Understanding Existing Smart Environments: A Brief Classification

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Abstract. In recent years, smart environments have emerged as a key target area for ubiquitous and pervasive computing research. As technologists contemplate moving the focus of their research from proprietary laboratories into 'real living spaces', such as the domestic environment, it becomes important to gain an understanding of existing work and experiences in this area. As part of our work within the 'Domus' strand of the Equator IRC, we have conducted an extensive survey of existing smart environment computing research; we have discovered a rich and diverse set of work drawn from many disciplines. In this paper we present an initial design space for domestic focused technologies and highlight areas that we believe require further work. In addition, we highlight a number of design opportunities drawn from the existing work in this area.

Keywords. Domestic environment, smart home, technology, classification.

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Introduction

The 'Domestic Space' as a research topic, social issue, and commercial market has grown over the past few years. As a part of our work on the Domus project of the Equator IRC we have embarked on an extensive survey of the technical contributions that have taken place in the field of 'intelligent environments' over the past decade. Intelligent environment research spans a broad range of research domains from sheltered housing to home control applications. One of the emergent issues from this survey work has been the importance of developing technologies that are specifically *designed for* the domestic space, rather than simply a transplantation of office focused technologies. To illustrate this point further, consider the now defunct Interval Corp. (Hindus *et al.* 2001). Initially, Interval took their office media space prototype (Hindus *et al.* 1996), and conducted a field trial, which placed it directly into the home environment. The researchers found the media space was not well used in this environment, people often found them to be an intrusion on their privacy due to the lack of control information that was available about them. As a consequence of this lack of acceptance, Interval engaged in an in-depth study of the home environment as a setting for technology. As a result of this study, Interval developed a product called 'the presence lamp', a very different product from their initial office focused starting point, but one suited the target environment. The Interval Corp. have learnt that the home is very different from the office, in terms of the physical and the social aspects, but we have found many other institutions using the home as a secondary validation for technologies that they have already created. It is rare to find a technology that has gone though a complete revision process after being tested in the home.

In considering the placement of new technologies in a domestic setting, we believe it's important to gain a thorough understanding of the placement of existing research and technologies. To this end, in this paper we present our formative work in developing a classification of existing domestic technologies - allowing us to form a structured view of the field; a 'design space'. To be able to create such a space we must choose classifiers that can capture the diverse range of work that is being carried out under the banner of 'domestic technologies'. In conducting our investigation we felt it appropriate to draw on research that

has been conducted in related areas that are, on the surface, similar to domestic spaces. Several technologies often used in augmenting meeting rooms have multimodal interfaces, which would clearly have a lot in common with a shared multimodal interface in the home. To be able to provide of more complete map of domestic research we feel that these fields are worthy of inclusion.

Creating the design space

The partitioning of such a diverse research area can be seen as somewhat clumsy and imprecise. As seen in Dix *et al.* (2000) design space for mobile computing, the absolute categorisation of devices or technologies is not necessarily possible, nor even feasible. Several technologies that we have investigated can cover more that one classification point, making them difficult to pigeonhole. To disentangle the space we have created three dimensions in which to regiment domestic technologies. They are: *control*, *binding to people*, and *interface*. We shall first consider the relationship of the point of control to the controlled device. Over the last 50 years, the point of control of a television (the switches and knobs) has moved from being *embedded* in the device itself to being *disconnected*, most televisions have infrared remote controls. A remote control still requires the user to be co-located with the television, but domestic research is pushing control further out, such that it can be done *remotely* via a web page or WAP phone. The migration of the control point of a technology, from *embedded*, though *disconnected*, to *remote* forms our first categorisation.

Our next dimension is taken from Dix *et al*.'s mobile taxonomy; 'the extent to which a device is bound to a particular individual or group'. This breaks down into three categories, *personal*, *group* and *public*. Personal devices only support one person, where as public devices are available to a wide group of people. In between these two extremes is the group category, in which a device supports several people. Dix *et al*. highlighted the fuzzy nature of this category by making explicit two types of 'groupness': groups together and groups over time. The television can be seen as a device that serves a group of people sitting around watching it, whereas a noticeboard on a fridge serves a group of people over time (they don't have to be temporally co-located in order to read the messages on the board).

