Citywide: supporting interactive digital experiences across physical space

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Abstract. The Citywide project is exploring ways in which technology can provide people with rich and engaging digital experiences as they move through physical space, including historical experiences, performances and games. This paper describes some initial results and experiences with this project based upon two prototype demonstrators. In the first, we describe an application in which a search party explores an archaeological site, uncovering enacted scenes within the virtual world that are of a historical relevance to their particular physical location. In the second, we describe a museum experience where participants explore an outdoors location, hunting for buried virtual artifacts that they then bring back to a museum for a more detailed study. Our demonstrators employ a varied set of devices, including mobile wireless interfaces for locating hotspots of virtual activity when outdoors, to give different experiences of the virtual world depending upon location, task, available equipment and accuracy of tracking. We conclude by discussing some of the potential advantages of using an underlying shared virtual world to support interactive experiences across extended physical settings.

Keywords: *mobile computing, virtual environments, mixed realities, novel applications*

1. Introduction

The Citywide project is exploring ways in which technology can provide people with rich and engaging digital experiences as they move through physical space, including historical experiences, performances and games. Our overall approach involves providing participants with various and diverse interfaces for detecting, revealing and experiencing events that are taking place in a parallel 3D virtual world; that is, a virtual world that is hidden behind, but available from everyday physical space. Our long-term aim is to create new experiences that are extended across space, for example that span indoors and outdoors locations across a city, and time, for example, that unfold over the course of one or more days.

One of the key technological challenges for Citywide will be to provide interoperability between heterogeneous devices, such as small mobile devices, and collaborative virtual environments. In order to meet this challenge we are currently developing a new software platform called EQUIP (Equator Universal Platform) [6]. EQUIP is a dynamically extensible platform for integrating C++/Java based applications with a variety of interfaces and devices, ranging from wireless portable devices through to fully immersive systems.

This paper describes some initial results and experiences with Citywide based upon two prototype demonstrators. In the first, we describe an application in which a search party explores an archaeological site, uncovering enacted scenes within the virtual world that are of a historical relevance to their particular physical location. In the second, we describe a museum experience where participants explore an outdoors location, hunting for buried virtual artifacts that they then bring back to a museum for a more detailed study. Our demonstrators employ a varied set of devices, including mobile wireless interfaces for locating hotspots of virtual activity when outdoors, to give different experiences of the virtual world depending upon location, task, available equipment and accuracy of tracking.

The following two sections provide an outline of these demonstrators and discuss potential refinements in light of initial user experiences. We conclude by discussing some of the potential advantages of using an underlying shared virtual world to support interactive experiences across extended physical settings.

2. A First Demonstration – The Haunted Campus

This section presents a first demonstration of devices and interfaces that may be utilised for Citywide. The setting for our demonstration is the campus at Nottingham University. Our campus was developed in 1999 on a brown-field site, the site of an old bicycle factory. Given this backdrop, we have created a 3D model of the campus in the MASSIVE-3 system [5], which performers can enter as avatars to enact (potentially fictional) scenes of history. These can be improvised live or captured as 3D recordings to be replayed within the virtual model at a later time [4].

Our participants are asked to explore the physical campus and discover any hidden virtual information regarding the history of the site. To uncover this information, participants must seek out the avatars that haunt the virtual campus and listen to their various tales and enactments. To aid the search, users are provided with a mobile device that detects hotspots of (paranormal) activity occurring within the virtual world. This device allows participants to listen to a particular enacted scene when their physical location is within range of the avatar positions within the 3D model.

Figure 1. *Tracked participant discovers a virtual avatar using radar and audio applications*

The device consists of a laptop and Compaq iPAQ that communicate with one another and also with computers in the nearby laboratory over a Wireless LAN. A GPS device is attached to the laptop, giving the position of the search party. This positional information is transmitted back to computers in the laboratory enabling them to update the position of an avatar (the search party's representation in the virtual world). In turn, the computers running the virtual world update the mobile devices with measures of proximity to different ghost avatars. This information is presented to participants using a simple 2D radar application (figure 2). The mobile device also uses MASSIVE-3's built in features for real-time audio to provide users with spatialised audio feedback of the activities occurring within their surroundings.

