The Role of Shared Context in Supporting Cooperation between City Visitors

Keith Cheverst, Gareth Smith, Keith Mitchell, Adrian Friday and Nigel Davies

Distributed Multimedia Research Group,

Department of Computing,

Lancaster University,

Lancaster, LA1 4YR.

e-mail: kc,gbs,km,adrian,nigel@comp.lancs.ac.uk

telephone: +44 (0)1524 594337

1. Introduction

The development and evaluation of the GUIDE system [1][2][3][4] demonstrated the potential value and acceptability of a mobile context-aware interactive assistant to city visitors. However, one of the concerns that has arisen through the development and evaluation of GUIDE is that it may lead to less social interaction by city visitors, e.g. less communication with actual tour guides, members of the Tourist Information Center, etc. Although this was certainly not the intention of the GUIDE system, the criticism is reasonable based on the fact that visitors are likely to ask GUIDE for information (e.g. guidance instructions) or services (e.g. ticket booking) that would have traditionally involved personal communication.

In a hope to redress the balance, we are currently extending the GUIDE system in order to support cooperation and encourage a sense of community between users. For one example of how this might be achieved, consider the following scenario:-

> *"John, a visitor to Lancaster, is looking for a café to visit and has asked his GUIDE to assist him in finding a suitable café. John is shown the relevant web-pages of a number of potentially suitable cafés based on their proximity and John's preference for vegetarian food. However, John is still unsure as to which café to choose and so reads a list of comments left by other visitors for the various cafés under consideration. In addition, John is shown that another GUIDE user, Mary, is currently located in one of the cafés*

listed. John would like to have an unbiased opinion on whether the café is currently quiet and accommodating and so decides to send a quick message to Mary enquiring about the café."

Supporting this kind of cooperation between distributed users is clearly relevant to the research fields of Groupware and CSCW. Indeed, the sub-field referred to as Social navigation [5] is concerned with enabling users to cooperatively navigate through complex information spaces, such as a virtual city model. Moreover, one common form of social navigation is based on the sharing of recommendations between users. Another related area, that tackles ways of facilitating cooperation between geographically distributed users, is that of social awareness. The motivation behind such awareness is to overcome the problems of remoteness by trying to provide some of the many (often subtle) audio-visual cues that are lost during remote communication [6].

However, to date, little research has investigated the ways in which mobile location-aware systems can be used to support cooperation and interaction between geographically distributed users. Moreover, there has been little research into the development of location-aware systems that enable mobile users to receive an awareness of other users whose location in the real world corresponds to those places being explored in the virtual world.

This paper describes the issues that have arisen while extending the GUIDE system to support this rich form of cooperation between geographically distributed visitors. The issues addressed include: supporting the sharing (and privacy) of location context, achieving the appropriate presentation of location context, managing the capture and storage of positioning information and an analysis of the new demands on the GUIDE communications infrastructure.

2. Background

The GUIDE system has been developed to provide city visitors with a hand-portable context-aware tourist guide. The system has been successfully deployed in the city of Lancaster and is publicly available to visitors who wish to explore the city.

The system is built around a cell-based wireless communications infrastructure based on Lucent Technologies' 802.11 compliant ORiNOCO system. This infrastructure has a dual

role, firstly, it is responsible for broadcasting location beacons in order to provide positioning information, and, secondly, the infrastructure is used to disseminate both static and dynamic information to mobile GUIDE units. Each cell has associated *cell-servers* with local storage and processing that effectively act as a proxy cache to the central GUIDE web server.

Currently, six communication cells have been deployed within the city covering the major tourist attractions. Although the range of ORiNOCO is approximately 200m in free space, ORiNOCO signals have poor propagation characteristics through buildings and therefore by the strategic positioning of cell-servers, we have been able to create some relatively small cells. However, the resolution of positioning information provided by the cells is course grained and one communications cell can contain a number of attractions. For this reason, interaction with GUIDE is to a large extent governed by the design of the infrastructure [3], i.e. the strategic placement of cells in order to provide appropriate areas of location resolution and network connectivity.

