Accessible Interface Design for Domestic Pervasive Environments: A Preliminary Investigation into the Requirements of the Visually Impaired

Michael Quantrill
Dept of Computer Science
Loughborough University
Loughborough
Leics, LE11 3TU

Alan Chamberlain
Dept of Computer Science
Loughborough University
Loughborough
Leics, LE11 3TU

Roy S Kalawsky
Dept of Computer Science
Loughborough University
Loughborough
Leics, LE11 3TU

Abstract: This paper outlines an initial study and findings, relating to the requirements and opinions of visually impaired users regarding their use of appliances and services in the home, and their opinions on aspects of domestic pervasive environments. Twenty-nine participants took part in the study and all were registered blind or partially sighted. We discuss the context of the study and the implications for accessible interface design. The preliminary findings suggest that a majority of visually impaired users embraced the concept of a domestic pervasive environment, and could see it adding to their quality of life and independence. The study was supported by the RNIB (UK,) and VISTA (Leicestershire UK).

1. Introduction

Pervasive computing is a concept originally proposed by Mark Weiser in 1991 [Weiser 1991]. Weiser proposed the notion that computing move away from the desktop and into the spaces we live and work. In pervasive systems, interaction using speech, gesture, gaze, and sensing mechanisms has moved away from the desktop interaction paradigm. This is often referred to as "natural interaction" [Abowd and Mynatt, 2000].

Researchers have begun to investigate the possibilities for enabling pervasive technologies in domestic environments [Kidd et al. 1999, Mozer et al. 1995]. Enhanced control of the home environment is possible along with increased communication services and access to entertainment and media [Spinellis 2003, Brummit et al. 2000].

The increasingly possible interconnectivity of devices that can provide pervasive computing, and the added value services that industry is seeking to provide for people in their homes is leading an exciting development in home services [Spinellis 2003, Brummit et al. 2000, Kidd et al. 1999]. However, there are dangers that the increasing numbers of devices and services could lead to confusion for home occupants due to the number of such devices and services, and the complexity that interconnection imposes [Edwards and Grinter 2001, Norman 1976, Miller 1956]. Such a problem is particularly acute for individuals with special needs, such as the elderly, disabled or visually impaired. For visually impaired individuals, for instance, simply accessing media services is a difficult task in itself, which can lead to exclusion. When media services can be combined with other information systems running concurrently, then there is a significant challenge for users with a lack of sensory cues [Stephanidis and Savidis 2001].

Support for individuals with special needs is often considered after a technology or service has been developed for individuals with no particular problem of access to such technologies [Emiliani 2002]. This paper seeks to promote consideration of individuals with special needs now, as the technologies and applications are in the first stage of developments in labs and manufacturers' research centres.

We report on recent and continuing work investigating user interface design in domestic pervasive environments. The aim of the research is to understand the implications for interaction in such environments. Many homes are multi-occupancy, therefore the interaction requirements specific to each occupant have to be considered when designing and developing user interfaces. Effectively supporting diverse user groups requires a deep understanding of each group's interaction requirements. These requirements must then be set against the interaction opportunities afforded by the technologies and services.

Section two presents in more detail the concept of a domestic pervasive environment. Section three outlines our approach to the problem of accessibility within domestic pervasive environments by focusing on visually impaired communities. Section four details a survey of the how visually impaired people currently use home appliances and their aspirations for new domestic technologies. Section five discusses preliminary results from the study. Section six concludes and discusses further work.

2. Domestic Pervasive Environments

The concept of a domestic pervasive environment is possible for a number of reasons.

- Advances in technologies are enabling integration of devices, services and applications [Brummit et al. 2000]
- Manufacturers and service providers are developing integrated entertainment and communications appliances and services [Spinellis 2003]
- Industry standards are being proposed to support integration at various levels within the device to service stack [OSGI, HAVi]
- Active sensing is possible and research is defining frameworks to design and test many aspects of sensing technologies and their implications. Active sensing enables some system automation and adaptability [Gellerson et al. 2002, Bellotti et al, 2002]
- Novel interfaces and interaction strategies are being developed [Hindus et al. 2001, Kidd et al. 1999]

There are two key aspects that form the core of domestic pervasive environments.

