HCI Design for pervasive computing

Anxo Cereijo Roibas

School of Computing, Mathematical & Information Sciences
University of Brighton, Moulsecoomb
Brighton BN2 4GJ, UK
a.c.roibas@brighton.ac.uk

Daria A. Loi

School of Architecture and Design
RMIT University
GPO Box 2476V
Melbourne 3001 VIC Australia
daria.loi@rmit.edu.au

Abstract

This paper describes the main assets to be considered in the design of non-invasive and ubiquitous personal communication, with particular emphasis on the use of multi-channel and multi-access devices for ubiquitous applications and services.

Mobile technologies are adopted for personal communication and collaborative work and learning and several European projects demonstrated their contribution in economic and cultural development areas due to their versatility and low cost (when compared to other wired communication technologies). Experiments in remote rural schools using handhelds to enhance the learning experience (Arnedillo Sanchez 2002) are examples of such a contribution.

The aim of this paper is firstly to overview the development and diffusion of mobile communication technologies, and secondly to focus on the main aspects to consider when designing successful applications and services for mobile and ubiquitous environments.

1 Introduction

Early movie, such as Marc Daniels' "Star Trek" in the 60s and James Cameron's "Terminator" in the 70s, showed to the broad public a series of futuristic scenarios where users were able to exchange information and communicate with anyone, in anyplace and at anytime. Today, in synchrony with these visions, impersonal spaces such as airports (Augé 1992) can be reinterpreted as personal environments for work or leisure.

These kinds of scenarios have been recently defined *ubiquitous communication environments* and are characterised by a system of interfaces that can be either fixed in allocated positions or portable (and/or wearable).

Following our experience with 2G technologies, we foresee that incoming 3G communication technologies will become protagonist in everyday lives. Portable and wearable devices can be indeed considered prosthesis, deeply reflecting the definition of interface as extension of the human body.

When in 1973 Martin Cooper from Motorola patented an interface called "Radio Telephone System" (the first mobile phone), he possibly did not suspect the substantial impact of such an invention on human microenvironments and on social spheres. Mobile phone technologies enabled interpersonal communication that is independent from time and place, changing the habits of people and how they relate to each other (Rheingold 1993). Such systems facilitated permanent and ubiquitous connections among users, enabling them to decide whether being or not available independently from where they are and in which moment they are contacted (Hunter 2002).

This paper is based on empirical field work undertaken with network operators (Vodafone) and handset manufacturers (Nokia), and on research studies conducted at Politecnico di Milano, the University of Lapland and the University of Brighton. The aim of this work is to give a practical approach to the design of interfaces in ubiquitous communication scenarios.

2 Background

Handhelds have been initially designed adopting methodologies and guidelines that had been developed for the Web (Nielsen 2000). Since 1999, when Mobile HCI started being discussed within workshops (Glasgow in May 1998, then Edinburgh, 2001 and finally Lille 2001 where it has been named 'Mobile HCI 01'), the issue of how to develop handhelds has started however to gain relevance as a research area. The proliferation of focused conferences and discussions around these themes in a series of HCI conferences (e.g. CHI, HCI, Interact, Ubicomp, etc.) demonstrates this emerging interest. Unfortunately the literature in this area is still scarce (Beaulieu 2002; Bergman 2000; Burkhardt 2002; Hunter 2002; Stanton 2001; Weiss 2002).

3 Internet mobile and mobile communication

The Internet is normally related to virtual spaces where interaction with information is possible. Mobile Internet, however, represents an evolution from the concept of *u-topical* interaction (no real space) to the concept of *topical* interaction, where interaction (within a virtual information space) happens in real places (Benedikt 1991). The simultaneous presence of the *u-topical* and *topical* interactions requires a direct relationship between virtual and real spheres. For instance, with GPS what happens in the real space has an effect in the virtual one (and vice versa).

This notion implies that communication becomes *space sensitive* or, better, *context sensitive*. Mobile communication is consequently a broader concept than mobile Internet, as it embraces not only a connection to the net (Intranet or Extranet), but also voice and messaging such as SMS, EMS, MMS (Cereijo 2001).