In order to provide acceptable scalability, a broadcast based approach has been adopted to information dissemination, one implication of this is that servers do not maintain any state relating to GUIDE clients, including their current position.

A visitor interacts with his or her GUIDE unit through a local web browser embedded within the GUIDE application. In effect, all HTTP requests are processed by a local web proxy, which may, in turn, interact with other objects in order to service the request. This aspect of the GUIDE system is described in detail in [2]. In order to support the generation of tailored web-pages, we enable page authors to reference or query the state of GUIDE objects, e.g. location objects or the visitor's profile, by augmenting pages with special GUIDE tags.

The system utilizes a purpose-built information model [1] in order to represent places, such as attractions and key buildings, within the city. The design of the information model and the GUIDE application enables city visitors to virtually explore parts of the city, e.g. to read about the City Castle while still in the Tourist Information Center. In addition, it allows visitors to use the system as a form of augmented reality, e.g. by viewing background information about the City Castle while standing outside the main gate.

3. Sharing the Location of GUIDE Users

The sharing of location information raises a number of issues. In particular, the notion of supporting privacy of location information needs to be considered. Other issues for consideration include achieving the appropriate capture of location information and managing the storage of this information. The following subsections describe these issues in turn.

3.1. Privacy Issues

A number of location tracking systems have encountered difficulties because of the unwillingness of users at work to allow their location to be known to the system, as experienced with the active badge system [7][8]. A comprehensive investigation into many of the human factors based issues relating to the sharing of such information (in the work domain) is presented in [9]. However, it is important to note that, to the best of the authors' knowledge, there has been very little research that focuses on the issues raised by the development of systems that support the sharing of location information between users that are acting at their leisure.

In the current GUIDE system, the server side maintains no state information regarding the location of clients. Furthermore, no GUIDE users are given reason to feel that their location is being explicitly tracked and that this information could be available to a third party, such as another GUIDE user. Indeed, during the system's evaluation no concerns appertaining to privacy of location were raised.

Some visitors are likely to feel concerned if they feel that personal context, such as their location, is available to others. For this reason, we have enabled users to specify if they wish to remain anonymous or if they do not wish to have their location recorded. This information is stored in the user profile object.

3.2. Capturing the Location of GUIDE users

3.2.1 Acknowledging the Location of Clients with the Server

As described in section 2, the server side of the system does not track the location of GUIDE units. Instead, each GUIDE unit maintains its current location and this information is sensed via the reception of location beacons. These beacons are broadcast every 3 seconds in order to provide the visitor with reasonably timely feedback when walking into a new communications cell.

In order to enable the server to capture the location of GUIDE units, the immediately obvious approach would be to have clients send an acknowledgement upon receiving a location beacon. However, this approach would generate a significant amount of network traffic and therefore compromise the desire for client scalability as described in [2].

One alternative to this approach would be to reduce client induced network traffic by requiring clients to only acknowledge cell handovers. However, this approach is currently unsuitable because the cell coverage in Lancaster is not complete. As a result, a client could leave a communications cell but the server would still assume that the client had not changed location.

The chosen solution is based on a compromise that requires clients to acknowledge every tenth location beacon that is received. In the worst-case scenario, this can lead to the server having location information relating to a given GUIDE user that is thirty seconds out of date. However, given the way in which location information is being used, i.e. for providing visitors with basic location awareness, this potential for inconsistency is not considered to be a significant problem.

3.2.2 The Requirement for Tight-coupling between Communication Cells and Places

In order to provide place awareness appertaining to a given visitor, the server clearly needs to place the visitor at a specific location, e.g. the City Castle or the Folly Café. However, the location information provided by the communications infrastructure was not initially designed

to provide this granularity of positioning information. Instead, it was designed to provide course ‘cell-based’ grained positioning information in which the cell could contain multiple places or attractions.