Our final dimension is based on the interface to the device or service, which we have segmented into *natural*, *familiar* and *artificial*. The usability of a domestic product is crucial to its commercial success, although several research projects are investigating alternative interfaces. Most often an 'alternative interface' is a web or WAP page allowing the remote control of the device. The device relies on another device or technology to mediate the interface, e.g. a web browser to display information and capture user input. The majority of current smart environment research regards the desktop metaphor as inappropriate for the home, prompting research groups to look for interfaces or interface metaphors that are more *familiar/simple* in this context. The far extreme of this dimension is the *natural* interface, where the interface can be seen to be pervasive and interaction is possible using different modalities, examples being speech, gesture or gaze.

Populating the space

Having segmented the space we can begin now to populate it using surveyed work. Shown below is a matrix of the space using the classification above criteria (see Figure 1). One of the most obvious trends in domestic research is the augmentation of control of a device, to allow a processor to change the state of a device. The gradual introduction of technology into the process of boiling water, from a boiling pan, to a specialised vessel that notifies you when the water is boiling (whistling kettle), to a vessel which turns itself off once the water has boiled (kettle with a bi-metallic switch), is an example proving that this type of evolution is nothing new. The technology is taking an increasing role in the process, yet becomes embedded and as familiar as domestic routine. Several projects around the UK use this approach for designing smart infrastructures for the elderly, disabled or dementia sufferers.[1]

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[1] CUSTODIAN - Conceptualisation for User Involvement in Specification and Tools Offering the Efficient Delivery of System Integration Around Home Networks:
http://www.rgu.ac.uk/subj/search/Research/SustainableHousing/Custodian/Home.html

Smart Homes: The Application of Home Automation and Assistive Technologies Within Social Housing:
http://www.sussex.ac.uk/spru/imichair/projects/template.cfm?content=smarthomes.cfm

Integrated control and communication systems for distributed sheltered housing in the community. The Queen's University of Belfast. http://www.qub.ac.uk/tbe/arc/research/projects/equal.html

Astrid: A Social and Technological Response to meeting the needs of Individuals with Dementia and their carers.
http://www.astridguide.org/