Device Connectivity and Environmental Control

Devices, appliances and data streams can be connected to the network, either permanently or temporarily. Sensors and small network devices are attached to many objects in the home, such as lights, meters, doors and windows. Network devices are also attached to appliances such as washing machines, cookers, toasters, fridges, stereo systems and visual media devices. Occupants and visitors of the home can have small identity announcing devices associated with them, either carried explicitly or as part of another carried device, or worn as part of their clothing. Video Cameras can be placed at entranceways and integrated with the doorbell. Cameras can also be placed inside the home, particularly in support of care management for the elderly or infirm. Control of the home climate is possible as heating, air conditioning and ventilation can be controlled or adapt to certain conditions. The home can also be configured to operate in modes, such as homework mode or relaxation mode or movie mode. Modes are particular configurations of environment and device settings, such as lighting levels, whether blinds are open or closed, volume levels, and type of music.

3. Supporting Diverse User Communities

New technologies, including new configurations of current technologies, are being placed in a context where they impact directly on the lives of all occupants of a home. Each person will access some or all parts of a domestic pervasive system as part of their everyday lives.

The home is a place where people of all abilities, skills and requirements live. These are spread across people of all ages, from young children to the retired and elderly. Home occupants could have a sensory motor problem or could have learning difficulties. Declining cognitive abilities due the effects of the aging process could also manifest themselves. An additional complicating factor is that people change, sometimes within a few minutes or hours and sometimes over a longer period of time. For instance a minor and transient health problem could affect their ability to interact with devices and services in the home for a short time. This could be either physically or mentally, perhaps because their movement is temporarily restricted or their cognitive processes are weakened, such that some tasks that were easy to perform could become troublesome. Another person could have greater sensory impairment with a more serious or longer-term illness, or they may have had an accident, and now their movement is restricted. In other cases individuals with long term illness or permanent disability could have good days and bad days where their ability to effect proper control of technologies varies wildly between comfortable and effective to difficult and frustrating. This means that a set of interaction strategies for a given set of people will not be static. Interfaces within a domestic pervasive environment must therefore support interaction for a diverse user population and incorporate the ability to adapt to the changing needs of the people that will use them.

In order for effective interfaces and interaction methods within the home to be developed the diversity within the user population must be addressed in order to prevent exclusion. The inclusion of requirements for many differing groups with diverse needs at the beginning of the design phase can negate costly adaptations and specialist bespoke solutions that would otherwise be needed at a later date [Emiliani 2002].

Our initial approach to addressing the problem of accessibility within domestic pervasive environments is to focus on visually impaired communities. Addressing the needs of visually impaired people mandates consideration of non-visual modalities, which include speech, audio, tactile and reduced information content through magnification. Interaction strategies in pervasive systems in general seek to use such modalities to offset the highly focused aspects of vision, which can be overloaded due to the nature of such systems. Consequently, interfaces for visually impaired users will also contribute to general non-visual interaction research in pervasive systems. Another benefit of investigating the needs of visually impaired communities is that it addresses the demographic changes that are resulting in a higher proportion of older people in the general population, with the consequent increase in sight defects due to the effects of the aging process [Marcus 2003].

In order to address the accessibility issues particular to visually impaired communities within domestic pervasive environments, an understanding of how people with a visual impairment currently manage their interaction with appliances and services within their home is needed. In addition to this the relevance of aspects of domestic pervasive technologies to individuals with a visual impairment should be established.

4. Survey of Visually Impaired Communities

Currently there are no surveys that capture the views of visually impaired people regarding their use of entertainment, utility and control services in a domestic pervasive environment. There is work that is related. Massoff [2002] concentrates on the social issues of living with a visual impairment in both the home and in other everyday contexts. Schuchard and Fletcher [2002] report on the relative importance of visual function, and eye movement ability on everyday function and quality of life. However, these studies do not provide sufficiently focused data to adequately inform the development of interaction strategies for visually impaired users of domestic pervasive systems. A more closely related study done by Williamson et. al [2001] focused on the everyday information needs of visually impaired communities, but their study concentrated on the social aspects of information access and related this exclusively to use of the Internet.

