Future Location-Based Experiences

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EXECUTIVE SUMMARY

Location-based experiences extend digital media out into the physical world – be it across a campus, the city streets or into remote wilderness. Users with mobile displays move through the world. Sensors capture information about their current context, including their location, and this is used to deliver them an experience that changes according to where they are, what they are doing, and maybe even how they are feeling. As a result, the user becomes unchained from their PC and experiences digital media that is interwoven with the everyday world, and that is potentially available in any place and at any time.

This Technology Watch report considers the relevance of location-based experiences to education, discussing potential applications, reviewing the underlying technologies and identifying key challenges for the future.

The research community has already demonstrated a variety of location-based experiences that are of relevance to education including: information services and tour-guides in which information is delivered *in situ*; educational games in which a combination of mobile and online users learn together; support for field trips in which the technology provides access to learning materials during a visit to a site of special historical or scientific interest; and support for field science in which learners actively gather data from the environment for subsequent analysis back at base.

These emerging applications can be delivered over a heterogeneous collection of technologies that consist of three core components: mobile devices, wireless networking and location-sensing. Mobile devices include current commercial products such as mobile phones, personal digital assistants, laptop computers, mobile gaming consoles and personal media players, as well as alternatives that have not yet left the research labs, e.g. wearable computing, smart fabrics, tangible and embedded interfaces, and mobile 3D displays. Wireless networking includes: three generations of mobile telephony–GSM, GPRS and now 3G (as commercial services for mobile phones); the 802.11 family of wireless network protocols which can be deployed directly by users and their organisations; and local *ad hoc* mechanisms such as Bluetooth. Finally, a very wide range of location-sensing technologies is becoming available (GPS, cellular positioning, WiFi triangulation, Ultrasonic, RFID, video-tracking and others), differing greatly in coverage, accuracy and cost.

This report concludes that location-based experiences could indeed introduce significant benefits for education in schools, colleges and universities, especially when they connect location-specific data delivery and capture to subsequent reflection and abstraction back in the ‘classroom’. However, some serious challenges need to be met first. Technical challenges include dealing with the uncertainty of positioning and connectivity and also supporting interoperability between the very diverse set of technologies involved, in particular by developing flexible middleware support. Organisational challenges involve addressing serious privacy concerns, integration with current e-learning services and dealing with the potential culture clash involved in encouraging widespread use of mobile devices in educational environments. Recommendations are for the educational community to conduct a series of pilot experiments on different wireless test-beds while consulting closely with users and their representatives over privacy issues and with mobile operators about future service provision.

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WHAT AND WHY ARE LOCATION-BASED EXERIENCES

What are location-based experiences?

Location-based experiences extend digital media out into the physical world – be it across a campus, the city streets or into remote wilderness. Users move through the world equipped with a wide variety of mobile displays including PDAs, laptops, mobile phones, gaming consoles, personal media players and potentially even wearable computers. Sensors capture information about their current context, including their location, and this is used to deliver them an experience that changes according to where they are, what they are doing, and maybe even how they are feeling. As a result, the user becomes unchained from their PC and experiences digital media that is interwoven with the everyday world and that is potentially available in any place and at any time.

Some potential pros and cons of location-based experiences for education

Location-based experiences might potentially enable radically new forms of learning experience. Some of the potential advantages for the education sector are already familiar from the idea of mobile learning (m-learning), most notably, making learning resources available anywhere and at any time, thereby enabling learners to personalise the learning experience to suit their individual schedule. However, *location-based* mobile experiences offer some potential further advantages:

- Accessing learning materials in the particular context where and when they are most immediately relevant, for example accessing materials about architecture when standing directly in front of a relevant building.
- Collecting field-data *in situ*, for example as part of a science field trip, either for immediate analysis or to be uploaded for analysis back at base.
- Even greater personalisation of the experience, for example by automatically adapting the learning experience to information that is sensed about the user's context – for example, are they currently busy or alternatively, open to a new learning experience?
- Deriving learning value from what is already an extremely popular and widespread technology – the mobile phone. Location-based games look set to become a major form of content for 3G mobile telephony and will be arriving on campus in the near future. It makes sense for the education sector to piggy-back on such technologies.