4 The usage of mobile communication

In the 80s the first generation (1G) of mobile communication systems revolutionised the TLC world as users could carry a phone in their pocket. 2G communication systems and related new protocols to access the Internet beyond voice calls, provided users mobility and a whole range of interactive services based on wireless data transmission.

Today the market is characterised by a range of different technologies. America and Japan use the IS95 network based on CDMA (Code Division Multiple Access), while Europe, Asia and Africa adopt the GSM (Global System for Mobile Communication) using TDMA (Time Division Multiple Access). 3G and 4G systems offer unprecedented bandwidth and speed connection up to 2 Mbps for data transmission with audio and video streaming capabilities directly on the phone. Besides, analysts foresee a relevant growth of Mobile Internet users in the upcoming years: by 2005 more mobile phones will be connected to the Internet than PC's (Ovum, 3G Mobile, May 31st 2000).

The variety and differences of contemporary technologies are a challenge for service and application developers that are increasingly asked to deliver usability and effectiveness (Cereijo 2002).

5 Multi-access and Multi-channel convergence

3G will merge (at least) four media: Internet, SMS, TV, and Smart-home. In such a scenario it will be crucial to offer an integrated system of new services with mobility as a perceived added value by the user. This integration (or convergence) requires a centralization of all the information exchanged in the system (independently from the device of access).

The notion of convergence is related to the concept of interoperability of the components of the same platform (e.g. the agenda, e-mail, block notes must share the same information) and among available multilingual devices. This means that a transaction occurring via a specific interface (e.g. flight booking from an iTV set-up box) must appear in real-time if the user re-accesses the related site through a different interface (e.g. PC or Pocket-PC). Convergence implies also other issues; for instance, information must be optimised according to the physical and technical features of each interface (Cereijo, 2003).

Finally, one of the main consequences of 3G will be an enhanced interaction with information (companies and institutions), people (personal and group communication), the smart-house and the automated office. This context of ubiquitous communication (across mobile phones, iTV, palms, pocket PCs, PDAs, etc.) will have applications in domotics, video-conferencing, commerce, iTV, entertainment, learning, finance, medicine, etc. (Burkhardt 2002).

6 Multi-channel identity

One of the challenges with 3G will be the design of multi-channel identity.

As each type of device has different technical and physical features (in relation to architecture, navigation, contents and graphics), a co-ordinated graphic and interaction design is required. Moreover, the peculiarities of each interface within the system (Figure 1) can obstruct the achievement of desired design homogeneity from a functional and visual point of view (Bergman 2000).

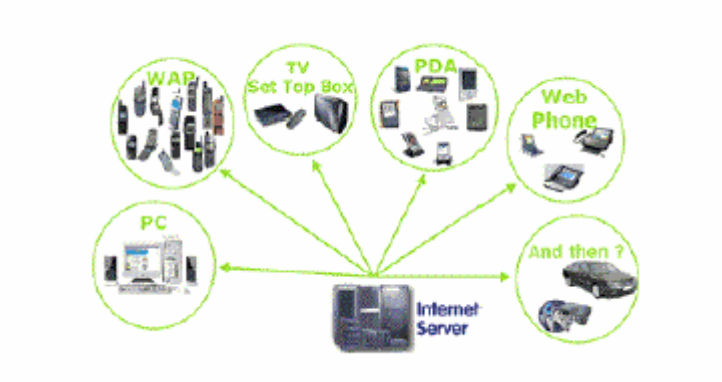

Fig. 1: Peculiarities of interfaces within a system

7 Usability & self-usability

The usability of a system is related to how effectively, efficiently, and satisfactorily specified users achieve specified goals in particular environments (ISO 9241, Ergonomic requirements for office work with visual display, Part 11). As a consequence, it is important not only to measure the performance of users while mobile, but also to unfold their satisfaction and what they perceive relevant when adopting mobile services in particular contexts of use.

In such contexts a participatory design approach (Sanoff 1990; Schuler and Namioka 1993; Muller and Kuhn 1993), where designer and user co-operate during the whole design process, can be adopted to reduce design and development costs as well as to provide successful services (Jordan 2000).

