technical crew. Our analysis draws on three sources of data: ethnographic observations of the runners and technical crew, including capture and transcription of video data, logs of the online players chat (over three thousand messages) and feedback emails from the players.

The players' experiences

Overall, CYSMN was well received and there seem to have been moments of genuine engagement and even tension, especially when the game was working smoothly. These included the players hearing their names over the audio channel and then being chased, struggling to meet up and run with their partners and colleagues without being seen, and also tuning into various aspects of 'life on the streets' including being aware of the runners negotiating traffic, hearing them breathe heavily, hearing other ambient sound (including a mobile disco at one point), and for some players who were in a public area in the game zone in Rotterdam, seeing the runners pass by a window as they came to get them. As one player put it in an email:

... the start of me becoming totally engaged was when I met up with my partner who was playing in the same room and through fits and starts we found each other and then ran 'hand in hand' in desperate flight across the city. I then had this real feeling of the need to protect her from being caught and we could work co operatively in keeping an eye out for incoming runners.

However, the game did not always run smoothly and in spite of the above mentioned mechanisms, the effects of uncertainties were sometimes apparent. Players noticed that runners would sometimes suddenly appear and disappear and would jump around, especially when they were caught as a result, as the following extracts from the text logs show:

hmm the runners seem to jump around a bit
they seem to appear quite randomly.
apparently it doesn't matter they boot you from miles away
sometimes I get seen while the runner is still miles away. do others have this?
the runner was nowhere near me!!!!
Runner 2 just appeared out of nowhere

Or as our previous email correspondent put it.

A couple of times I was caught and I just hadn't seen anything, which is a shame because the adrenalin rush when you see a runner approach and you try to escape is part of the draw in the game.

Online players appeared to sometimes weave accounts of these noticeable effects into the structure of the game, attributing them to power-ups or characteristics associated with the runners, including invisibility ...

player 1: attention runner1 is cheating by using his invisible coat
player 2: whats an invisible coat?
player 1: never mind what the coat is he can pop out of nowhere

blindness ...

is runner 1 BLIND?? I closely passed him

laziness ...

player 1: they seem to be resting

player 2: not resting lazy

blindness and laziness:

player 1: Runner one is blind

player 2: And lazy too

and even roller skating!

runner 1 you moving very fast sure you're not roller skating?

Runners would sometimes mention the causes of uncertainty, especially GPS, over the public audio channel and some knowledgeable players homed in on this.

Runner1 needs a GPS update&3 maybe shes already on me

Looks like runners without a red circle don't have GPS

Too bad the GPS is so unreliable. I was supposedly seen with no runner in sight

Some speculated that the runners deliberately exploited the characteristics of GPS:

Ah! thats how they hide

gps cant pick you up on the Map if youre inside

And some even recognised its tactical advantages to themselves:

Not only have wee a scary looking dark building to hide behind but its also crap GPS.

Quick - pray hard to the anti satellite god

It seems that GPS uncertainty was a core part of the game, but that it was experienced in different ways. Sometimes it was a noticeable problem; sometimes hidden; sometimes inexplicable; and sometimes even offered a tactical advantage.

Other effects of uncertainty were better hidden from the players. In spite of questions about where the runners were or whether they were present, failure to connect at all seems to have been largely hidden, possibly for the reasons mentioned above (the walkie-talkie channel would continue and there was no global overview of the game space available). Network delays were also large invisible, except for when several players consoles shared the same physical space in which case the audio streams could be heard out of sync or (as one player reported) it would appear to each player that their colleagues were lagging behind them (because each player sees their own local movements immediately they make them and before they are received by other players).

The runners' and crew's experiences

The runners and crew were directly aware of the uncertainties inherent in CYSMN. Indeed, they had to constantly battle against them in order to stage an experience for the online players. Our ethnography reveals how our approach of revealing GPS error and connectivity status, combined with a private walkie-talkie back-channel supported this. The following fragment of conversation between the control room

(‘controller’ is monitoring the overall game state, ‘networker’ the network state and John is specifically responsible for helping the runners) and runner 4 illustrates this.