However, as with any new technology, there are potential disadvantages too:

- Tracking users' locations raises serious privacy concerns, especially when this information is stored centrally 'in the network' rather than on users' local devices, since others may be able to obtain access to information on a person's movements.
- People may suffer more frequent interruptions, finding it increasingly difficult to concentrate on specific tasks or to separate different aspects of their lives, especially work from leisure.
- The proliferation of devices onto which users can directly download programs over *ad hoc* and possibly insecure network connections raises interoperability and security challenges.

Why is this a Technology Watch issue?

It is timely to examine the educational potential of location-based experiences, as well as the challenges that they raise, because the three technologies that underpin them – mobile devices, wireless communications and sensing technologies – are maturing rapidly. While emphasising that location-based services might be delivered on a very wide variety of platforms, it should be noted that the rapid uptake and continuing evolution of mobile telephony is of particular interest here. Mobile phones are rapidly gaining in computational power, display capability and peripherals and mobile operators are currently rolling out 3G: this combination of devices and networks increasingly offers location-sensing capabilities. Furthermore, as discussed in detail in a previous JISC Technology Watch report on Mobile and PDA Technologies (Anderson and Blackwood, 2004), mobile phones are now a truly ubiquitous technology in the UK, with extremely high adoption rates for young people between the ages of 16 and 24 (between 80% and 90% in 2002 according to the Learning and Skills Development Agency).

It seems that commercial, location-based experiences will be appearing on our campuses in the next few years; the question is whether or not they will be integrated into the educational experience.

The structure of this report

This report considers different kinds of location-based experience that may be relevant to education, including information services and guides, games, field trips and field science, before describing the unique combination of technologies that underpin them – mobile devices, wireless networking and location sensing. It then considers the challenges that need to be met in order to fully capitalise on the educational value of this technology. Readers are also recommended to read two related Technology Watch reports that focused on location-sensing (Roussos, 2002) and wearable, personal and mobile devices (De Freitas and Levene, 2003).

EXAMPLES OF LOCATION-BASED EXPERIENCES

We now review likely key application areas for location-based experiences, illustrating them with selected examples.

Information services and guides

Guides and information services were among the earliest proposals for location-based applications. Navigational aids such as route-finders are available and have proved relatively successful when built into cars. Other systems aim to provide users with useful information in response to their current location, for example details of local facilities (shops, bars and restaurants), cultural and heritage information as part of mobile tourist guides, or more general documents and other relevant resources (Brown and Jones, 2001; Imielinski and Navas, 1999). Commercial, location-based audio guides are becoming increasingly common inside museums and galleries, and there are clearly possibilities for moving outside as demonstrated by the Guide system from Lancaster University (Cheverst et al., 2000) and Georgia Tech's Cyberguide project (Abowd et al., 1997), two formative research projects in this area. The Active Campus Explorer from the University of California at San Diego has developed location-based information and guide services specifically for a university campus, providing residents with location-specific links to webpages and opportunities for social contact (Griswold et al., 2002). Beyond delivering information, other services also enable users to upload their own annotations for specific locations which others find later as they pass by, and some even enable them to locate physical items that have been hidden as part of a treasure hunt, for example as demonstrated by the emerging sport of GeoCaching (see the GeoCaching website at www.geocaching.com for more information).

Games

Moving beyond core information services, location-based *experiences* aim to provide the user with a richer experience that extends across a series of locations. Perhaps the most compelling – and commercially promising – example is location-based games. Wireless games are already popular among mobile phone users, even if the current generation mostly consists of traditional games that are downloaded wirelessly and then played 'stand-alone' on the phone. However, the next generation of games looks set to be both connected and multiplayer, with users communicating with remote servers or directly with other users, and, beyond this, they will be location-based as well, where users will have to actually move through the physical world in order to interact with the game.