In order to identify the place where each GUIDE user is located there needs to be a tight-coupling between the resolution of positioning information currently provided by the communications infrastructure and the area occupied by attractions presented in the GUIDE information model. To achieve this tight-coupling we are currently extending the existing 802.11 based communications infrastructure with Bluetooth micro-cells using the Bluetooth development kit [10] produced by Stonestreetone Ltd. If this approach proves unsuitable then we will reinvestigate the use of alternative positioning solutions, e.g. GPS or Ericsson’s Mobile Positioning System (MPS).

3.2.3 Storing the Location of GUIDE users

Two main strategies have been considered for storing the location of GUIDE users within the system infrastructure, namely: on the GUIDE server, and, replicated across the client end-systems. With the latter approach, an update would need to be sent to all clients each and every time a GUIDE user changed location (note: since the information can be broadcast to all clients within an ORiNOCO cell, this approach is not as inefficient as it first appears).

The key benefit of storing the group’s location context on the client is that this information can be accessed quickly and will be available even when the client is disconnected from the network. However, the longer this period of disconnection the greater the likelihood of the information becoming out of date. Alternatively, the advantages of storing the group’s location information on the server are: network traffic will only be generated when a client makes a specific request, location information will be consistent and managing privacy through access control techniques is relatively straightforward. One possible drawback with this approach is that disconnected visitors cannot access location information.

4. Facilitating Cooperation

Our goal has been to create a system in which GUIDE users are encouraged to cooperate and feel a sense of community with other users of the system. Our approach towards achieving this goal is to enable a visitor that is using the GUIDE system to read about a particular attraction to:

- Create a comment and rating for association with a particular attraction, e.g. “The espresso served at this café is superb”. Alternatively, the visitor can associate a comment regarding usage of the GUIDE system in general, e.g. “I found it useful to use the map facility while following a tour”. Such comments can be read via the system’s Help page.

- Realize when another GUIDE user is (or has recently been) physically located at a particular attraction. On noticing that another visitor is located at the attraction being considered, the visitor may then choose to contact the other visitor in order to explicitly ask for his or her subjective opinion of the attraction.

4.1 User Interface Design

We have added links to those pages that relate to attractions within Lancaster in order to facilitate the reading or creating of comments associated with the given attraction and to simplify the process of sending a message to someone who is actually located there.

Figure 1, illustrates how these links might appear on the page describing Lancaster’s Folly Café. In the example shown in figure 1, if the GUIDE user clicks on the name ‘Keith’ the send message dialogue box will appear with the recipient’s name automatically filled in. This should make the process of contacting a fellow GUIDE user that is located at a given attraction reasonably straightforward. Given that a user may simply wish to contact another GUIDE user in order to receive some form of recommendation, we are currently investigating the potential for enabling a GUIDE user to be able to make a single ‘click’ in order to request another GUIDE user to fill in a short recommendation type checkbox. The advantage of this

facility is that it would remove the necessity for typing by both the visitor wishing to receive the recommendation and the visitor being asked to supply the recommendation.

Figure 1: Presenting location awareness.

A ‘collaborate’ button is also available for enabling a GUIDE user to discover the location of other users around the city (given the appropriate permissions) and to read or publish comments relating to his/her actual location.

We anticipate that some GUIDE users will be prepared to share their location information with members of their group, e.g. family, but not with other GUIDE users. Similarly some users will want to be contactable by other members of their group but may not find acceptable the possibility of being contacted by other GUIDE users on an ad-hoc basis.

The task of designing an easy-to-use interface that enables a GUIDE user to constrain the way in which their personal context is shared with others is not trivial. In particular, if the choices made available to the user for constraining the sharing of information are insufficiently flexible then users may well simply reject the sharing/cooperation features altogether. For example, given the simple choice of ‘do you wish to share your location with everyone and be contactable by everyone’ a user may consider this level of sharing unacceptable and therefore

answer negative even though they would be prepared to allow their current location to be seen by their friends. Alternatively if too many choices are made available to the user then the choice may become overwhelming and the interface too complicated, again causing the user to reject the feature altogether.