Our demonstration also includes support for performers to enact scenes within the virtual campus in order to create material for the participants to find and, more generally, to orchestrate their experience. We build upon our experience of mixed reality performances, such as 'Desert Rain' [7], to provide two key aspects to this support: the ability to monitor the participants and the ability to intervene via the virtual world. Monitoring is supported by a dedicated interface, a shared tabletop that displays a parallel projected map view of the virtual campus [3]. The participants are represented on this map as avatars, positioned according to the GPS data from their wireless devices. A second element of this interface provides a detailed in-world view, controlled through a camera on the map-view that allows the performers to see and hear the activities of the participants in more detail.

2.1 Immediate Refinements

Experiences with the first demonstrator suggest a number of immediate refinements. Participants found it awkward to keep a view of the PDA's radar display and move at the same time. As a result, it was often difficult to maintain interactions with passing ghost avatars. Under such circumstances, a purely auditory interface may have been more successful. Several participants also commented that they expected the handheld devices (the iPAQ and GPS) to be sensitive to orientation. In other words, the display would change according to the direction in which these devices were being pointed. To achieve this, we would require a direction sensor (such as an electronic compass) to be added to the device setup.

The variations in accuracy of the GPS also caused problems for performers trying to orchestrate the experience. When GPS accuracy was poor, performers could be misled into enacting a scene for a participant whose location was misrepresented within the 3D model. Clearly, some form of visual feedback is required in the virtual world regarding the accuracy of readings for the tracked avatar. The inaccuracy of readings could also be improved by applying semantic knowledge about the physical environment to the virtual model. This way, we could discard inappropriate readings, such as when an avatar moves through a wall or into a lake.

Finally, due to the intermittent connectivity imposed upon wireless environments, we found that mobile users required additional feedback regarding their current connection status. One familiar metaphor that could be incorporated into our system is the bars of connectivity used by mobile phones, and employed within the GUIDE [2] application.

3. A Second Demonstration – Unearthing Virtual History

Learning from our early experiences, we have developed a more focused second demonstrator. This application is intended as a museum experience, where participants hunt for fragments of buried virtual artifacts that are then brought back to the museum for a more detailed study. The experience has been inspired by the results of a number of museum projects [1, 8]. We anticipate that the process of actively searching for history will be engaging for visitors and will lead them to more critically reflect on the information that they find than if it was directly presented to them [9].

The initial setting for this demonstrator remains the campus at Nottingham University. Each search party is sent out to search the island on our campus using a “virtual history detector” (figure 2). This device conveys the proximity of various virtual objects that exist in the 3D model of the campus. To further explore issues from the first demonstrator, we opted for a different approach to designing the interface for this device, one that is primarily based upon audio information. We use a laptop to create an audio sonification of the measures of proximity to the various virtual fragments in order to guide the search party. Participants cluster around the laptop to hear a mix of different pulsing audio tones, one for each fragment. The volume and frequency of a tone increase as the search party gets closer to that particular fragment. When they are within a (configurable) distance of a fragment, they are deemed to have acquired it. They now hear a different tone and a secondary handheld (iPAQ) device displays an appropriate image and some text.

Figure 2. *Hunting for fragments of virtual objects outdoors*

Once a variety of virtual fragments have been captured, the search party returns to the museum (in this scenario our nearby laboratory) to view the items in more detail. Each captured fragment is loaded onto a ‘periscope’ – a rotating, ceiling-mounted screen that allows a user to view and hear a virtual world by turning on a fixed virtual location (figure 3). Grasping and revolving the periscope rotates one’s viewpoint in the world and controls associated audio (ambient sounds and commentary), heard through wireless headphones. A small projector mounted on the base of the periscope projects an additional viewpoint onto surrounding screens that are supplemented with four external audio speakers. This allows the exhibit to be shared by groups of people (such as families) and attracts other visitors to the piece.

The periscope shows the user that they have been transported back to the island, but this time as a 3D model, and that a historical scene from the object’s past has now appeared at the location where the fragments were found. By rotating the periscope, the user can explore the scene and can control an associated audio dialogue, giving details about the discovered artifact.