There are already a few commercially successful location-based games for mobile phones, for example Bot Fighters from the Swedish company It's Alive!, and the research literature suggests that there is much more to come. One common approach is to reinterpret classic computer games, mapping them onto real-world settings so that players have to physically run about in order to control their avatars, as demonstrated by the Mindwarping (Starner et al., 2000) and ARQuake (Piekarski and Thomas, 2002) projects. Other examples focus strongly on social interaction, for examples Pirates!, a fantasy game about trading and fighting at sea (Bjork et al., 2001). Professional artists have also developed game-like performances that mix players on the streets of a city with those who are online in a parallel virtual city, requiring them to share perspectives as the game proceeds. Recent examples of this include the chase game Can You See Now?, in which actors chase online players through a virtual city by running through the streets of a real city (Flintham et al., 2003), and Uncle Roy All Around You, which explores the theme of trusting in strangers through the interaction between online and street players as the latter are guided on a journey through a city in search of an elusive character called Uncle Roy (Benford, Seagar, Flintham et al., 2004).

At first sight, games such as these might appear to be far removed from the needs of education establishments. However, just as conventional video games have been a driving force for the development of the PC, so location-based games may well play a significant role in shaping the development of the mobile phone and related technologies (indeed, several dedicated mobile game consoles are currently entering the market, as we shall discuss below). It is therefore important to track developments in location-based gaming as they offer an insight into the kinds of services that we can expect in the future. Indeed, some recent research projects have begun to directly explore the educational potential of location-based games, including the Savannah project that we now discuss in more detail.

Savannah – an educational location-based game

Savannah is an educational game developed by NESTA Futurelab, Hewlett-Packard Laboratories, The BBC and the Universities of Nottingham and Bristol, in which children learn about the ecology of the African savannah, specifically about lion behaviour (Benford, Rowland, Flintham et al., 2004). Groups of six children at a time role-play being lions by exploring a virtual savannah that appears to be overlaid on an empty school playing field, an open grassy area of roughly 90 by 60 metres. Equipped with handheld computers with WiFi networking and GPS location sensing, the children move around the playing field, exploring the varied terrain of the savannah and discovering the resources that lions need to survive.

The game requires collaboration: just as a pride of lions has to work together to survive, so players have to work together to win the game by first scouting for resources, and then, in later levels, by deciding which animals to attack and how many lions must attack together at the same location in order to succeed. For example, a lone lion can bring down a stray calf, whereas several lions are needed to bring down a mature buffalo, and even all six lions will not bring down a fully-grown elephant.

'Lions' hunting for food as part of the Savannah location-based education game

Savannah also includes a Den, an area of the classroom to which the players retire after playing a level and where they use a smart-board to replay a system recording of their actions so that they can reflect on how they performed. A system recording is essentially a log of time-stamped events as seen from the system perspective that allows the experience to be recreated as if it were live: a technique that has also been employed in other experiences, for example to create replay installations of the game Can You See Me Now? or to support ethnographic analysis as part of research.

This approach of moving between periods of physically active play in the field and more contemplative reflection back indoors may be important for effective learning, and other location-based experiences should consider similar 'record and replay' techniques.

Field visits

Building on the idea of tourist guides, another form of location-based experience is the field visit, in which participants undertake a trip to a site of special interest, often either historical or scientific. In this case, location-based technologies can be used to deliver information in context, for example, enabling the participants to uncover a complex history or ecology as they explore the site. Among recent projects that have explored field visits in an educational setting are Ambient Wood (part of the UK's Equator Interdisciplinary Research Collaboration that demonstrated and studied a variety of location-based experiences–see the Equator website at www.equator.ac.uk for more information), in which groups of school children used wireless sensors and displays to explore the ecology of a woodland (Price et al., 2003; Weal et al., 2003). In the European Shape project, groups of visitors (typically families) to an ancient castle used a variety of location-based devices to reveal historical events that had occurred around the grounds (Fraser et al., 2003). Finally, the European RAFT project also explored support for schools taking part in remotely accessible field trips (see the RAFT project website at www.raft-project.net for more information).

The City project – a museum and gallery co-visiting experience

The City project, also part of the Equator IRC, explored how local and remote (i.e. online) participants could share a museum co-visiting experience (Brown et al., 2003). In collaboration with Glasgow's Lighthouse museum, which is dedicated to the work of the architect and artist Rennie Mackintosh, the project created a visiting experience in which three quite different kinds of visitors could share information, albeit from radically different perspectives. Local visitors explored the physical space of the museum using handheld computers with WiFi communications and an ultrasonic positioning system for determining their location. They were joined by two different kinds of online visitors, one using a standard Web interface and the other in a 3D virtual model of the museum space. The co-visitors could also communicate through real-time audio.

