A PATHWAY TO INDEPENDENCE: WAYFINDING SYSTEMS WHICH ADAPT TO A VISUALLY IMPAIRED PERSON'S CONTEXT

Nicholas A. Bradley; Mark D. Dunlop
University of Strathclyde, UK

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ABSTRACT

Despite an increased amount of technologies and systems designed to address the navigational requirements of the visually impaired community of approximately 7.4 million in Europe, current research has failed to sufficiently address the human issues associated to their design and use. As more types of sensing technologies are developed to facilitate visually impaired travellers for different navigational purposes (local vs. distant and indoor vs. outdoor), an effective process of synchronisation is required. This synchronisation is represented through context-aware computing, which allows contextual information to not just be sensed (like most current wayfinding systems), but also adapted, discovered and augmented. In this paper, three user studies concerning the suitability of different types of navigational information for visually impaired and sighted people are described. For such systems to be effective, human cognitive maps, models and intentions need to be the focus of further research, in order to provide information that is tailored to a user's task, situation or environment. Methodologies aimed at establishing these issues need to be demonstrated through a multidisciplinary framework.

INTRODUCTION

It is estimated that 7.4 million people in Europe are visually impaired (1). Enhancing and maintaining the independence of this community has in recent years caused an escalation of research and development into orientation and wayfinding technologies. For instance, ETAs (Electronic Travel Aids), such as obstacle avoidance systems (e.g. Laser Cane, Kay (2)) and ultrasonic obstacle avoiders have been developed to assist visually impaired travellers through the immediate or local environment. Whereas, navigation through the distant environment has been addressed by Global Positioning Systems (GPS) and Geographical Information Systems (GIS), e.g. the MOBIC Travel Aid (Strothotte *et al* (3)). Radio Frequency (RF) beacons have also been used to provide assistance for both local and distant navigation, as well as for navigation through outdoor and indoor environments (Kemmerling & Schliepkorte (4)). Other indoor technologies which depend on relative positioning include sensors such as digital tags, active badge, accelerometers, temperature and photodiodes.

By enriching the visually impaired traveller's knowledge of the local and more distant environment, these technologies have the potential to facilitate them to unknown destinations along unfamiliar routes which, until now, has either been impossible or considerably vexatious and problematic. These technologies discover aspects of the user's context, which are used to provide feedback on navigational assistance or obstacle avoidance. However, these are usually designed specifically for local or distant navigation within indoor or outdoor environments and can rarely be integrated. A harmonisation of technologies therefore becomes apparent.

The essence of 'context-aware computing' exemplifies this concept. By using a combination of technologies, which discover and take advantage of a user's context, a context-aware application can analyse and predict what information might be relevant and useful to users depending on their task, situation or environment, thereby minimising the need for traditional user-interface interaction. For this to be achieved, requires an understanding of what dimensions make up a user's context, in particular to the processes involved in constructing cognitive maps and models of the environment (an issue given limited appreciation within current research).

Despite the recent technological advancements of wayfinding technologies for visually impaired people, there is still a lack of research which integrates and utilises principles and methodologies of

Human-Computer Interaction (HCI). To illustrate, (i) Maeda *et al* (5) describe how their evaluation of a GPS-based guidance system involved asking sighted people to wear blindfolds and 'behave as if temporarily blind', (ii) Golledge *et al* (6) describe how existing computing travel databases do not provide information which would be useful to visually impaired people, and (iii) Franklin (7) states how, in relation to speech output, there are difficulties in interpreting spatial relations from common speech (natural language). In addition, Kitchin *et al* (8) describe how 'more research is needed to more fully understand the "mental landscapes" of people with blindness or visual impairments'.

This paper firstly describes three of our user studies concerning the suitability of different types of navigational information for visually impaired and sighted people. The second part discusses the required focus of further research, with an emphasis on the capabilities of mobile context-aware computing for meeting the requirements of the visually impaired community.

PREVIOUS RESEARCH STUDIES

Our first two studies concerned an investigation of how sighted and visually people describe a route (Bradley & Dunlop, (9, 10)). This provided an insight into how people use clues in the environment to help them navigate and orientate. Collectively, the route descriptions from each participant were used to identify eleven categories of utterances relating to the environmental context: *directional* (e.g. left, right), *structural* (e.g. road, monument), *textual-structural based* (e.g. Border's bookshop), *textual-area/street based* (e.g. Sauchiehall Street), *environmental* (e.g. hill, river), *numerical* (e.g. second, 100m), *descriptive* (e.g. steep, tall), *temporal/distance based* (e.g. walk until you reach…), *sensory* (olfaction/hearing/touch) (e.g. sound of cars passing), *motion* (e.g. cars passing, doors opening), and *social contact* (e.g. asking people or using a guide dog for help). Accumulated tallies were solicited for each contextual category across each participant and group.

Both sighted and visually impaired participants varied within and between groups. Within the sighted group, younger participants used more textual-structural information (mainly names of bars, restaurants) than textual area/street information, whereas this trend was reversed for older participants. Within the visually impaired group, there were differences between the amount of local and distant information used. When comparing both sighted and visually impaired groups, visually impaired people used considerably more contextual information generally and used information, not used by sighted participants, within *sensory*, *motion*, and *social contact* categories.

Our third study* involved calculating proportions, from our first two studies, of information used across all contextual categories for each group. These were used to design two sets of messages, which were presented to sighted and visually impaired participants as they walked to four pre-determined landmarks. Messages given to two of the landmarks were derived from sighted participants descriptions (i.e. more textual-structural and textual-area street information), whereas visually impaired participants' descriptions were used to give messages to the other two landmarks (i.e. more sensory information). By using an objective and subjective assessment, it emerged that visually impaired people rated their mental workload lesser when presented with information from visually impaired participants' descriptions. This was also reflected in fewer deviations from the route and quicker times to complete those stages. Sighted participants, however, found this information to cause a higher mental workload.