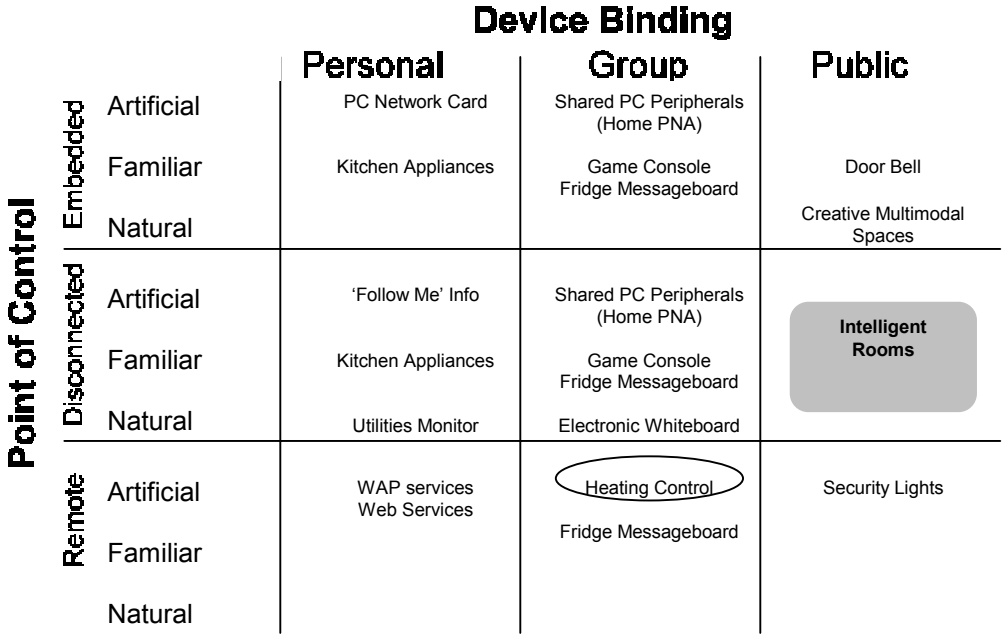

Figure 1. A design space matrix for the home

Experiments with multimodal interfaces are also being performed in the home, as further recognition that a desktop interface is not always possible or desirable in a domestic context. Much of this research is based around business meeting rooms; using natural forms of interaction to allow a group of people to control a shared device (the Group-Disconnected-Natural cell in our matrix) or collaborate more effectively. The capture of these natural interactions is often performed by voice recognition,[2] or video processing.[3] Novel devices and displays are also used to display information in a shared environment. Solutions can range from the embedding of PC-style displays in furniture,[4] or on public display boards (McCarthy *et al.* 2001) to more ambient methods as seen in the Presence Lamp (Hindus *et al.* 2001;

Smart Homes in Portsmouth: http://www.envf.port.ac.uk/arc/research/index.htm
The Gloucester Smart House: http://www.bath.ac.uk/Centres/BIME/projects/smart/smart.htm

[2] IBM: Natural Interactivity: http://researchweb.watson.ibm.com/natural/

[3] Microsoft EasyLiving project:
http://research.microsoft.com/easyliving/
FXPal Smart Media Spaces Group:
http://www.fxpal.com/smartspaces/index.htm
AVIARY Audio-Video Interface for Intelligent Environment. CVRR Lab, San Deigo, California:
http://swiftlet.ucsd.edu/~kimng/research/dimi.html

[4] Ambiente. Work Spaces of the Future. GMD.:http://www.darmstadt.gmd.de/ambiente/home.html
Domisilica: Bring people and places together. GaTech: http://www.cc.gatech.edu/fce/domisilica/index.html

Schmidt *et al.* 1999). In the Group-Remote-Artificial cell, ringed in Figure 1, we can see a good example of a technology that spans across multiple classifications – where an interface within the home is also being coupled with a remote interface. These interfaces may be presented via web pages, WAP decks or even using augmented reality in wearable computing and allow the control of domestic services, particularly air and water heating. The mobility of access to services is being investigated by Project Aura amongst others.[5]

GAPS IN THE DESIGN SPACE

Some cells in the matrix denote research areas yet to be explored. The Public-Remote-Artificial cell, a remote web/web style controller for a device or service that is bound to the home and those outside it, has 'Security Lights' as a technology – realised by using X10 home automation equipment and an always on network connection.[6] This public display of information, turning on lights in the home to make it look as if you are in, is an interesting use of technology. Work done by Interval reports that devices that make public information about what is happening in the home can force a inhabitant into commitments which they do not want to make (Hindus 1999). Hence the only Public-Remote-Artificial device, which can currently fit into this category, is the one that supplies misinformation to the outside world.

The whole bottom row of Figure 1, the Remote-Natural section is completely blank. We have touched on natural interfaces for workspaces above, but the hardware and software requirements of natural user interfaces make their portability an issue, indeed whole infrastructures have to be created and fitted into the home in order to be able to dependably capture multimodal input. This is also why we have blank areas for Personal-Embedded-Natural (a personal device which you can speak to, although it could be argued that voice dialling in mobile phones could be classified in this section), and Group-Embedded-Natural (a standalone device that to which a group of people could talk at).

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[5] Project Aura: Distraction-free Ubiquitous Computing. Carnegie Mellon University: http://www.cs.cmu.edu/~aura/

[6] http://www.x10.com

Conclusions

The design space has proved a useful tool in placing current research into some sort of context in addition to identifying new research opportunities. Across nearly all of the technical work that we looked at the research was technologically driven. The two exceptions to this rule are those research activities that are concerned with augmenting homes to support 'care in place' and the work done by the Interval Corporation. Many of the technologies that have been sold for the home have migrated from the workplace, be it automated building security, networking, or the Personal Computer itself. There are several pitfalls to this migration, which we shall discuss in our presentation, together with a classification of the emerging work within the Equator IRC project with respect to our design space.

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