Following a number of early designs attempts, we have arrived at a prototype interface for enabling the user to specify how their location should be shared and who should be able to contact them. The interface is based on a wizard paradigm whereby the user is led through a series of steps in order to specify any preferences that they might have. The 'preferences wizard' is first run when a user is initially presented with a GUIDE unit. However, the wizard can also be run at any point thereafter should the user wish to change their preferences.

The first two steps of the wizard are concerned with the specification of the users interests that was present in the initial single-user version of GUIDE.

The third step (as illustrated in figure 2) is concerned with enabling the visitor to specify their preferences for sharing information with members of his/her group.

The next (i.e. fourth) step (as illustrated in figure 3) is concerned with enabling the visitor to specify whether or not they are prepared to let their location be viewed by other GUIDE users that are not in their group and whether such users should also be able to make contact.

Given the nature of the problem we anticipate that this interface will undergo a number of revisions following feedback from real users. In particular, we would like to experiment with the notion of enabling visitors to specify specific contexts in which they would not wish to be interrupted by other GUIDE users, e.g. while visiting certain attractions, such as the city museum.

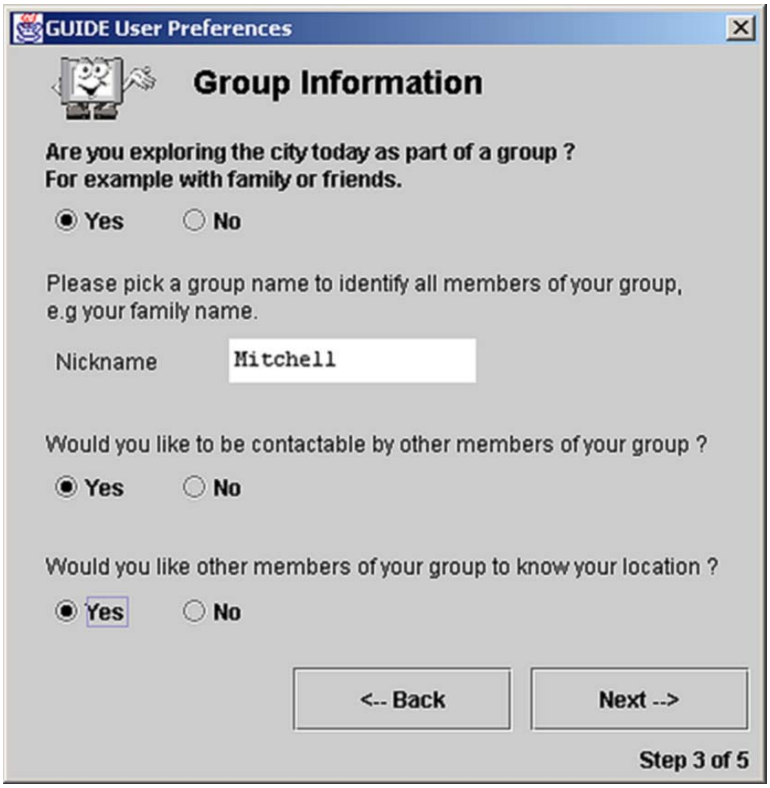

Figure 2: Enabling the user to control how personal information is shared with other members of his/her group.