Like the artistic games Can You See Me Now and Uncle Roy All Around You, the City project demonstrates the potential for connecting mobile users with remote online users to create new kinds of experience in which they collaborate, exchange different perspectives, or even compete. We might expect this to be another recurring feature of future location-based experiences.

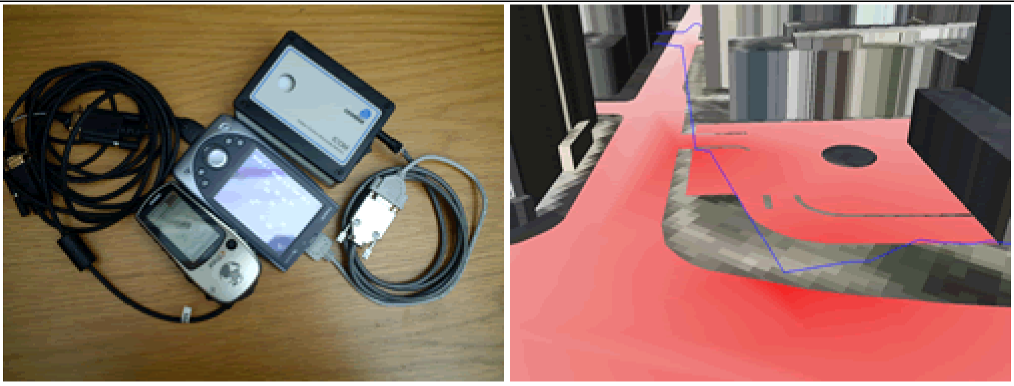
A mobile user and an online user share a visiting experience in Equator's City project

Field science

Field science projects introduce the further dimension of *collecting data* from a local environment rather than just accessing information that is already known to the system. Projects include supporting research scientists as part of their everyday work, providing them with enhanced ways of working both around the laboratory (e.g. the Labscape project that developed an electronic lab book that tracked researchers around potentially hazardous experimental environments–seeArnstein et al., 2001) and also when working out 'in the field' (see the example below). They also include learning experiences that simulate scientific work so that students can experience and appreciate the scientific process. The key to such applications is using mobile sensors to take readings, in concert with location-sensing systems to measure where these were taken. The readings are often logged on the mobile device, to be uploaded to a common data repository later on, but may sometimes be uploaded live: especially where remote scientists may wish to guide the local scientist in real time, for example encouraging them to investigate particular locations in response to the readings obtained so far.

The environmental e-science project

Equator's environmental e-science project has been exploring how mobile carbon monoxide sensors can be combined with GPS positioning to give scientists a more detailed picture of how people experience pollution in urban environments (Steed et al., 2003). For example, sensors have been attached to commuters' bicycles or repeatedly carried around areas of central London by pedestrians in order to log exposure to carbon monoxide during individual journeys, with the results being combined and then visualised in various ways, including within a large-scale 3D model of central London.



Mobile carbon monoxide sensing kit and 3D visualisation of individual journeys

Sense was a spin-out project funded by JISC to explore how the same technologies could be used in schools. Groups of children captured pollution readings and video material during short journeys around their local environment and then analysed these back in the classroom, including sharing them with other schools and even remote expert scientists. A key feature of this project was replaying the video alongside time series visualisations of the measurements in order to understand how the carbon monoxide sensor was affected by local events such as passing traffic. Once again, we see a learning experience that oscillates between action in the field and reflection back in the classroom.

These various projects demonstrate a wide variety of location-based experiences that could be relevant across all levels of education, including supporting researchers, students, children and even family experiences. Between them they raise some important general points about the ways in which location-based technologies can be embedded into an overall learning or research experience:

- Exploring and then reflecting – the idea of combining physical exploration of the real world with more analytical reflection back in the laboratory or classroom.
- Record and re-use – supporting this by recording data during a location-based experience so that it can be replayed, as if live, later on.
- Local/remote collaboration – mixing online and 'street' participants, each with a different perspective or different capabilities.
- Multi-site collaboration – for example sharing data obtained from different locations, ultimately maybe even as part of 'Big Science' projects where the general public gather environmental information using their own devices, for example their mobile phones.

