Sentinel: Towards an Ambient Mobility Network

Simon Harper
University of Manchester

Stephen Pettitt
Salford Electronic Consultants

Carole Goble
University of Manchester

May 30, 2003

Abstract

Purpose

We are concerned with aiding the mobility of visually impaired travellers around often complex and unfamiliar internal and urban environments. To do this we focus on a users interaction with ambient devices because these device types provide an easy entry point for visually impaired individuals to interact with their surroundings. By augmenting the physical environment with mobility focused ambient devices and making existing devices universally accessible our goal of easy, focused, and confident mobility can be achieved.

Method

We identify, through paper reviews and studies of empirical and anecdotal evidence, the social and technical problems that have so far barred consistent and cohesive development of an ambient mobility-network.

Results

We suggest that multi-model sensory-interaction with objects and assistive devices within an environment is the only way to accomplish easy, focused, and confident mobility for visually impaired travellers. We find that universal access to ambient devices does not exist when the user interface and the device functionality are conjoined. And we also suggest that this universal access will not occur if there are only benefits for one small minority user group.

Conclusions

We conclude that to assist mobility we need to provide universal access to objects and devices within the environment. Also, to support the mobility of visually impaired

travellers we must first support all travellers regardless of their mobility needs. And To accomplish this we must separate the user interface from the real purpose (the functionality) of the object / device.

Introduction

We are concerned with the mobility of travellers in complex and unfamiliar internal and urban environments. We liken the mobility of sighted travellers in these environments to the mobility of visually impaired travellers in all environments because of the similarities in the mobility problems both groups face [3, **?**]. This is especially the case when environments such as airports, bus or train stations, shopping centres, and unfamiliar cities are to be traversed. In such cases the traveller conventionally becomes disoriented from a lack of preview, knowledge of the environment, and orientation information and is consequently without the foundations on which to base mobility decisions. These decisions can be aided by systems that adapt to an individual based on their planned and completed journey, their mobility requirement, and the environment being traversed [9]. To address these requirements we suggest the use of ambient technologies to assist in travel, distributed computational support and large scale storage facilities for possibly complex routing tasks, and a method of enabling meaningful communications and data transfers between ambient devices developed by different manufacturers.
While complex environments and ambient (pervasive / ubiquitous) technologies to interact with these environments are a fairly new concept simpler ambient devices have been under development since the mid 1960s [2]. Devices placed in the environment and on users have been developed by researchers in the field of the mobility of visually impaired individuals, and in some instance have continued to full if limited implementations [4]. These devices have aimed to bridge the gap between visual and audible mobility information and as such have focused on sensory translation. While, most systems have mainly been concerned with large-scale environments centring on Global Positioning (GP) and Mapping technologies there have been very few systems concerned with mobility within small complex internal or urban environments and the general problem of interacting with ambient devices of any kind within an environment.

In This Paper...

In this paper we theorise that mobility models of visually impaired people are similar to those of all disoriented travellers handicapped by their environment and the static nature of objects to aid mobility (signs etc) within that environment. We also show that ambient devices created to specifically aid mobility and for more generalised purposes are not universally accessible even to the niche group they are intended to assist.
We identify, through paper reviews and studies of empirical and anecdotal evidence, the social and technical problems that have so far barred consistent and cohesive development of holistic systems for mobility and interaction with physical environments.
We then show how the novel use of new technologies, knowledge of mobility, and previous work on mobility aids can be used in combination to aid all travellers. We show

how these areas can help to create a heuristic to help solve the problems faced by all disoriented travellers, and that by describing mobility in a more logically rigorous way models to actively assist mobility can be created.
Finally, we propose the development of an ambient network of accessible devices which would include those specifically designed to increase mobility, in effect creating an ambient mobility-network. We achieve this by augmenting the physical environment with mobility focused ambient devices and making existing devices universally accessible, in this way our goal of easy, focused, and confident mobility can be achieved. Our system overcomes the problems faced by previous developments by supporting all travellers in complex and unfamiliar internal and urban environments using developed technologies like Bluetooth, Infrared, and GPRS and developing technologies like the Semantic Web for knowledge representation.