A survey has therefore been carried out to establish the appliances and services used in the home by visually impaired communities, problems of access and operation, use of and problems with a personal computer to access the Internet from home, aspirations for services in domestic pervasive environments, and preferred modalities for input and system feedback. A questionnaire was designed with 5 categories. These are detailed below with the aims for each category.

- **Current Home Environment -** Determine which current appliances are used in the home and identify any problems with their use. Identify any technologies or strategies that assist with the use of appliances in the home and determine the usefulness of such technologies and strategies**.**

- **Navigation and Orientation -** Identify and determine the extent of any problems with mobility and navigation when trying to locate or operate devices and appliances

- **Accessing the Internet from Home -** Identify any accessibility tools and strategies used to access the Internet from within the home and determine how useful such tools and strategies are

- **Evaluation of Services in Domestic Pervasive Environments -** Present a scenario based illustration of services proposed for domestic pervasive environments and determine the usefulness of aspects of such environments for visually impaired people

- **Interface Design and Modality -** Present interface options using a number of input and output modalities including speech, audio, descriptive audio, touch and gesture and identify preferences using a 5-point Lickert scale

The study was implemented as a series of one to one interviews, which were conducted throughout the Leicestershire region in the United Kingdom. Answers to questions were recorded and entered into a database. Twenty-nine interviews were conducted during the period November 2003 until February 2004. Each interview lasted between one and two hours.

The people interviewed were either registered blind or registered partially sighted according to the UK government classification of sight disorders, and their ages ranged from 21 to 81. The study was carried out with the assistance of the Royal National Institute for the Blind (RNIB) vocational college in Loughborough, and VISTA, an organisation responsible for community care for all visually impaired people in the Leicestershire region of the UK.

5. Discussion of Preliminary Findings

Despite the variability in useful vision within visually impaired communities, some general classifications can be made. Of the twenty-nine participants 7 had no useful vision at all. Of the remaining 22, 16 could see large text in certain circumstances, whereas 6 of the 22 could not. However, of the 6 that could not see large text, all could see shapes and objects where there was good contrast, but with varying degrees of definition. The ability to see large text or shapes is also constrained by the distance between the person and the object being viewed.

16 people used all typical household appliances, 11 people used most, but not all, and only 2 people said they could not operate most appliances. Of the difficulties people found with appliances, the most common was not being able to effectively tune the radio, followed by trouble locating remote controls and then programming the video recorder. Other problems were setting the correct program for the washing machine, managing the contents of the fridge, text too small on control panels, being unable to set the heating interface, difficulties because of inappropriate colour use on control panels, and problems identifying callers at the front door.

Surprisingly few high-tech solutions were used to assist people to use appliances in their homes. Common devices were those that spoke, such as talking clocks, a talking dictionary, and talking weighing scales. 13 people used talking devices. 9 people used various types of magnifying devices. 7 people used Braille devices. 7 people used small “bumpons”. These are often made out of simple household materials such as blue-tak, glue, sticky pads or, in one case, thick paint. These provide a simple raised surface that can be easily discovered using touch. A common strategy people used was their own memory (13 people): remembering where things were or knowing whether something is on the right or on the left, counting button sequences when using appliances, and just practicing how to use a device and remembering it.

Other devices and strategies included a liquid level indicator for cups, which proved problematic in use, and a Pocket Reader (small optical scanner with LCD display). Adjusting lighting levels or placing spot-lights in specific locations also helped.

16 people got some help with services in the home. 10 of these were family members. People got help with shopping, cooking and cleaning. One person employed a gardener.

9 people had some problem with navigation related problems such as:

- If something is on the floor then they can fall over it
- If something is at the wrong angle then can miss the button, like a tape player on the lap, if it is at an angle then they can miss stop button and hit pause
- Generally getting a bit disoriented occasionally
- Banging into things with the right side of the face
- Tripping over chairs and cables if someone leaves them out
- Putting plugs in sockets
- Aligning with an appliance

Each of the 9 people mentioned strategies to help them as well as another 3 people who did not have navigation problems because of the strategies they use. The most common strategy was touch, just feeling their way around to orient themselves. Other strategies were using memory, mental mapping, keeping everything in its place, and adjusting device positions.