THE TECHNOLOGIES OF LOCATION-BASED EXPERIENCES

Location-based experiences build on three core technologies: mobile devices, wireless networking and location sensing.

Mobile devices

Location-based experiences can be delivered through a wide variety of mobile devices. Commercial products range from high-specification laptop computers, to personal digital assistants (PDAs), through to mobile phones. They vary greatly in terms of computing power, display size, form factor, portability and battery life. Previous attempts to classify such devices include the IEEE's distinction between mobile devices (including phones and PDAs, which are essentially small enough to fit into a pocket), and larger devices such as laptops that are classed as portable (IEEE, 2002). However, emerging devices such as mobile gaming consoles and future developments such as wearable computing, may soon challenge such classifications. As noted previously, perhaps the key technology to watch here is the mobile phone, both because it is so widespread and also because mobiles are beginning to emerge as genuine computing devices (for example, high-end phones can now support simple 3D graphics).

Another interesting technology to watch is mobile game consoles, with major players in the mobile phone and/or gaming markets releasing innovative mobile consoles (e.g. Nokia's nGage and Sony's forthcoming Personal Playstation), and other interesting new devices such as the Gizmondo, which supports inbuilt GPS positioning. At the very cheap end of the market, even Tamagotchi now have basic peer-to-peer communication facilities for multiplayer use.

The research community has been exploring the long-term options for mobile devices, including:

- Wearable computers that are embedded within clothing, jewellery, glasses and other personal effects. Wearable computing has been an active area of research for many years and is now supported by its own international conferences, most notably the IEEE Symposium on Wearable Computing. Leading edge research is currently exploring the idea of smart fabrics which embed networking, display and power into future fabrics.
- See-through, head-mounted displays that enable graphics to be directly overlaid onto the user's view of the physical world and be updated according to their movements. They form a staple part of augmented reality experiences, perhaps the most extreme form of location-based display, in which a 3D virtual environment is superimposed upon the user's view of reality. These have been deployed in both indoor and outdoor applications including gaming, engineering, and training and simulation (Piekarski and Thomas, 2002). See-through head-mounts have also been built into other devices, for example masks that children hold to their faces in order to view the augmented reality 'Magic Book' (Billinghurst et al., 2001). Software environments are also available to support the development of augmented reality applications, most notably the AR Toolkit (Kato et al., 2000), a widely used platform based on video-tracking of visible glyphs that can be printed on pieces of card or other objects.
- Stand-mounted and hand-held 3D displays such as the Augurscope (Koleva et al., 2002), a wheeled public display for use in outdoor visiting experiences that enables groups of users to view a 3D historical reconstruction from different physical vantage points.
- Tangible interfaces and interactive surfaces that embed computing functionality into everyday objects (Ishii and Ullmer, 1997). Users manipulate phicons – physical icons – that represent digital information or operations, moving them across interactive surfaces such as tabletops, in order to control a digital experience in a natural and aesthetically pleasing manner. Other researchers have been exploring how everyday walls and notice boards can be made digitally aware and interactive, for example pinboards that can deliver power and networking to pin-like devices that are pushed into them (van Laerhoven, Schmidt and Gellersen, 2002). Several generic research platforms are available to enable researchers to create such embedded hardware devices, for example Smart-Its (Holmquist et al., 2004).

Wireless networking

While there is a wide range of wireless networking that might be used to deliver location-based experiences to mobile participants, three broad classes of technology seem likely to dominate the field in the immediate future: cellular telephony, Wireless Ethernet and Bluetooth.