There is another aspect that concerns usability that deserves special regard: self-usability. This is related to the *emotional effects* of multi-access communication services (e.g. iTV users by interacting with distributed interfaces). As a matter of fact, to make technology friendlier mobile users have developed the so-called *new m-language of the Mobile Interactive Community*: a language made of slang words, neologisms, acronyms, numbers and icons, that was born by interacting with SMS, email, chat, forums and newsgroups and that evolved with WAP and GPRS communication (Macleod 1994).

8 Microdesign

An interface is not a physical object but the space where a human body, a device and the intents of a user interact. Therefore, in a human centred *microdesign* scenario, the interest of a designer is not a single button, display or screen but the whole human-machine interface (Nielsen 1992).

The interaction with a wired device is related to a specific user experience: usually the contents are *fat* and audio-visual factors are relevant. Navigation has in such cases a number of possible schemes due to the large size and rich colour of the screen. Moreover, animated images and videos can enrich and facilitate interaction.

On the other hand accessing the net through mobile devices is different from a typical PC-based access. In fact, when compared with PCs, these interfaces demonstrate some crucial limitations, such as: reduced size of the interactive area and its low resolution; high cost of device and connection; slowness of data entry; reduced memory storage; limited processing; and short battery autonomy (Weiss 2000).

Another aspect contributing to such complexity in *microdesign* is related to the shape of the device and in relation to this two main trends can be highlighted. In the first case navigation tools have been gradually transferred to the graphic interface and voice commands: this is the case of the PDAs, Palms, and table PCs where keyboards have been almost eliminated in favour of the screen (Figure 2a). In the second case the device is configured as a more traditional mobile phone (Figure 2b).

Figure 2a: When the screen is favored

Fig. 2b: Traditional mobile phone interface

Whatever the trend, it is crucial to develop services that offer positive experience to end-users independently from such technology limitations. In line with this mindset, services where information retrieval is no more a frustrating experience and where users are satisfied in less time, throughout a logical sequence, and with minimum effort (Picard 2000) should be developed.

From GSM to 3G systems, wireless devices are driving the Mobile Internet evolution and opening up innovative ways of communicating and interacting with content. Knowledge of this interaction context is crucial to the design and development of multi-access services and any uncertainty related to how future and appropriate technologies should be can be reduced by accessing such knowledge.

Wireless communication enables innovative ways of getting the best out of the information world through its main key aspect: mobility. Anytime anywhere access means quick and successful end user experience in getting the right information at the right time, in the right place (Leed 1991).

Mobile devices are personalisable tools containing personal information (agenda, phone book); they are switched on for most of the day and carried around as connecting devices which are perceived as essential; and they not only enhance communication, but modify the nature of social relations (Ravy 2000).

The first step in developing these devices should be a definition of scenarios of ubiquitous interactive communication (UMTS, MMS, iTV, etc.) to develop multi-access communication contexts where users can interact among each other, with information, with the TV, and with other devices independently of place and time thanks to a system of distributed interfaces such as PC, TV, PDA, pocket PC, mobile phone (Cereijo 2003).

Secondly, once 3G scenarios and contexts of use are well defined, the designer should:

- understand the expectations, limitations and behaviours of users while mobile;

- adopt participatory design approaches;
- design appropriate interaction models and patterns;
- foresee trans-cultural adaptability;
- ensure the provision of good communication services to guarantee a satisfactory added value to users; and
- maintain a coherent and relevant multi-channel identity.

Moreover, a designer should recognize the level of usability of an interface according to:

- self-learning & length of the training phase;
- fulfilment of the expectations and the perceived value of the provided services in users;
- speed in task completion;
- number of irreversible mistakes; and
- degree of interaction enabled.

The designer must know who the mobile users are: know their limitations (Wharton 1992), needs and expectances; imagine their behaviour; predict a model of multi-access interaction; measure (Sears 1993) their performance and emotive level; optimize human interfaces (Shneiderman 1987); and find a balance between automation and creative-affective interaction (that deals with the pleasure of the 'savoir faire' of users).