John on runner 4’s walkie-talkie: Can you confirm runner 4’s connectivity.
Networker: *Looks at network monitor.* Runner 4 is connected.
Controller on walkie-talkie: OK, we’ve got that. Can you run the client now runner 4.
Runner 4 on walkie-talkie: Runner 4, client is connected.
Controller on walkie-talkie: Runner 4, we have the connection and you’re getting GPS.
Runner 4 on walkie-talkie: Runner 4, confirm that – GPS down to 5 metres, connectivity 98%.
Controller to Networker: Yep. So we now have 3 runners online all reporting GPS.
Networker: Down to 2 to 3 metres, which is nice.

A second fragment shows how the runners would monitor the status information on their handheld interfaces:

Runner 2 on walkie-talkie: Runner 2. I’m heading seawards on Wilamena, waiting for a server update.
He continues walking down the street, looking at the handheld and his place on the street.
Runner on walkie-talkie: My GPS is currently 35 metres.
Runner on walkie-talkie: My server position is about 50 metres out.

This fragment also illustrates the main strategy employed for dealing with GPS problems – that of moving to a new (and hopefully better) location. The same strategy was used for dealing with connectivity problems as shown by the following exchange:

Runner 2 on walkie-talkie. *Looking at his handheld.* Runner 2. I’ve just lost all players, I’ve lost all players.
Runner 2: *Looking at jornada.* I’ve got disconnection here.
The runner turns around and starts walking back down the street.
Runner 2 on walkie-talkie: Runner 2. Heading seawards on Otto. I am currently disconnected.
The runner walks down the street for about thirty metres.
Runner 2 on walkie-talkie: Runner 2. I’ve connectivity again. I’m in Vern.
The runner then crosses the road into the carpark. Consulting the handheld, he turns left, moving towards the top of the carpark.
Runner 2 on walkie-talkie: Runner 2. I’m in Vern. I can see 1 player on the extreme end of the gameplay. That player is Dave. Runner 2 is closing in on Dave.

The runners and crew built up an extensive working knowledge of good and bad locations over the course of more than ten days rehearsal and live game play. The control room would also update runners with ongoing changes to conditions as the following example shows:

John on walkie-talkie: John to control room.
Controller on walkie-talkie: OK, what’s the status of runner 4?
John on walkie-talkie: Can you pass on a message to all runners not to use Edam at all.
Controller on walkie-talkie: Not to use where, Edam (*a street in the runners’ place*)?
John on walkie-talkie: Do not go down Edam.
Controller on walkie-talkie: OK, why?
John on walkie-talkie: Because we have low coverage and that’s what’s screwed runner 4’s jornada up.
Controller on walkie-talkie: OK. Runners 1 and 2, do not use Edam, there is a problem with waveLAN connectivity. Do not use Edam.

And runners would respond accordingly:

Runner 2 on walkie-talkie: This is runner 2. I'm into Vern now. I can see Jules and Mike heading into Edam. I'm going to leave them. I'm looking for Tommy.

A particular ongoing concern was the changing nature of GPS uncertainty over time as different configurations of satellites became available. This could change radically throughout a single two hour session, occasionally worsening to the point where only three of four satellites were potentially available, making GPS very unreliable. In response, a member of the crew printed out charts of satellite availability over time which were pinned on the wall of the control room and also discussed in daily briefing sessions so that crew and runners would be aware of likely difficult periods.

Runners also exploited their knowledge of GPS uncertainty tactically. This was apparent after the initial Sheffield experience, as shown by the following conversation between a runner and crew member.

Crew: So your tactics: slow down, reel them in, and get them?

Runner: If they're in a place that I know it's really hard to catch them, I walk around a little bit and wait till they're heading somewhere where I can catch them.

Crew: Ambush!