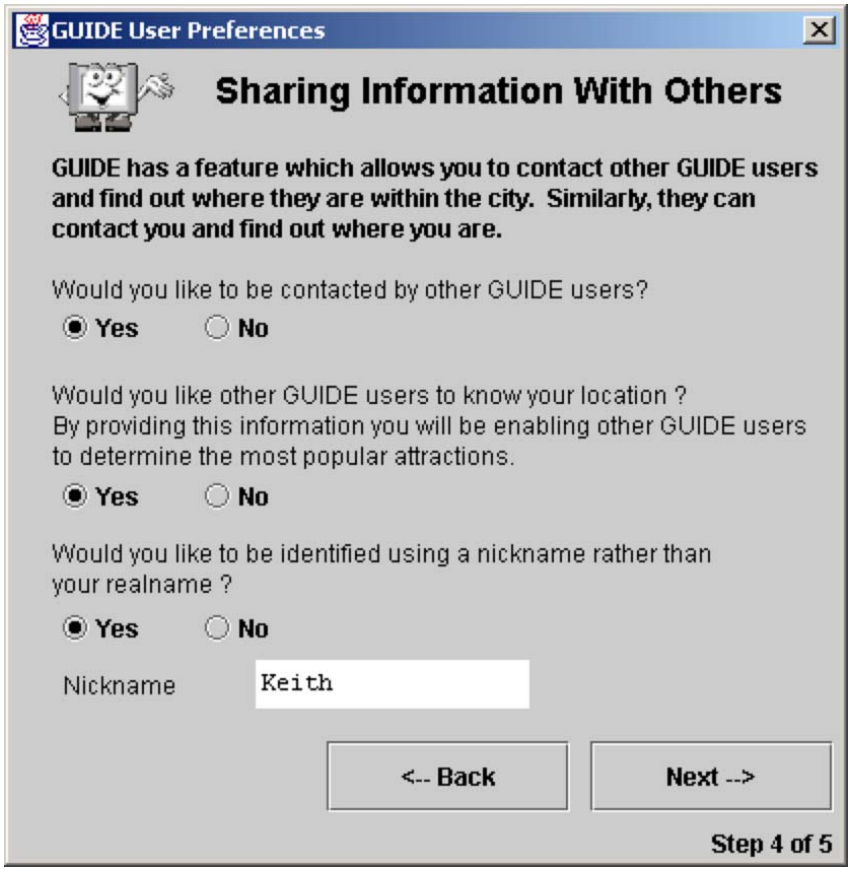

Figure 3: Enabling the user to control how personal information is shared with other GUIDE users.

4.2 Enabling the Markup of Location Awareness

In order to provide pages with the ability to query the location awareness information a new 'Collaboration' tag was created as shown below.

<GUIDETAG COLLABORATE *LOCATION*>

As with other GUIDE tags, this tag can be embedded in an HTML page for preprocessing by the GUIDE filter object prior to display (see [4] for a detailed example).

On reaching the collaborate tag, the GUIDE filter object expands the tag by checking that the visitor has network connectivity and (given that this connectivity is available) makes a remote request for a list of GUIDE users currently in the cell. The server responds to the query by returning the identity of those visitors currently recorded as being present at the specified

location. For privacy purposes, the actual name of a visitor is only passed back to the client if the visitor has agreed to be contactable (and the permissions for this are stipulated in the user's profile object). If a visitor has requested anonymity then a unique id is assigned and returned for that visitor, e.g. anonymous1, in order to mask the visitor's identity.

5. Future Work

5.1 Tagging Context

Our avenue that we a keen to explore is the notion of explicitly capturing the context affecting a user's rating. In more detail, we want to enable the person providing the rating to explicitly state the context, which most affected their decision.

Our chosen technique is to initially identify a likely set of context identifying tags that may affect a user's rating. The set of tags to be presented to the user is not constant but is context-aware. In more detail, the set is dependent on a number of factors including the nature of the attraction and the user's profile, e.g. whether or not they are supervising children. The next step is to enable the user to specify which, if any, of these context tags are appropriate for their particular rating. Returning to the café example, because the system knows the following: *Mathew has children* and *he has rated the café highly* and *the café has special child facilities* then the system could present Mathew with a dialog box similar to that shown in figure 4. Notice that as Matthew has given an excellent rating (5) the potential responses (context tags) are all positive.

Figure 4: Tagging ratings with context.

Having explicitly captured the context associated with a given rating, the underlying system can now process these context tags as it would with any other form of contextual data. This provides the system with a great deal of flexibility for supporting additional context-aware functionality. In practice, this functionality is likely to include the automatic filtering and prioritisation of comments based on their associated context tags.

This technique also enables other novel means of providing the user with tailored (context-aware) information. Consider, for example, a scenario in which Jane, a GUIDE user, visits the City Castle at sunset and then rates the castle with a 5. Because the visit took place at sunset (and the system knows this context) one of the context identification tags offered to the user is that of SUNSET. Having been impressed by the sunset Jane decides to associate this tag with her rating.