Problems

Human Factors

We propose that travellers in complex and unfamiliar internal and urban environments must contend with a lack of preview, knowledge of the environment, and orientation cues giving rise to feelings of confusion, disorientation, and frustration. This is because personal mobility is important not just for the implicit benefits of easy and accurate navigation and orientation, but also because it supports the less tangible factors of self worth, freedom, and independence [**?**].
Consider the problems facing a visually impaired traveller arriving for an appointment in an unfamiliar office. Firstly the traveller must find the correct building, and then the correct entrance. Once inside the problems increase, the correct company must be found, the user must orientate themselves to the environment and decide how to get to that company. They need to know what floor it is on, how to get to that floor, should they use the stairs or is there an elevator? How do they know if they are on the correct floor? Is there a reception and are they expecting me? How should I announce my arrival, and will someone come to collect me or will I need to make my own way to the office I require? Do I even know what office I require or do I just know the name of the person I'm having the meeting with? Which way should I go to the office and how do I know if I've reached it?
The journey is a fairly trivial one but the complexity of the questions, their sequence, and an answers ability to inform the formulation of the next question are important [1]. Looking at these questions we see that they are concerned with answering the questions 'where am I?', 'where can I go?', and 'what can I use to help?' and when examining this travel experience these questions are not just asked by visually impaired individuals but by all disoriented travellers [9]. This is important because as with everything else in life cost is a major factor in the provision of services, and the only way to increase the mobility of visually impaired travellers is to provide infrastructure that everyone can use.

Technical Issues

Ambient Devices

At it's simplest Ambient Computing[1] has the goal of activating the world by providing hundreds of wireless computing devices of all scales everywhere. Ambient systems stem from the belief that people live through their practices and tacit knowledge so that the most powerful things are those that are effectively invisible in use. Therefore, the aim is to make as many of these devices as possible 'invisible' to the user, where applicable. In effect making a system 'invisible' really means that the computer is highly imbedded and fitted so completely into its surroundings that it is used without even thinking about the interaction.

However, when a user interacts with this sort of system, the very interaction exposes the system (whether the user knows it or not) and on some level makes it visible. The system becomes more visible if it cannot be interacted with properly, and most systems expect user interaction to be on a uni-sensory level, mainly visual. We believe this interaction problem makes ambient devices highly visible therefore negating their purpose.

As we shall see in section many devices created to aid the mobility of visually impaired individuals overlap with the ideas proposed in the ambient field and therefore could be called ambient devices[2].

Attempted Solutions for Visually Impaired Travellers

While attempts at simple electronic solutions in the form of Electronic Travel Aids (ETA's) have been in development since 1897 more complex developments have only occurred within the last 50 years. Through the 1990s the focus switched from remote sensing to orientation, navigation, and location and as such a number of simplistic ambient devices were created [**?**]. These devices transmit a remote signal once a user - who must also carry a device - gets into range. While they do solve some problems they have a high infrastructure cost and are time consuming to place with and environment. Other systems have been proposed to overcome these costs which try to give accurate positional information based on electronic maps stored in general-purpose computers and using the Global Positioning System (GPS) to allow a fix to be made. Problems existed with the accuracy of GPS (50-100 meters) and so Differential GPS (DGPS - 6 meters) was brought online in 1998. DGPS systems can also suffer from signal loss within these types of environment, and the costing for such devices would be high therefore precluding uptake by occasional users [**?**].