Scenarios relating to services within domestic pervasive environments were given and responses obtained using a Lickert Scale of 1 to 5 (1 – lowest ranking, 5 – highest ranking). The scenarios that obtained the highest scores (3-5) were:

- Being able to have electric, gas and water meters automatically read by the utility company and to be able to check on how much energy has been used since the last bill (27 people)
- To have your cooking appliances linked to others so messages are delivered anywhere in the house such as the meal will be cooked in 2 or 3 minutes or for cooking to start 10 minutes before the program being listened to or watched finishes (27 people)
- To be able to watch a movie or listen to the radio or mp3 from anywhere in the house with volume levels and viewing/listening options automatically set to individual preference (27 people)
- To have your doorbell pause or lower the volume of the music being listened to whilst being able to speak to the person at the door from anywhere in the house (27 people)
- Being able to control the heating and ventilation for any room in the house from anywhere in the house (25 People)

As could be predicted, the most commonly preferred feedback mode was speech, closely followed by sound signals. 28 people gave a rating of 3 and above for information that is spoken, with 27 giving audio feedback a rating of 3 and above. 16 people gave devices that provided tactile responses or "force feedback" a rating of 3 and above. Whereas only 11 people gave a rating of 3 and above to information magnified and presented very large.

Regarding input devices the most preferred was a small hand held device with just a few large keys that used speech as an auxiliary mode (27 people ranking 3 to 5). Using speech input scored similarly highly with 25 people ranking it 3 to 5. The lowest ranked input method was gesture with only 5 people giving it a score of 3 or above.

A number of the questions in the survey related to metaphor. For instance, the metaphor of hot and cold can be related to the colours blue and red. Many temperature scales use a mathematical formula that maps a given numeric value to a particular colour in a range from blue to red. This metaphor was extended to include general scales, such as audio volume and frequency range for radio and TV. An interesting finding was that many people could appreciate this metaphor, however they suggested an intensity scale would be better, where tonal contrast was used (from dark to light), as a majority of those interviewed could not easily distinguish colours, especially subtle changes, but most of those who had some useful vision could distinguish changes in tone and contrast.

A more favourable response to the use of metaphor in domestic environments related to the concept of audio icons. For example if the user wanted to operate a media player they may hear a clip of music (according to their preferences), the sound of boiling water if they were to use the heating interface or the sound of a cash register if they had bills to pay. There could even be a level of feedback that relates to the state of a device that they are controlling in their environment, such as sounds that emulate the wash cycle of a washing machine, where a "wash" sound, a "spin" sound or and "unlock" sound would give feedback on the state of the cycle.

Another example of the benefits of metaphor was the use of analog time indicators, such as on the hour, quarter past, half past and quarter to. The use of this metaphor was a common strategy where a dial or control knob would be set in one position based on a clock face. The position would then be a sufficiently informative indicator of current control position or a constraint for setting a particular control level. This strategy was also combined with the use of "bumpons" discussed earlier, for instance a 40 degree wash cycle may have a bump next to its start position.

The general response to aspects of domestic pervasive environments was very positive, with over 90% of those interviewed stating that such technologies would lead to greater access to services and inclusion in the benefits of information technologies, with slightly less (over 80%) saying it would lead to a more independent life.

Conclusions

The preliminary findings suggest that the variation in the differing visual capabilities of visually impaired users will impact significantly on any interface design in domestic pervasive environments. There have been surprisingly few developments in technology to adequately support access for visually impaired users to current appliances and services in the home.

The preliminary findings suggest that a majority of visually impaired users embraced the concept of a domestic pervasive environment, and could see it adding to their quality of life and independence in the home. Although there are issues surrounding the use of domestic pervasive technologies, such as multi occupancy, the transferring of one sensory mode to another e.g. visual to tactile and the increasing proliferation of interconnected devices, our findings have strongly indicated that there is a need for this type of domestic system. The overwhelmingly positive opinions shown regarding the possibilities for domestic pervasive technologies, confirms our initial hypothesis that such technologies could provide significant benefits for visually impaired users.

One future direction for this research to develop would be in terms of audio-based metaphor use. The existing use of metaphor and the favourable response to proposed extensions of metaphor use is encouraging. The ability for an interface to mirror the actions of its associated appliance or service in terms of the audio and visual sensory modes, may be a strategy that could create a highly usable, intuitive interface for all occupants of the home, regardless of impairment.

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