Later that month, Lucy is in Lancaster just before sunset and is considering a trip to the City Castle. Consequently, she decides to read comments left by other people with an interest in

historic architecture. Jane also had an interest for architecture; therefore her comment on the Castle is presented to Lucy. Furthermore, because of the imminent sunset Jane's comment is highlighted in Lucy's display.

Clearly, the relevant context in this case involves not only the location and user profiles, but also temporal information. However, in this example the temporal aspect is related to the time of the sunset and not the time of day.

Information such as impending sunsets can be presented to the end users in a number of ways; one interesting technique is to seamlessly blend this new information into their user interface. This technique, similar to that used by the onCue system [17], would add a 'Sunset' button onto the user's interface.

5.2 Other Future Work

One of the key areas for future work is to evaluate the support for cooperation and location sharing by a real set of end users. Such an evaluation is required in order to ascertain whether cooperation will indeed occur and whether or not visitors will generally accept the sharing of their location with other visitors. Furthermore, it will be interesting to see whether users are prepared to trust the comments of other visitors and whether or not visitors are prepared to invest the time to compose comments or respond to the queries of other GUIDE users.

Another area for future work is to further examine the issue of access control. The traditional notion of access control is based around the notion of relationships, e.g. [11] and this is clearly appropriate for GUIDE, e.g. only allowing the sharing location information to members of a family group. However, we also plan to investigate the issues raised by supporting privacy in relation to place. For example, a visitor might only be prepared to let their location be revealed to others who are in the same place; this might be because the person can implicitly trust the other people in that place. One example of such a place might be a 'members only' club. This notion of utilizing spatial boundaries for access control is reflected in the work on SPACE by Bullock [12].

Consider also the situation in which a visitor might be prepared to be open to interruption when sitting in a café, but not when rushing around an art gallery that is about to close. There

is clearly a great deal of potential for using context, such as location, to enable some form of agent to determine when cooperation is appropriate.

An area that is of much current interest is the creation and standardisation of sophisticated location models, such as that proposed by Leonhardt [13]. Future work on GUIDE will need to investigate the adoption of such a model in order to cope with the complex relationships that arise from having places within places.

6. Related Work

A significant amount of related work exists that has investigated the tracking of users by utilizing some form of indoor communications infrastructure. This work was primarily introduced through work on the Olivetti active badge system [7,8] and has evolved to highly accurate systems such as the RADAR system [14].

However, the area currently being investigated is very much inspired by the research into supporting cooperation between users in a virtual space, such as providing users with awareness of other users currently viewing the same web page, as demonstrated in the CoBrow system [15]. In addition, the work of Benford *et al* on mixed reality boundaries [16] has also inspired much of our current work and is concerned with the merging of physical and digital worlds. One example of this work has been to investigate the staging of a poetry performance within real and virtual theatres.

7. Concluding Remarks

This paper has described our experiences of extending the existing the GUIDE system to facilitate a richer means of social interaction and cooperation between visitors using the GUIDE system. To this end, we have adopted the novel approach of bridging the gulf between virtual and real worlds by providing GUIDE users who are exploring an attraction virtually with an awareness of those visitors that are physically located at the corresponding attraction. Implementing this support has required changes to GUIDE at numerous levels, including:

- Modification to the GUIDE application's user interface in order to enable users to specify the extent to which their location-based context should be shared and to enable users to observe the location of other GUIDE users around the city's attractions.
- A Redesign of the server in order to enable the effective storage of the location of GUIDE users and to support the querying of location information.
- Extending the user profile to include access control rights for the sharing of location information between other GUIDE users.
- A Re-evaluation of the GUIDE communications infrastructure.

This latter point has been caused by the need to have a tight-coupling between the resolution or granularity of positioning information currently provided by the communications infrastructure and the area occupied by attractions presented in the GUIDE information model. In particular, if awareness information is to be provided for a given attraction then the positioning information available should only relate to that attraction and not include other attractions within the area covered. In order to obtain appropriate location resolution we are currently extending the GUIDE communications infrastructure with micro-cellular Bluetooth-based wireless technology.

ACKNOWLEDGEMENTS

This work was carried out as part of the EPSRC funded GUIDE project (GR/L05280) in cooperation with Lancaster City Council and has received support from HP Labs, Bristol and Lucent Technologies.

REFERENCES

1. K. Cheverst, N. Davies, K. Mitchell and A. Friday. Design of an Object Model for a Context-Sensitive Tourist Guide, in *Computers and Graphics, Vol. 23, No. 6 (December, 1999) 883-891.*

2. N. Davies, K. Mitchell, K. Cheverst and A. Friday, Caches in the Air: Disseminating Tourist Information in the Guide System, in *Proceedings of 2nd IEEE Workshop on Mobile Computing Systems and Applications* (New Orleans, 1999) 11-19.

3. K. Cheverst, N. Davies, K. Mitchell and A. Friday, Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences, in Proceedings of *CHI'2000* (ACM Press, Hague, Netherlands, 2000) 17-24.

4. K. Cheverst, N. Davies, K. Mitchell and A. Friday, Experiences of Developing and Deploying a Context-Aware Tourist Guide: The GUIDE Project. In *Proc. of MOBICOM'2000* (ACM Press, Boston, USA, August, 2000) 20-31.

5. P. Dourish, Where the footprints lead: tracking down other roles for social navigation, in Alan J. Munro, Kristina Hook, & David Benyon (eds.) *Social Navigation of Information Space* (Springer-Verlag London Limited, London, 1999) 15-34.

6. P. Dourish and S. Bly, Portholes: supporting awareness in a distributed work group, in *Proceedings of Human factors in computing systems*, (Monterey, CA, USA, 1992) 541-547.

7. R. Want, A. Hopper, V. Falcao and J. Gibbons, The Active Badge Location System. In *ACM Transactions on Information Systems, Vol. 40, No. 1* (January, 1992) 91-102.

8. M. Spreitzer and M. Theimer, Providing Location Information in a Ubiquitous Computing Environment, in *Proceedings of 14th Symposium on Operating System Principles*. ACM Press. (1993) 270-283.

9. S. Hudson and I. Smith, Techniques for addressing fundamental privacy and disruption tradeoffs in awareness support systems, in *Proceedings of ACM 1996 conference on Computer Supported Cooperative Work* (ACM Press, Boston, USA, 1996) 248-257.

10. More information is available at: http://stonestreetone.com/bluetooth/products/bdk/ (2000).

11. K. Sikkel, A Group-based Authorization Model for Cooperative Systems, In *Proc. of ECSCW'97* (Kluwer Academic Publishers, 1997) 345-360.

12. A. Bullock and S. Benford, Access Control in Virtual Environments, In *Proc. of Symposium on Virtual Reality Software and Technology 1997 (VRST'97)* (Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland, 1997) 29-35.

13. U. Leonhardt, Supporting Location-Awareness in Open Distributed Systems. *Phd Thesis, Department of Computing, Imperial College of Science, University of London* (1998).

14. P. Bahl and V. N. Padmanabhan, RADAR: An In-Building RF Based User Location and Tracking System, In *Proc. of IEEE INFOCOM 200*, (Tel-Aviv, Israel, March, 2000) 775-784.

15. G. Sidler, A. Scott, H. Wolf, Collaborative Browsing in the World Wide Web, in *Proceedings of 8th Joint European Networking Conference* (Edinburgh, May 1997) 12-15.

16. S. Benford, C. Greenhalgh, G. Reynard, C. Brown and B. Koleva, Understanding and Constructing Shared Spaces with Mixed Reality Boundaries, in *ACM Transactions on Computer-Human Interaction*, 5 (3) (ACM Press, 1998) 185-223.

17. Aqtive Homepage: http://www.aqtive.co.uk (2001).