- Cellular telephony itself refers to a wide range of technologies that share the common goal of supporting commercial mobile telephone services. These include the most established but low bandwidth technologies of GSM and SMS as well as more recent, higher-bandwidth (but lower coverage) protocols such as GPRS (2.5G) and now 3G. The defining feature of these technologies is that they are commercial services provided by operating companies, meaning that users and their organisers do not have to provide or manage the core infrastructure but they do have to pay for data transfer. Of course, they are also the networking protocols of choice for mobile phones.
- Wireless Ethernet (the 802.11 family of protocols of which some variants are also known as WiFi) are now almost standard in computing devices such as laptops and PDAs. They typically provide far greater bandwidth than cellular telephony, but currently have less global coverage. The defining feature of this technology is that users can deploy it for themselves, requiring investment in the infrastructure but avoiding the need for direct payment for each data transfer. Wireless Ethernet can be deployed in a very *ad hoc* manner, including being able to establish peer-to-peer connections between client devices, and therefore avoiding central servers.
- Bluetooth is a far more localised and low-bandwidth protocol that has been designed to support communication between local devices, e.g. connecting mobile phones to peripherals such as hands-free headsets. Bluetooth is increasingly available on mobile phones, but is also spreading to other devices, and also enables users to establish their own *ad hoc* peer-to-peer networks. Localised networking technologies such as Bluetooth are driving the development of Personal Area Networks (PANs) that offer the potential to dynamically and flexibly

connect a user's various devices without the need for cumbersome cables and wires (Zimmerman, 1999).

Further discussion of wireless networking in relation to mobile phones and PDAs can be found in the previous JISC Technology Watch report on Mobile and PDA Technologies (Anderson and Blackwood, 2004).

Location sensing

Our third core technology is location sensing (or more generally, context sensing). Once again, there is a very wide variety of technologies available, many of which were reviewed in detail in a previous TechWatch report (Roussos, 2002). The following briefly summarises the most significant approaches.

- The Global Positioning System (GPS) enables a mobile receiver to triangulate time-of-flight of transmissions from multiple orbiting satellites in order to compute its location above the Earth's surface. The appeal of GPS is the potential to track the user's position across a wide geographical area, potentially to within a few metres (or even better with some variants of GPS). In practice however, while GPS has enjoyed great success in relatively constrained and predictable situations such as vehicle navigation, early attempts to use it as part of coherent location-based experiences indicate some of its frailties, especially coverage and accuracy, that vary with both location and time-of-day, especially in built-up urban environments.
- Wireless networking technologies can provide estimates of the locations of connected devices. At the crudest level this involves reporting the antenna or base station to which they are currently connected (the 'current cell ID' in a mobile telephone network, and the local base stations in a WiFi network). Building on this, such networks can triangulate position in relation to multiple antennae in order to provide more accurate estimations of location. For example, the Ekahau system provides estimates of location in WiFi networks (see the Ekahau website at www.ekahau.com for more information).
- Ultrasonic systems triangulate from time-of-flight of ultrasonic sound chirps and are suitable for use indoors. A low-cost ultrasonic system has been developed by the University of Bristol and was used in the City project described previously (Randell and Muller, 2001).
- Radio Frequency ID (RFID) tags that may be embedded into many everyday objects, providing more localised estimates of position as they pass closely by RFID readers, often at a distance of just a few centimetres.
- Small accelerometers can be embedded into mobile interfaces to measure their acceleration through space, from which velocity can be derived, as part of inertia tracking. These can be complemented by digital compasses and gyroscopes to measure rotations and orientation. In general, orientation may be an important factor in location-based experiences, for example, it may be important for the system to know which way you are facing (i.e. what you are looking at).
- Specialised computer 'vision' techniques can also determine location. One approach is to recognise objects within a scene, for example specialised optical markers (the approach used in motion capture systems and the AR Toolkit described previously), or bodies, faces and other classes of object for which the devices have been trained. Alternatively, motion estimation techniques determine the movement of the camera from frame-by-frame changes to the image of a scene, a technique that has recently been demonstrated running on mobile phones.
- Finally, there are technologies for sensing information about the user's general context of interaction beyond their current location, including sensing activity (e.g. talking and movement) and physiological state (e.g. heart rate and skin resistance).

Although a detailed comparison of these different approaches is beyond the scope of this report, it should be noted that they differ in a wide variety of ways including: the extent of the geographical area that they cover; whether they work indoors or outdoors; their resolution, accuracy and jitter; the potential for interference; cost; and whether position is determined by a centralised technology (e.g. 'the network') or by the device itself (which may provide greater privacy).