Runner: Yeah, ambush.

Crew: What defines a good place to catch them?

Runner: A big open space, with good GPS coverage, where you can get quick update because then every move you make is updated when you're heading towards them; because one of the problems is if you're running towards them and you're in a place where it slowly updates, you jump past them, and that's really frustrating. So you've got to worry about the GPS as much as catching them.

In short, runners and crew were able to coping with and even exploit the uncertainties in CYSMN, but only as a result of building up extensive knowledge of the behaviour of the technologies in the context of the game zone. While our interfaces for revealing these uncertainties to them appear to have been useful, they were clearly only one part of a complex mix of processes and technologies.

Reducing, hiding, revealing and exploiting: four approaches to dealing with uncertainty

Reflecting on our experience of CYMSN, we propose that the designers of these kinds of mixed reality experiences can adopt four broad strategies to dealing with uncertainty.

Strategy 1: Reduce uncertainty. It may be sensible to remove the uncertainty from the experience as much as possible. This might involve using more accurate and reliable technologies and using multiple technologies in a way that support each other (e.g., employing multiple positioning technologies). It may also involve carefully choosing the physical environment (e.g., limiting the game zone to avoid black-spots) and time of play (e.g., avoiding predictable periods of poor satellite visibility).

Strategy 2: Hide uncertainty. If uncertainty cannot be removed, then perhaps it can be hidden. It may be possible to cover up its effects at critical points of the experience (e.g., not allowing avatars to appear in buildings), although this may at the cost of emphasising other presumably less important aspects (e.g., avatars making sudden

jumps from one side of a building). It may be wise to use ambiguous terminology ('seen' not 'caught') and media (e.g., making liberal use of audio). However, these techniques may be harder in situations that involve making a direct comparison between the digital and physical representations of location and other information, for example when trying to show a strictly registered augmented reality overlay or where the user is on the street and can directly see where they are in relation to where the system is telling them they are.

Strategy 3: Reveal uncertainty. We have seen that it may be sensible to reveal uncertainty to some participants rather than hide it. This might be a useful approach when it is their primary task to create an experience for others (e.g., the runners in CYSMN) or when it is not possible to hide uncertainty (see above). This approach involves seeing uncertainty as a natural phenomenon, a normal characteristic of the technology to be recognised, understood and worked with, rather than as a problem to be solved (an approach previously discussed in terms of revealing the characteristics of underlying network delay in collaborative virtual environments [11]). For example, designers might avoid 'inappropriate' metaphors such as virtual worlds that are meant to behave as if they the physical world in favour of more realistic portrayals of technologically mediated environments. However, CYSMN also shows us that it may not be sufficient to merely reveal the presence of uncertainty; it may also be important to reveal its dynamic properties - how it varies over space and time - and also to suggest what to do about it.

Strategy 4: Exploit uncertainty. The final strategy is to actually exploit uncertainty as a useful feature of technologies. We see this in the way that both players and runners in CYSMN consider the tactical advantages offered by GPS error. Uncertainty might be directly woven into the game-play, for example by requiring participants to actively seek out regions of good connectivity and GPS in order to gain visibility or acquire 'energy'. Imprecise media such as audio and abstract models also provide space for the imagination, encouraging users to interpret them and read meaning into them. More generally, the ambiguities that can arise from uncertainty can be a powerful tool for provoking users and causing them to reflect, something that has been understood by artists for many years and that has recently been proposed as a design tactic for human-computer-interaction [2].

Of course, there is no one right approach. All four of these strategies may be valid under different circumstances or may even be combined in complex applications such as CYSMN that involve different kinds of participants with different roles.

In summary, our experience of CYSMN has shown that dealing with uncertainty can be a complex and challenging business. Uncertainties can arise from many sources and can have different effects on different participants. Our experience has also suggested four possible strategies for dealing with these uncertainties - reducing, hiding, revealing and exploiting - approaches that we plan to explore further in future experiences.

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