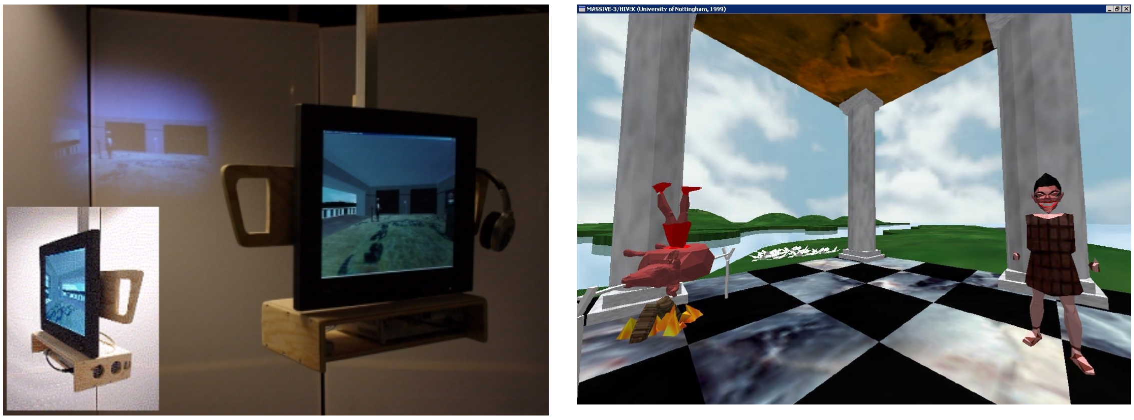

Figure 3. *Viewing the captured artifacts indoors*

3.1 Immediate Refinements

Experiences with the second demonstrator provide some useful insights into future refinements. It was possible, but quite slow and sometimes difficult to locate the target fragments when outside. The island presents a relatively featureless landscape and the virtual fragments were not sited at obvious locations. One solution would be to scale up by making the targets larger, placing them further apart and attaching them to more obvious locations. This approach might work at the scale of a city-centre where people visit a series of well-known sites.

It is also interesting to speculate whether the physical design of the wireless device would have encouraged an enhanced style of use. For example, what if the GPS compass had been embedded into something resembling a metal detector or a resistivity meter of the kind regularly used by archaeologists to search a location for buried objects? Perhaps more attention needs to be applied to the physical design of our wireless devices. Rather than using off-the-shelf devices, maybe we should be designing bespoke devices that naturally embody an appropriate sense of use and theatricality (in a way that the periscope does).

4. General Reflections

Having presented our demonstrators and considered some possible extensions, we finish with some general reflections on the approach of using diverse devices to access a shared virtual world. We are particularly concerned with how varied devices can provide radically different experiences of the virtual depending on the user's location, task and available technology. Some devices will offer high fidelity and accurately registered views of the virtual, whilst others may offer more impressionistic or peripheral views of the virtual, for example audio sonifications or projected shadows. We propose that such a widely heterogeneous approach might bring a number of benefits:

- *Variable engagement* Heterogeneous interfaces allow participants to vary their engagement with an experience. An unfolding story may gradually introduce participants to the virtual world. Bystanders may have only a fleeting awareness of virtual events whereas committed players may be fully involved. Participants in a long-term event in a persistent world may vary their level of engagement over time, moving between full and peripheral awareness throughout the day.

- *Variable tracking* The display of the virtual can be configured to match the accuracy of tracking in different locations. Where accurate tracking is available the user may be offered a fully 3D view of the virtual. Where it is not, they may be offered more abstract views such as sonifications, maps and shadows.
- *Variable lighting* Sound-based and more abstract views of the virtual may be able to accommodate bright and variable lighting conditions, where certain display technologies might prove more problematic.

Finally, from a systems perspective, implementing a wireless physical experience on a common underlying virtual world offers other potential advantages. Virtual environment research has developed techniques in which virtual space is used to manage connectivity and QoS among large numbers of communicating users [10]. These techniques can be directly applied to mobile devices that are tracked and represented in the shared virtual world.

In conclusion, a common underlying virtual world can act as both a framework for creating coherent user experiences as well as a technical platform for integrating diverse and possibly wireless devices.

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