In conjunction to the three user studies, we conducted a multidisciplinary literature review* on the notion a 'context', specifically in relation to context-aware applications/systems. Proposed context models for psychology, linguistics and communication, and computer science, combined with a multidisciplinary model, revealed that the relationship or interaction between internal (e.g. cognitive maps/models) and external contexts (e.g. other people, mobile device, etc.), need to be addressed further with respect to how they influence our decisions and the process by which we interact with our environment. Temporal changes and notions of relevancy are intrinsic factors in this understanding.

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* Described in full papers currently under review.

THE REQUIRED FOCUS OF FURTHER RESEARCH

Context-aware computing offers a great potential to visually impaired people, not just for navigation but also to facilitate them for other potential needs or requirements (informing them of the nearest café, post office, etc.) To illustrate, Pascoe (11) proposes four generic categories of context-aware capabilities, as shown below (a description of how they could apply to visually impaired people is presented):

1. *Contextual sensing*: The context-aware application simply detects various environmental states and presents them to the user. A GPS receiver, for instance, takes in a location, compares it to a digital map, and then informs the user of their location.
2. *Contextual adaptation*: The application leverages contextual knowledge by adapting its behaviour to integrate more seamlessly with the user's environment. For instance, by linking with a server containing locations of excavation work, the context-aware system could adapt the original route path in order to navigate around potentially problematic areas.
3. *Contextual resource discovery*: The application discovers other resources within the same context as itself and exploits these resources while they remain in the same context. Bus and train timetables, for example, could be downloaded and then used to inform the user how long they have to wait for the next bus.
4. *Contextual augmentation*: The application can augment the environment with additional information. Visually impaired travellers, for instance, could leave messages at particular locations in the environment for other visually impaired people (e.g. information about potential hazards), thereby creating a community of users sharing personal experiences.

It should be noted that current wayfinding technologies and systems for the visually impaired largely use just contextual sensing. Context-awareness therefore extends the possibilities that could be made available, allowing applications to provide more useful and pertinent information.

Ultimately, however, context-aware systems will only be useful if they manage information derived from those sensing technologies in a way that is compatible with the users cognitive map, model and/or intentions. Jonsson (12), for instance, describes how we develop cognitive maps in order to navigate; a process which involves encoding the location, attributes and orientation of landmarks in the environment using a variety of human sensory sources (i.e. visual, olfaction, haptic and auditory). A cognitive map, however, for one particular area can change depending on the (i) time of day (i.e. day/night), (ii) season (e.g. summer vs. winter), and (iii) direction of travel (travelling the same route forward or back). It is therefore reasonable to assume that visually impaired people would develop different cognitive maps or models based upon additional factors such as differing levels of sight or whether they are adventitiously or congenitally blind. Kitchen (8) indicates that there needs to be 'an effective and reliable assessment of the spatial knowledge structures (or cognitive maps) of visually impaired people in order to comprehend their unique environmental interaction processes'. Essentially, a multidisciplinary approach to context-aware interface design needs to taken. An understanding of (i) human cognition is essential, as described, (ii) computer science enables the technological possibilities to be realised, and (iii) linguistics and communication enables designers to establish methods of communicating contextual information to the user.

CONCLUSIONS

Previous research, coupled with the findings of our studies, suggest that more HCI research is required into how human variability influences usability, in particular how differences in visual impairment affect the processes by which knowledge is derived from the environment to construct cognitive maps/models and consequently how this affects their behaviour or interaction with the environment. Technologies must be used to sense, not just the environment, but also both the user's cognitive context and the interaction of both external and cognitive worlds. For this to be achieved, there needs to be an amalgamation of sensors which are actively managed through context-aware applications; the design of which must be a filtered through a multidisciplinary framework. By doing so, context-aware systems will facilitate visually impaired people through unknown territory, enriching both their knowledge of the environment as well as enhancing their independence.

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BIOGRAPHICAL

Nicholas A. Bradley: In October 2001 Nick started a PhD in Human-Computer Interaction (HCI) at the department of Computer and Information Sciences, Strathclyde University. Before joining Strathclyde, Nick graduated with a BSc honours degree in Ergonomics from the Human Sciences Department of Loughborough University in July 2001, where he was also awarded the Departmental Prize for Ergonomics. During his undergraduate degree he spent 15 months working for a Human Factors and Ergonomics consultancy in Glasgow, called Nickleby HFE Ltd, as part of a student placement. Nick is a member of the Glasgow-based interactive systems (GIST) group and is a Student Representative of the Events Committee of the British HCI Group.

Mark D. Dunlop: Since August 2000, Mark works as a Senior Lecturer at the department of Computer and Information Sciences, Strathclyde University. Before joining Strathclyde, Mark worked at the Danish Centre for Human Machine Interaction, based in its site at Risø National Laboratory, near Copenhagnen. Previous to Risø, he was a lecturer in Computing Science at the University of Glasgow, where he worked closely with the interactive systems (GIST) and IR groups. He has co-organised two meetings of the International Workshop Series in Mobile HCI: Mobile HCI 01, held at IHM-HCI 2001, and Mobile HCI 99, held at INTERACT '99 and is currently a member of the board of Personal and Ubiquitous Computing. His research interests lie in the area of usability of mobile devices and their evaluation.