CHALLENGES FOR LOCATION-BASED EXPERIENCES

Location-based experiences are in their infancy and the technologies on which they build are diverse and still maturing. Unsurprisingly, significant challenges need to be addressed before they reach their potential. In particular, it is important to be aware of the limitations of the technologies involved.

Dealing with the uncertainty of location sensing

All of the location-sensing technologies mentioned previously introduce considerable uncertainty – far more than traditional input technologies such as keyboards and mice, which tend to be precise and predictable. These uncertainties include limited coverage, accuracy and often considerable variation of performance over both space and time. Early studies of location-based experiences have shown how these uncertainties can have a profound impact on the user's experience (Crabtree et al., 2004). Consequently, researchers in human-computer interaction have begun to articulate the design challenges that have to be met, for example, Bellotti's 'five questions' for sensing-based interfaces (Bellotti et al., 2002):

> How do I address one (or more) of many possible devices?
> How do I know the system is ready and attending to my actions?
> How do I effect a meaningful action, control its extent and possibly specify a target or targets for my action?
> How do I know the system is doing (has done) the right thing?
> How do I avoid mistakes?"

Others have proposed approaches to dealing with these questions, for example by carefully comparing the likely movements of interfaces against capabilities of sensors (Benford et al., 2005); revealing uncertainty to users so that they can better cope with it (Benford et al., 2003); and even exploiting uncertainty, for example by designing games in which users can use inaccurate location-sensing to their advantage as part of the gameplay (Chalmers and Galani, 2004).

Dealing with uncertainty of connection

A second major source of uncertainty lies in wireless networking. It is highly likely that the user of an extended location-based experience is going to suffer from one or more periods of disconnection. Again, it may also make sense to reveal the state of the connection to the user, a technique already familiar from everyday mobile phones, which display an estimation of signal strength. It may also be important to provide some level of continued experience when disconnected, requiring designers to cache information on the user's mobile device (or at least guidance on how to get reconnected), even though its memory may be small. Finally, designers must anticipate potentially inconsistent information as users continue to interact with the local part of an experience while disconnected.

Interoperability

We have seen previously that there is an almost bewildering variety of technologies – devices, networks and location-sensors – upon which location-based experiences might be developed. Our third major technical challenge is therefore interoperability. Interoperability of networks is a key issue, including roaming between different network providers and eventually exploiting multiple network technologies and/or architectures within a single experience, for example, simultaneously using cellular telephony to communicate with remote servers and peer-to-peer Bluetooth connections in order to communicate with other users nearby. Similarly, it makes sense to combine multiple location-sensing technologies so that they reinforce one another, an approach known as sensor fusion.

Given that such heterogeneity is likely to be a feature of location-based experiences, it is important to develop suitably flexible middleware to support application developers in a 'pick-and-mix' approach to combining devices, networks and sensors. Several publicly available research platforms show how this can be achieved e.g. the Context Toolkit for developing context-aware applications from The Georgia Institute of Technology (Dey and Abowd, 2000); the Equip platform from the Equator project (see the Equator project website at www.equator.ac.uk for more information) that was used to implement elements of the City, Savannah and urban pollution monitoring projects described previously; Placelab, which integrates multiple, location-sensing technologies to deliver an improved positioning system that also supports privacy by avoiding reliance on a central server (Hong et al., 2003).

Social and organisation challenges

Beyond the technology there are equally, if not more, significant user and organisational challenges. Some of these have been discussed in previous Technology Watch reports (Anderson and Blackwood,

2004) and include extending current infrastructure to support widespread wireless access (which may include providing dedicated servers to handle and authenticate wireless connections), and moving away from supporting lab-based PCs to supporting students' own devices (including dealing with the challenges of synchronising these devices with network servers and interoperability issues as discussed previously). The full costs of developing this infrastructure will depend on whether an organisation is providing its own network and positioning infrastructure (in which case there will be equipment costs for access points, servers and positioning systems–especially indoors) or using commercial services such as those that will be provided by mobile operators. Institutions may find it beneficial to start developing links with network operators to explore the relationships between their own infrastructure and that of commercial services.

- Privacy is perhaps the most significant long-term challenge facing the successful roll-out of location-based experiences. Monitoring a user's location and transmitting this to other users, or storing it centrally, has the potential to seriously compromise individual privacy. Solutions are likely to rely in a mixture of technical, social and perhaps even legal mechanisms. Technical mechanisms for handling privacy will involve the careful choice of location-sensing technologies (e.g. preferring those that run only on the user's local device), along with mechanisms for controlling disclosure, backed up with appropriate security mechanisms. Developing appropriate social mechanisms requires raising awareness of the privacy implications of location-based technologies through a close dialogue with users and/or their representative organisations. Legally, institutions will need to be aware of data protection and be increasingly aware of the implications for disclosure of location-based data under the Freedom of Information legislation.
- The potential widespread use of users' own mobile phones to take part in educational location-based experiences raises important issues in the area of management and billing. Users will most likely be responsible for administering their own devices (raising important issues of security), and where cellular telephony is used, may need to pay directly for each data transfer. Beyond this, there is a potential culture clash over the increasing use of mobile phones in an educational setting–mobile phones may be seen as problematic in environments such as schools and the use of personal communication devices in public settings can still be controversial.
- The demand for location-based services seems most likely to come from the student body, which will already be familiar with them from social and personal use. One organisational challenge is therefore to 'educate the educators', helping university staff to become equally familiar with their potential. There are also social issues to be addressed concerning the relatively *ad hoc* and (from a central point of view) uncontrollable use of mobile communications, especially in formal situations such as lectures and examinations. These include dealing with interruptions, being aware of the potential of electronic side-chat (which might be seen by some as subversive), through to the more extreme possibility of cheating in examinations.

SUMMARY AND RECOMMENDATIONS

Location-based experiences are an exciting prospect for education, from schools through to universities and from learners through to researchers. They offer the potential for new forms of learning that take place outside the conventional lecture hall, laboratory or classroom. We can anticipate new learning experiences such as augmented field-trips and field-science as well as more general location-based information services and also new forms of educational games and simulation.

Location-based learning experiences can be delivered over a wide range of technologies. Mobile devices include mobile phones, handheld computers and other emerging forms of wearable, embedded and tangible interfaces. Wireless networking includes cellular telephony, wireless Ethernet and protocols for *ad hoc* local networking such as Bluetooth. Finally, there is a plethora of possible location-sensing technologies such as GPS, network triangulation, RFID, video tracking and others.

However, the diversity and relative immaturity of these technologies raises serious technical challenges, especially in terms of dealing with the uncertainty of positioning and connectivity, and also with regard to interoperability. Beyond these, there are further user and organisational challenges to be met in areas such as privacy, ownership, billing and, more generally, adaptation to the 'mobile culture'.

Given these observations, this report recommends that educational organisations consider the following steps in the near future.

- Consult closely with potential users – students, teachers and administrators – over the potential use of location-based technologies, especially privacy and ownership issues.
- Maintain a further watch on emerging technologies, especially mobile phones and games.
- Explore potential educational applications through a diverse range of pilot activities.
- Establish contrasting, limited scale location-based testbeds in order to gain greater practical experience with the different technologies, applications and issues involved.
- Form appropriate links with mobile operators to explore potential relationships between organisational and commercial infrastructures.

GLOSSARY

e-learning – learning that is accomplished over a computer network or the Internet, potentially remotely from the host educational service provider.

GPS – The Global Positioning System.

GSM – A mobile telephone system that is used in many parts of the world and has become a *de facto* standard in Europe. It provides the lowest bandwidth but is the most widespread cellular telephony service for voice calls.

GPRS – General Packet Radio Service – mid-bandwidth cellular telephony service also known as 2.5G

3G – higher bandwidth mobile telephone service.

m-learning – learning that is accomplished using mobile services over wireless networks, potentially while on the move.

PDA – Personal Digital Assistant – a type of handheld computer.

RFID – Radio Frequency ID – a system of small electronic tags and readers for close range positioning.

SMS – Simple Messaging System for transferring text messages to and from mobile phones.

WiFi – Wireless Ethernet network protocol, also known as 802.11b.

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