Waypoints are often used within a journey and are mostly implicit as signs, junctions, or landmarks however explicit devices have been created so that users can tailor journeys and descriptions, non-descript areas with few implicit waypoints can be augmented, and so different types of information can be passed to the user. These devices have since become known as talking signs, audible beacons, or smart signs (although 'smart' may be a somewhat of a misnomer as the present 'intelligence' of the sign is limited)

[1]also known as ubiquitous or pervasive computing

[2]even though they where proposed and prototyped long before the term 'ambient' was first coined

[**?**].
Audible traffic signals (ATS) are one of the commonest forms of waypoint devices although not intended to be so. ATS are used to allow visually impaired people to differentiate between certain road conditions within an environment. These signals are intended to aid travellers in crossing a road or move around a pedestrian walkway associated with a road [**?**].
Beacon systems work by using infrared, radio, and inductive or electrostatic technologies to transmit information between devices carried by the user and a device fixed within the environment. When the user moves into range either the beacon - within the environment - or the user device can give feedback. Beacons are often placed at strategic points - say on a platform or railway concourse - to augment implicit waypoints or create additional explicit ones, and the pools of mobility information around then are known as 'information islands' [4, **?**].
Although beacons and other types of place marking devices give some sort of information based on their location or the users proximity very few actually give more complex information, or tailor their output to the specific user journey. This information would include spatial, temporal, and planning information such as bus timetables, next bus arrival information, information about the stops being passed on a form of public transport, etc. [**?**].
Unfortunately each system only addresses a part of the mobility process and few recognise that combinations of technologies are more effective than one 'catch all' system. The systems do not take a holistic approach to mobility and are mainly based on adhoc ideas as opposed to rigorous models and do not provide gateways to other more comprehensive information and resources. This means that they have inbuilt flaws.

Problem Summary

We can see that our problem domains run along six distinct tracks:

Human *All* travellers move around an environment by answering the questions 'where am I?', 'where can I go?', and 'what can I use to help?'. The ease of movement is determined by the complexity of the questions, their sequence, and an answers ability to inform the formulation of the next question. These questions have not yet been answered with regard to the feedback given by current devices.

Single Focus Systems Systems are focused on only providing mobility information for one user modality (visual impairment). This means that they are not useful to many sections of society who do not need mobility information but may take advantage of other benefits like language translation of signs or 'value-added' features like automatic check-in in airports etc.

Socioeconomic Cost and community cannot be ignored because previous devices have been expensive, placing them in the environment has taken time, and these devices have only been created for very specific sections of the community, making them costly and unattractive to agencies wishing to place them.

Closed Systems Previous attempts to address mobility issues have failed to have large scale appeal and therefore a large scale implementation because of their bespoke nature. Systems which are bespoke cannot share information because they rely on bespoke syntax and grammar – with the same interpretation of the meaning of that grammar. They need a separate user device to access each mobility system because they use different transmission methods and are reliant on specific hardware for data access making the systems unusable.

Resource Limitations Small devices, embedded systems, and imbedded systems normally have power and storage limitations. This means that they may not be able to provide full, meaningful, or accurate information.

Static Systems Systems previously investigated do not provide dynamic or tailored information with regard to an individual's personal journey and therefore mobility. This dramatically reduces the quality of the mobility information given.

In Section we suggest solutions for all these problems and therefore move toward our goal of increasing the mobility of visually impaired travellers.

Discussion

Addressing Human Factors - Encoding Mobility Information for Better HCI

In many respects focusing on navigation (and some orientation) leads to confusion, because navigation and orientation are only parts of a picture of mobility and are by no means the whole story [5]. In fact orientation and navigation are only high level classifiers to a set of mobility techniques, acted upon mobility objects, conforming to mobility principles. These objects, techniques, and principles fit together to form a coherent mobility model and the relationships between these mobility items can be used such that a cohesive view of the mobility information, tailored to the needs of a visually impaired user, can be supplied (see Figure 1).

Mobility objects such as cues, obstacles, out-of-view items, and memories, may or may not be present within a local environment. These objects can be identified by using mobility techniques upon them (these techniques can be encoded within mobility instruments like probing with a cane) to decide their presence, type, and the course of action to take, when encountered. Finally, mobility techniques conform their actions to mobility principles to enable them to accurately relate relevant information to the visually impaired user.

Mobility Principles

In [8] we presented the following principles, refined here, so that we may later integrate them into our developed system.

Information Flow Visually impaired travellers use simpler information more frequently than complex information.

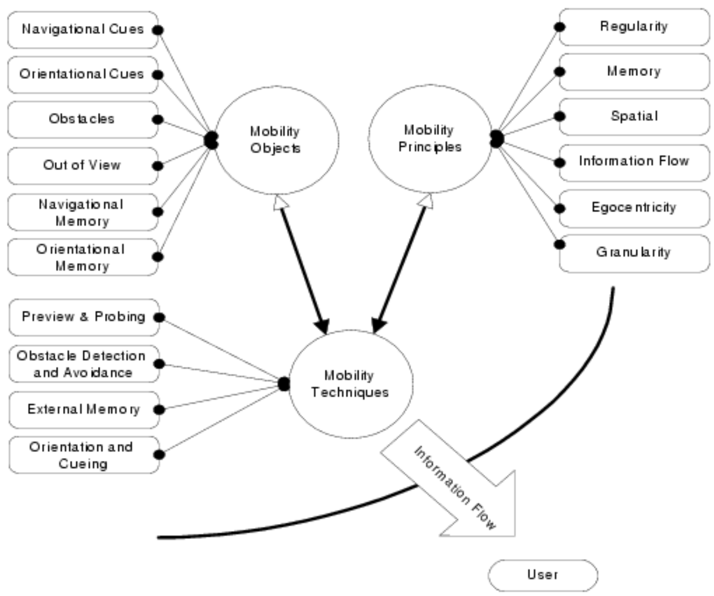

Figure 1: Combined Objects, Techniques, and Principles

Granularity Routes are broken into a greater and more complex number of stages than by sighted people, route descriptions are more complex and in finer detail, and obstacle information is more specific.

Egocentricity Descriptions of distance and journey, route and survey knowledge, become associated with the traveller and not the environment.

External Memory and Mental Maps Visually impaired people have an increased use of cognitive or mental maps of route and survey knowledge. The use of hearing is increased and movement is focused on getting to a point.

Regularity and Familiarity of Environment Travel is normally confined to areas with regular features, and a traveller would normally only travel unassisted in areas that were familiar to them. This is an issue of predictability.

Spatial Awareness Visually impaired people find it difficult to track their position against spatial information.

Mobility Objects

Mobility objects were addressed as specific instances within our initial mobility framework in our early work (street corners, lamp-posts) [8, 9] however to be truly useful more generic terms need to be used and definitions added. This means that a firm set of objects can be created and these objects can then be accurately decoded by mobility techniques. Both preview and learnt knowledge exist in the environment as cues, and external to the environment as part of either internal or external memory such as maps and descriptions. Using this information it is therefore possible to group mobility objects within the virtual environment into a number of roles and sub-roles.

Cues Cues are objects or combinations of objects that a traveller actively users to facilitate their onward journey.

  Navigational Cues answer a traveller's question 'Where can I?' and could be for example a signpost.

  Orientational Cues answer a travellers question 'Where am I?' for example a unique combination of objects.

Obstacles Obstacles are objects that inhibit a users onward journey, however under certain conditions (such as familiarity with the object) an obstacle can change to a cue.

Memories Memories are either internal or external, and contain the knowledge that enables a traveller to decide if the object is a cue or an obstacle.

  Navigational Memory answers a travellers question 'Where can I?' for example the results of a search on a help system.

  Orientational Memory answers a travellers question 'Where am I?', for example a site map on the world wide web.

Out-of-View Out-of-view objects address the concept of preview. Valid travel objects can be present but out-of-view. They are therefore not obstacles because they do not inhibit travel but they are not cues either because they do not facilitate travel until they come into view.

Mobility Techniques

Mobility Techniques act enacted upon mobility objects, and as such form the basis of any implemented solution. These techniques are used to both decipher the mobility objects within the environment, and to implement appropriate actions to make then useable by visually impaired users.

Preview and Probing : In blind mobility, a lack of preview of upcoming information is one of the major issues to be addressed. Consequently, preview is considered to be a primary task for good mobility and is achieved by probing the environment. However, in all cases the 'probing' task is used such that a limited amount of preview is given, complex information has been found not to be easily assimilated by non-visual means. Therefore, too much information was found to be as unhelpful as too little.

Obstacle Detection and Avoidance : Blind mobility solutions exist to accomplish obstacle avoidance and are based on enhancing preview (as above), planning to avoid obstacles through knowledge of the environment (external memory), and on navigating oneself around obstacles based on encounters with those obstacles within the environment [7].

External Memory : Planning to avoid obstacles suggests a certain knowledge of the environment at hand. This knowledge may be in the form of tactile maps, audible route descriptions, tape guidebooks etc. However, in all cases the desired effect is to transfer knowledge (external to the recipient) to the traveller such that a better understanding of both the route and destination is achieved. While it is true in many cases that the route and destination are not always known at the outset, the related travel information may be used in transit as the goal becomes more evident.

Orientation by Cueing : Orientation or 'where-ness' (detecting cyclic behavior, direction and distance) is important in blind mobility as it enables travellers to navigate with some degree of accuracy. However, visual cues provide implicit orientation information. Therefore, the environment must be updated such that cues are provided in an appropriate manner, giving explicit orientation information, such that navigational information can also be detected.

We can now make some assumptions about disoriented travellers based on the mobility habits of visually impaired travellers and by encoding these assumptions into new mobility systems free and easy movement for all can be achieved.

Universal Ambient Networks - Addressing Single Focus Systems

Through our work on the project we have become aware that single focus systems exist because the user interface and the functional parts of an ambient device are conjoined such that just one user modality is supported and one system functionality is addressed. Consider the example of a lift, in which a dyslexic user may have difficulty choosing floors and accessing lift functions because the lift user interface (in this case an LCD display) does not support their needs. Or the problem of how to notify a deaf person working in their office that there is a fire when the user interface to a fire alarm is only a siren.

We decided to take a lesson from conventional Human Computer Interaction (HCI) design heuristics which supports a separation between the user interface and the code that implements the functionality of the application[3][6]. By this separation universal access to applications can be accommodated because the interface can adapt to the user without the need to change any part of the other functionality.

Simply we offer the argument that this should also be the case with ambient or ubiquitous devices. However, we extend this rubric further by separating the ambient device into a computational device (within the environment) and a user interface device (specific to the user). In this way human computer interfaces within ambient systems can cater for multi-model sensory user interaction and multiple device / system functionalities.

[3]This is ably demonstrated in the Java (JFC-Swing) Graphical User Interface (GUI) implementation which allows a different 'Look and Feel' to be used over different applications.

Addressing Socioeconomic Factors

By addressing the issues of single focus systems in section we also answer the socioeconomic problems posed in section . Creating a system that will interact with all ambient devices in a way any user can access means that our 'Ambient Mobility Network' is supported as a subset of a 'Universal Ambient Network' by default. If the infrastructure is created to aid all interaction modalities across all possible devices usages, the small additional cost becomes economic to installation agencies and technology developers.

Open Systems - Addressing Issues in Closed Systems

We will enable our system by describing the type and capabilities of the device, by describing the environment and the information needed to be mobile within that environment, by separating the data structures from the data, and by describing all data elements by using ontologies. We wish to enable all devices to share information based on inferences present within the documents in effect we creating a 'semantic web of ambient devices'. These devices will use the ontology languages that underpin the semantic web to communicate more effectively.
We combine eXtensible Markup Language (XML) information with descriptions of the meanings associated with the system. This means that the dynamic nature of the intended system can be supported because there is no direct tie between the information output by the fixed location ambient device and descriptions of the the environment.
Finally, most systems define their own bespoke communication systems and cite specific devices in their specification. So we fix on the de-facto standards of Bluetooth / IrDA, IR-RS232, and GPRS[4] or HTTP[5].

Additional Resources

The User device may be a PDA or mobile phone however the computational and storage resources on either will be limited. Small devices suffer from a lack of computational resources and physical storage so we solve this problem by using GPRS and HTTP to harvest the power of the Web. Computational tasks and storage resources requests can be transferred to the Web probably using remote procedure calls (RPC) to take care of the real processing. If however, the device has adequate computational and storage resources then the processing can occur, and data can exist, on that device.

Dynamic Systems - Making the User Interface the Hub

In previous sections we have suggested:

- Separating the user interface from the ambient device
- Making the system open
- Allowing connection to more computational power and larger storage

[4]for web connections by mobile phone
[5]for web connections over Wireless Networks

In effect we change the nature of the system from static to dynamic. This means that the user device can be the hub of the interaction and therefore use additional information to support dynamic interactions.

Sentinel: Proposing an Ambient Mobility Network

Sentinel is based on the premise that travellers in unfamiliar and complex internal and urban environments need help when traversing such environments. This help should take the form of a mobility interface (called the Used Device) carried by the user that interacts with ambient mobility devices within the environment.

The user device will be a software-enhanced personal consumer electronic (like a mobile phone or PDA) so that the occasional traveller can also make use of the system. This also facilitates the devices expansion into a generalised ambient technology interface.

Devices in the environment should be both cost effective and implement-able by many different suppliers. We accomplish this by creating solutions to aid everyone, we build complex and expensive devices to transmit complicated and verbose information however each installation only needs 2 or 3 of these, and simple cheap devices for extensive use within the installation. We also use common technologies and leverage the technologies already on devices (like mobile phones and PDAs) to further reduce costs.

While it is intended that this system can aid all users in travelling through complex environments like airports and rail terminals it may also be used to augment the whole experience by providing additional services like light security features and automated check-in facilities. As such our system is divided along three avenues:

Physical Devices The system can be described in terms of four physical devices:

- **User Interface Device / Computational Hub** This device joins the following disjoint ambient devices into a cohesive mobility system. By processing descriptions of devices within the environment and enabling access to the larger storage or computational resources found on the web complexity can be moved from the ambient devices to the user device. This means that the interface can also be moved from the ambient device to the interface device. In effect ambient devices have a limited real world presence and provide a real world hypertext anchor to virtual world resources.
- **Complex Ambient Device** A device that stands at the entrance of an area and transmits the Universal Resource Identifier (URI) of a hypertext document, which shows the relationships and abilities of the simple devices within the area covered.
- **Simple Ambient Device** These smaller devices just transmit their identities via simple methods like infrared. In this way their location and their relationships can be inferred when analysed in conjunction with the XML document transmitted by a complex device.
- **Gateway Ambient Device** This type of device is directly connected to larger storage or computational resources, like timetables and calender for instance. Access to these type of devices would not normally be required as

their hypertext description would link them to increased resources through the user interface device / computational hub. However, they are useful if there is any degree of real world control required, like changing the temperature on a heating system that was not networked.

Describing Information, Control, and Functionality We describe the information, control, state, and functionality of our system using eXtensible Markup Language (XML) descriptions and ontologies (stored as part of the semantic web). This means that dynamic descriptions of the local area can be created and disparate equipment manufacturers can use one cohesive structure to describe a device.

Software Resources Creating a fixed application to control these resources is specific to the device in question, however specifying an interface that all devices should provide does enable all developers to create devices for the system, much like the Java Beans Interface enables creation of components that can all work and interact together but are created separately. In fact because we say that ambient devices are just components of an ambient network (a great distributed network of devices) flexibly reacting and forming a specific computational resource based on a users requirements. This scenario suggests that interface specification is the most appropriate outcome.

The synthesis of these three areas create an Ambient Mobility Network which can be used to guide us to our destination. This is because we now have access to an increased richness of information stored as part of the building infrastructures, computational resources for route planning and other complex tasks on the Web, and mapping knowledge of the environment our location and orientation within it generated at the computational hub from semantically correct descriptions. Finally, we can make use of all this information because the interface is specifically tailored to the user to give output and receive input in an appropriate way augmenting a users needs and their perception of reality.

Again consider our visually impaired traveller arriving for an appointment in an unfamiliar office. Our user walks through the entrance to an office building. The Bluetooth device at the entry transmits information about the environment, in the form of a URI pointing to an XML document, to a Bluetooth enabled mobile device carried by the user (possibly a mobile phone - currently the most ubiquitous mobile device). Optionally the phone may transmit user information (for a ‘light’ security check), the buildings appointment system may be accessed and a route to the destination office generated if appropriate. The user then starts the journey within the ambient environment, the phone receiving infrared signals from small cheap devices - normally located on the ceiling - sending at a minimum their identification code. This code along with the stored URI is then sent (via GPRS) to a the web and a description about the location is sent back to the phone. This process involves the acquiring of mobility information and processing it with a history of previous ambient interactions. This means that the journey will be dynamic and will change based on the required destination (if set), the devices already encountered (so direction and distance are accurate), and the type of device encountered. Each device can be from a different supplier (as long as it uses our mobility ontology) this means that Otis may create an elevator device, Thorn may create an enhanced mobility fire exit system, and the building may use bespoke devices to mark up the physical locations of offices.

Summary

By using ambient technologies, models of the mobility of visually impaired travellers, the Web and Semantic Web, and previous electronic solutions we will attempt to solve both the human and technical problems associated with disoriented travellers in unfamiliar and complex internal and urban environments. Our system will address duel sets of problems associated with both good general mobility and those failings found in previous systems by providing a dynamic, open, appropriate, and Personal (egocentric) system to enhancing mobility. Our system will take into account the environment being traversed, the individual feedback required, the purpose of an individuals current travel task, and the multitude and types of devices supplied by possibly several different companies, and for a number of different travel purposes.
We intend to prove our concept by delivering a working mobility interface for both sighted and visually impaired users. We shall also deliver a set of semantic descriptions[6] for data exchange and an abstract Java interface for both ambient device and user interface device.

References

[1] D. Appleyard. Notes on urban perception and knowledge. In R. M. Downs and D. Stea, editors, *Image and Environment*. Edward Arnold, USA, 1973. ISBN 0713157259.

[2] T. A. Benham. Electronic travel aids for the blind. *Human Factors in Technology*, 1963.

[3] B. L. Bentzen. Orientation aids. In R. L. Welsh, editor, *Foundations of Orientation and Mobility*, pages 291–355. AFB Press, New York, USA, 1979.

[4] P. Blenkhorn, S. Pettitt, and D. G. Evans. In *Proceedings of the Eleventh Annual International Conference on Technology and Persons with Disabilities*, Los Angeles USA, March 1996.

[5] M. Brambring. Mobility and orientation processes of the blind. In D. H. Warren and E. R. Strelow, editors, *Electronic Spatial Sensing for the Blind*, pages 493–508, USA, 1984. Dordrecht, Lancaster, Nijhoff.

[6] A. Dix, J. Finlay, G. Abowd, and R. Beale. *Human Computer Interaction*. Prentice Hall, London, UK, 2 edition, 2002.

[6] XML Schema / DTD

[7] C. Goble, S. Harper, and R. Stevens. The travails of visually impaired web travellers. In *Proceedings of the 11th ACM Conference on Hypertext and Hypermedia*, pages 1–10, New York, USA, 2000. ACM Press. Towel Project (http://www.man.ac.uk/towel) - Winner of the Doug Engelbart Award for Best Paper at ACM Hypertext 2000.

[8] P. Green and S. Harper. An integrating framework for electronic aids to support journeys by visually impaired people. In *International Conference on Computers Helping People with Special Needs*, 2000.

[9] S. Harper and P. Green. A travel flow and mobility framework for visually impaired travellers. In *International Conference on Computers Helping People with Special Needs*, Germany, 2000. OCG Press. POLI Project (http://www.man.ac.uk/towel) - under the auspices of the UNESCO.