According to European experiences with mobile interactive communities via WAP and SMS (Palen 2000)., users seem to appreciate enhanced interaction; personal and always-on immediate communication (information delivered with sensibility to time and context); new emotional experiences; new ways of socialising and sharing experiences; and new entertainment channels (e.g. multiplayer games, group iTV interaction).

An adequate focus on users in terms of lifestyle, needs, behaviour, and social roles can lead to a successful personalization of the devices. To provide users a high perceived value of mobile interfaces, it is crucial to develop a human centred *microdesign* approach that can lead to innovative interaction schemes (via multi-devices such as PC, smart phones, PDA) , site architecture, and intuitive navigation.

A scarce attention to human factors and behavioural science principles (learning ergonomics, social psychology, bio-mechanics and HCI) is fatal for mobile Internet in the same way in which it is detrimental for web design. For example, the frustration of users using WAP is undoubtedly more dangerous than when they use the web because mobile devices interfaces are smaller and the delivery of the service is slower and more expensive (Cooper, 1995).

Even thought there are not standards yet for usability in mobile Internet, it is possible to indicate some basic guidelines for a User Centred *Microdesign*.

9 Infodesign

Terminology (the use of a concise but relevant, auto-evident and consistent language for contents and the name of the navigation elements) is a basic issue in *microdesign* due to its spatial context. A strong effort of organisation and hierarchy of content (providing to the user, with progressive levels of deepening) is essential as well, especially for mobile phones where graphics have a discrete presence and most of the design is focused on contents. Moreover, these devices must consider the limited memory of users and the fact that not all information can be provided. Each part of the transaction must provide what users would expect to find (e.g. address of a company).

The *Infodesign* must also guarantee a high level of interaction (i.e. after searching for a hotel in London both the displayed e-mail and telephone number must be intuitively perceived by a user as interactive links to indicate that the e-mail can be directly sent and/or the number can be called by clicking on it). Figure 3 shows a case of auto-evident content: a number in brackets expresses how many sections are contained behind each link.

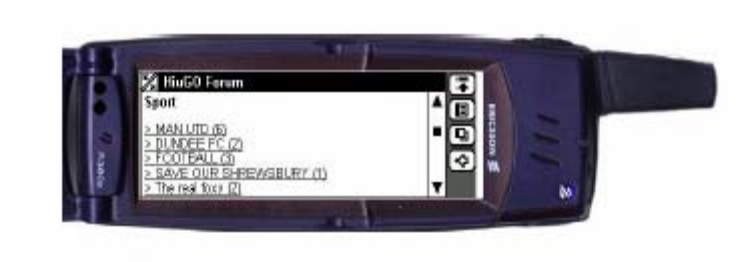

Fig. 3: Auto-evident content example

10 Multi-platform architecture

The structure of a site is a complex framework reflecting multi-device accesses (e.g. WEB and WAP). The architecture of a mobile Internet site should be in harmony with the workflow of users and its layout must make the content easily accessible. Internet designers build the structure of the site once the information has been divided in hierarchies and organised into different levels.

In mobile Internet contexts such a process is emphasised. In fact, in *microdesign* a good balance between horizontal and vertical organization is needed. According to our research in mobile phones and PDAs not more than 3 mouse clicks (stages) are advisable in order to reach any service. As a general rule, while vertical scrolling is easy on most devices, horizontal is not (Brewster 1999).

11 Graphics

Ergonomically speaking, a small screen requires graphics to aid the comprehension of contents and the navigation (i.e. the relationship between the intentions of users and any related outcomes must be intuitive). Graphics that reduce readability have to be avoided.

The use of multi-device graphics that are independent of the device to keep communication coherence, requires the use of some crucial tricks (such as using contrasted monochrome icons and avoiding scrolling) not to loose in efficiency and efficacy when using the same graphic elements with different interfaces. Indeed it is common to find sites for PDAs with unreadable text (type too small, colour of the type and colour of the background, etc.).

Moreover, the use of some graphic elements can be useful to differentiate different types of contents (e.g. HiuGO's WAP site uses the string to entitle a related section). Last, but not least, graphic elements should contribute to service personalization (Reyes 2001).

12 Navigation

Although interfaces for mobile internet evolved from first models (which enabled one way scrolling only – sequential menu) to 3G devices (that permit bidirectional movement – matrix menu – by means of a rocket, central key, joystick or keypad), basic principles of mobile Internet navigation (such as evidence, fluidity and quickness) will not change considerably. In fact, navigation should enable users to easily satisfy their expectations and needs (relevance) and to easily and quickly reach any section of the site.

All pages should display all the basic navigation elements (back, top, home, etc.) in an evident manner and any confusion between buttons and non-linkable icons should be avoided (this problem is more visible in the case of devices with touch screens, where linkable icons can undoubtedly help navigation). Mobile users dislike losing their way within a site and they do not appreciate dead links – situations that can impact the reliability of the site.

Some recent researches on the behaviour (Cereijo 2004) of users put into evidence a reluctance to use the physical buttons of mobile devices as function keys – only some expert users are prone to make currently use of them. Consequently, only a minimum number of navigation functions/commands should be placed in the options menu

(the most frequent ones) and such commands should been displayed in the screen together with the rest of the functions/links or via physical buttons.

13 Future trends

According to the outputs of conferences such as Mobile HCI and Ubicomp, there are three main trends for the future of mobile HCI. The first one is related to the need to improve usability and accessibility of mobile interfaces which are more and more 'rich brains in poor bodies'. The second trend regards the solution of new emerging dichotomies/dilemmas such as: personalization/privacy, ubiquity/security, context-awareness/confidentiality, info-accessibility/info-overload, effective-communication/affective-communication, etc.

Finally, some trends are linked to the challenges offered by how synchronization of information between multiple devices requires multi-platform systems. This last trend emphasises a complexity from the interactive point of view that has to be hidden to make more realistic the dream of ubiquitous communication.

14 Conclusion

The incoming 3G-communication scenario will increasingly place users in the centre of a holistic communication network. This implies scenarios where people will be physically surrounded by devices that enable their interaction with others and with other machines.

This environment of ubiquitous communication is becoming a mass consuming phenomenon and users will progressively interact with different interfaces at the same time. This implies a need for creating shared universal interaction code – a coherent language between holistic systems of interfaces.

Innovative design patterns, human factor studies, behavioural theories and evaluation techniques in ubiquitous communication scenarios have to be considered for these technologies to enjoy wide spread popularity and usage.

15 References

Arnedillo Sanchez, I. et al (2002). Pathway to m-learning. *Proceedings of the European Workshop on Mobile and Contextual Learning*. Birmingham: University of Birmingham.

Augé M. (1992). Non-lieux. Seuil.

Beaulieu, M. (2002). Wireless Internet: Applications and Architecture. Addison Wesley.

Benedikt M. (1991). Cyberspace. First step. MA: MIT Press.

Bergman, E. (2000). Information Appliances and Beyond. Interaction Design for Consumer Product. Morgan Kaufmann.

Brewster, S., Cryer, P. (1999). Maximising Screen-Space on Mobile Computing Devices. *Proceedings of CHI'99*.

Burkhardt, J. et al. (2002). Pervasive Computing: Technology and Architecture of Mobile Internet Applications. Addison Wesley.

Cereijo Roibas A. (2001). Examining the UI Design challenges of supporting multimedia applications on next generation terminals and identifying ways to overcome these. Proceedings of the User Interface *Design for Mobile Handsets Conference*. London.

Cereijo Roibas A. et al. (2003). How will mobile devices contribute to an accessible ubiquitous iTV scenario. *2nd International Conference on Universal Access in Human -Computer Interaction (ICUAHCI).* Crete.

Cereijo Roibas A. et al (2004). The future of ubiquitous gaming, Proceedings of the Mobile Entertainment Conference, Manchester, 2004.

Cereijo Roibas A. (2001). Usability for Microdesign: the HiuGO Experience. *Proceedings of the Usability for Mobile Devices and Services Conference.* London.

Hunter, R. (2002). World without Secrets: Business, Crime and Privacy in the Age of Ubiquitous Computing. Basil: Wiley.

Jordan, P. (2000). