A Synchronised Virtual Environment for Developing Location-Aware Mobile Applications

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1. Introduction

The increasing power and robustness of mobile devices coupled with positioning capabilities is allowing a wide range of location-aware applications to be developed. Some of these applications focus on navigation and the design of geographic representations which offer a more egocentric approach to mapping (Meng, 2005). Other applications concentrate on augmenting the user's view of the world with supplementary information such as the display of the horizon annotated with features of interest as in the recreational package Viewranger (Augmentra, 2007). Whatever the focus of the application there is usually a requirement to associate the information on the device with the real world around the user. This reconciliation of 2D representation with the 3D world around the user is one tangible element of spatial literacy, the formal ability to think spatially (Golledge, 2003).

This paper describes the use of a virtual environment for testing location-aware mobile applications during development and presents one such application in detail. The virtual environment features a visualisation theatre with large screen stereo projection of 3D virtual worlds, the user location in these models being synchronised with any mobile devices in the room through a simulated GPS signal (as a text-based NMEA string) transmitted from the ceiling. The mobile application currently under development is an example of what could be termed 'Mobile Geospatial Augmented Reality' where supplementary information of various types is presented to the user relevant to their spatial context, not only their position but the area visible from that location. The application is designed for use in the context of a geography fieldtrip to allow students to directly compare computer generated landscape visualisations to their real world counterparts, as well as offering the same scene draped with geology or with a model of retreating glacial ice.

2. Background

Rather than focus on the effectiveness of interactive virtual environments as with the related research of Whitelock and Jelfs (2005) the approach was to develop techniques to be used in the context of real fieldwork. The development of these techniques began with field-based exercises designed to engage students in the issue of the representational fidelity of Digital Surface Models through the use of landscape visualisation in fieldwork (Priestnall, 2004). Students render and print views from known points within a 3D model of the field site and take these out into the field to undertake direct comparison from these points in the field. These techniques are now being extended through the use of mobile computing devices supported by ongoing developments in SPLINT (SPatial Literacy IN Teaching), a Centre for Excellence in Teaching and Learning funded by the Higher Education Funding Council of England (HEFCE). Involving the University of Leicester (lead), the University of Nottingham, and University College London, SPLINT aims to advance the pedagogy of geospatial technologies, and to explore and enhance spatial literacy in a range of disciplines across Higher Education.

The focus of activity for the Nottingham arm of SPLINT is on the development of mobile applications in support of fieldwork and in the wider use of virtual models and visualisation. Virtual models of the University Park campus, Nottingham and the Newlands Valley fieldtrip site in Cumbria are the first models under construction. Location-aware mobile applications have been developed for both sites and in order to allow the operation of these to be tested and developed further the lab-based visualisation has been synchronised with mobile devices operating in the same room.

3. Synchronised Virtual Environment

The visualisation theatre (Figure 1) features two pairs of data projectors creating a 5m x 2.5m image, viewable in stereo through the use of ‘passive’ eyewear. The real-time rendering software used is Vega Prime and models are currently being built in the Blueberry, Creator and 3D Studio MAX software packages. The user’s position within the virtual model is transmitted every second as a GPS NMEA string via a Bluetooth transmitter in the ceiling of the lab. Any mobile device equipped with Bluetooth reception can therefore pair with the transmitter in exactly the same way as it would with a Bluetooth GPS in an outdoor environment. Location-aware applications which use GPS positional information to trigger actions based on user movement can therefore be tested within this environment before actual field testing is undertaken. Ongoing developments with the use of the transmitted position will include the simulation of variable positional accuracies of GPS including the influence of urban canyons and heavy forest cover. Such a configuration clearly offers potential to explore the way people use instructional media to assist wayfinding as demonstrated by Li and Longley (2006) in an unsynchronised virtual environment.

Figure 1. Synchronising a lab-based Virtual Environment with a mobile device.

To test the synchronisation procedure a ‘proof-of-concept’ application has been created in the Visual Basic.NET Compact Framework on a Personal Digital Assistant (PDA) using a demonstration terrain dataset of Lake Tahoe, USA. The Tahoe Tourist Trail featured in Figure 1 represents a simple ‘orienteering’ exercise was developed whereby users had to visit a series of way points in the fastest time possible.

4. Mobile Geospatial Augmented Reality

A series of location-aware mobile applications are being developed building on the Tahoe Trail application and focusing on techniques for augmenting real scenes with various computer-generated imagery relevant to the user’s position. These applications are being developed for PDAs and tablet PCs where the screen is held up towards the real scene to offer additional information about that scene, ‘augmenting’ reality for the user. This technique could be considered to fall within the domain of ‘Mobile Geospatial Augmented Reality (MGAR)’ although not true Augmented Reality as described by Piekarski (2006). The handheld MGAR technique currently adopted (Priestnall and Polmear, 2006) is being further developed within the synchronised virtual environment. A PDA-based application has been created to allow students to take computer-generated landscape visualisations out into the field to develop a schema for assessing such images against reality. A 5m resolution Digital Surface Model (DSM) derived from airborne radar draped with colour aerial photography forms the model of the ‘current’ landscape, with solid and drift geology data giving a ‘hidden’ landscape, and a reconstruction of the retreating glacial ice a ‘past’ landscape. Five viewpoints are chosen and for each of these three 3D views are created (current, past, and hidden), and then copied to the PDA using a purpose written data loader.

Once in the field the GPS-enabled PDA displays a navigation screen as shown in Figure 2. The locations and directions of the loaded views are shown on the map along with a moving icon representing the user. Upon reaching the first viewpoint the 3D view representing the radar model is displayed automatically. Students are encouraged to critically assess the degree to which such visualisations offer faithful representations of the real scenes and a sketch facility has been developed to allow annotations to be made to these images in the field (Figure 2, upper right image). The equivalent view with geology drape and also the glaciated model can be viewed, as shown by the lower two images in Figure 2. Students are encouraged to observe physical evidence to support or refute the glacial scenario represented and for evidence of the influence of subsurface geology on the observable landscape.

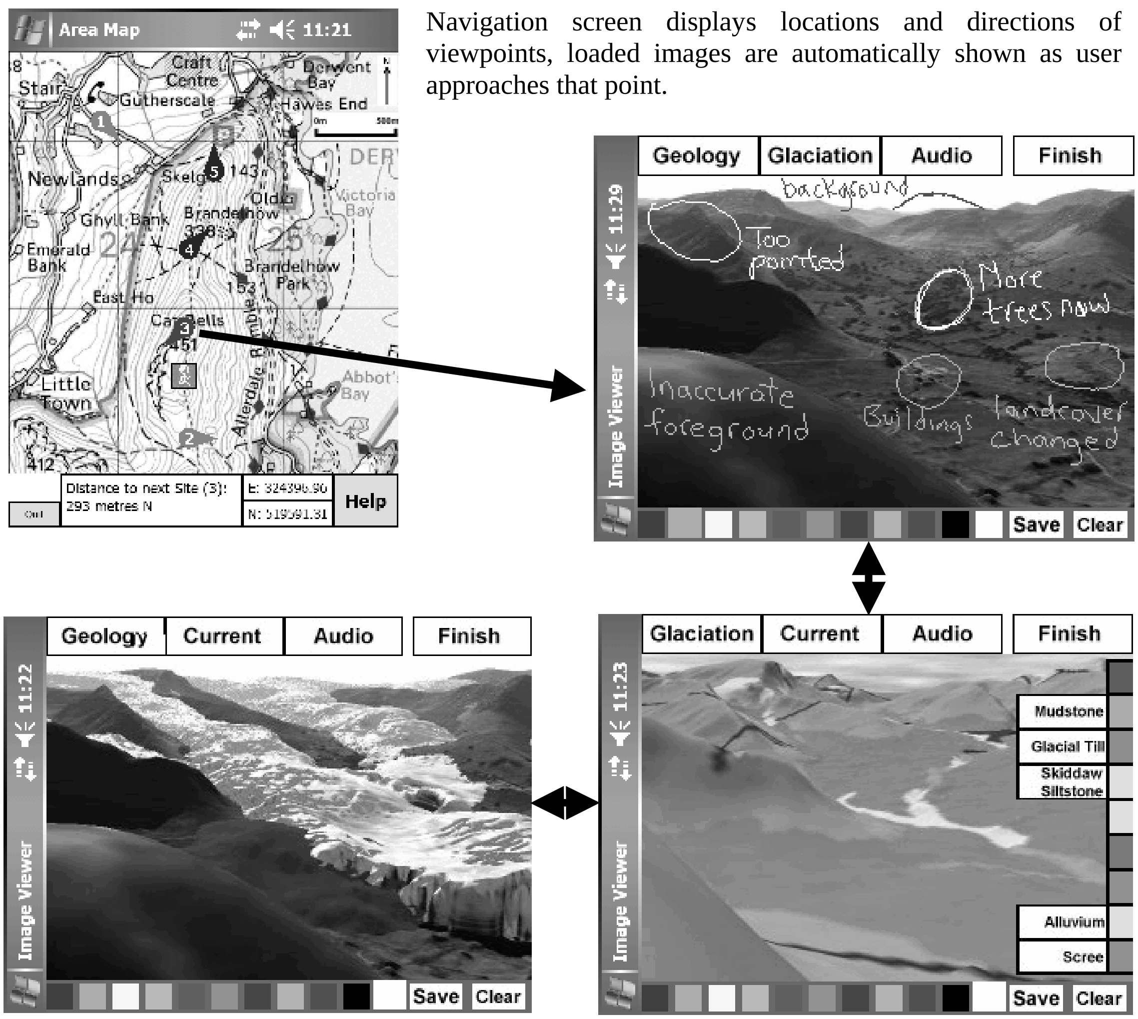

Figure 2. Mobile Geospatial Augmented Reality Application

An additional feature of the current application is the use of pre-determined visibility maps which record whether certain key landscape features should be visible from any given location. Grid-based binary viewsheds were created within ArcGIS by digitising areas of interest using evenly distributed observer points within these areas. To improve computational efficiency when querying on the mobile device various encoding techniques are being explored. Currently the binary viewsheds representing a series of landscape features of interest are re-coded following a geometric sequence beginning with 1 and having a scale factor of 2, ie: 1, 2, 4, 8, 16, 32, etc. In this way the viewshed grids can be added together giving cell values which represent unique combinations of the original inputs, in a similar way as multiple water flow directions are often encoded. For example in Figure 3 the landscape areas 1, 2, 4, and 16 are visible from location X so the cell at X would receive the value 23, being the sum of the individual codings. The 'audio' button on the mobile application interface triggers a query of the visibility map and interprets the local cell value as a series of individual inputs, knowing the geometric sequence used to create it. This series of input values in turn triggers a sequence of sound files to be played, each of which describes the evolution of a landscape feature which should be visible from that location. This technique is similar to the way audio was used in the city tourist guide developed by Mackaness and Bartie (2005).

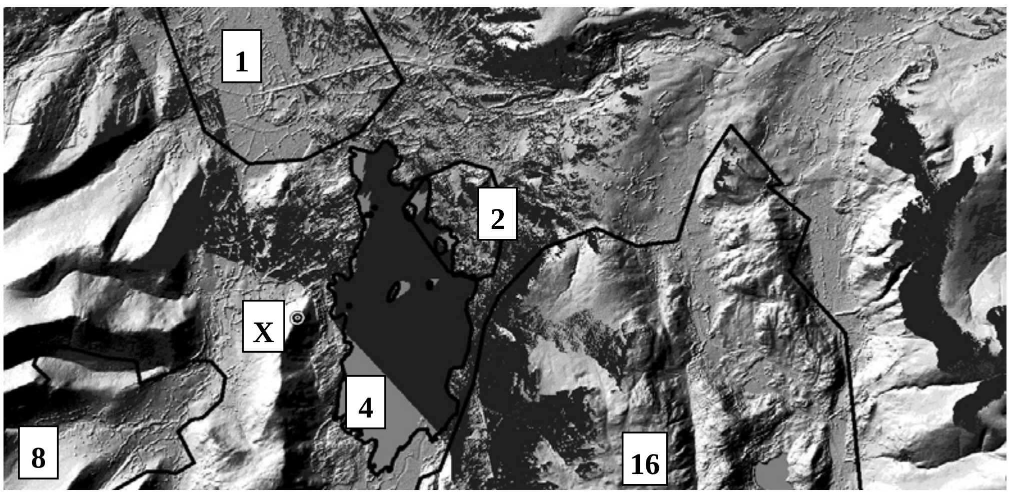

Figure 3. Visual context: The use of composite visibility maps

The usability of the mobile applications under development is critical and the synchronisation with the lab-based 3D visualisation offers a controlled development environment for testing and refining the basic operation of the applications. The second phase of testing relates to field-based operation and addresses usability issues of the devices themselves. Initial testing reveals that in full sunlight the trans-reflective screens generally perform well apart from when the view direction is directly into the sun. The simplicity of design proved critical and many such issues can be tested in the lab but it will only be after several field tests with large numbers of students when the effectiveness of the application will become clear. The intention is to evaluate usability issues of the mobile application alongside the original technique which used printouts in the field to ensure that the mobile technology is not interfering with the learning objectives. This will be reported on in future research output.

5. Ongoing developments

In addition to the use of the virtual environment as a test bed for location-aware mobile applications several aspects of what may be termed spatial literacy are being investigated including:

- The ability for users to associate various portrayals of terrain on a mobile device (smart phone, PDA, tablet PC) with realistically rendered 3D landscape visualisation. One study of this type is being undertaken in collaboration with the Visual Learning Lab, a HEFCE-funded Centre for Excellence in Teaching and Learning led by Education, University of Nottingham.
- The effectiveness of various portrayals of urban environments for way finding, using a virtual model of the University of Nottingham campus under construction. In addition to testing

applications designed to assist outdoor navigation the use of the same application in both lab and field offers the opportunity to study the differences in way finding behaviour between virtual and real environments.

- Further investigation into the use of ‘visual context’, investigating more thoroughly the creation and use of visibility maps in mobile applications.

6. Conclusions

A test bed environment linking lab-based 3D visualisation with location-aware mobile applications has been presented and an example of a ‘Mobile Geospatial Augmented Reality’ application is described. There is great potential for the further use of this environment for exploring certain aspects of spatial literacy in addition to exploring certain design and usability aspects of mobile applications.

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Biography

Gary Priestnall is an Associate Professor (Senior Lecturer) whose research interests lie in geographic representation, landscape visualisation, spatially-aware mobile applications for geography fieldwork. Gemma Polmear is a Research Associate working on the HEFCE-funded Centre for Excellence in Teaching and Learning - SPLINT (Spatial Literacy IN Teaching), developing mobile geospatial augmented reality applications.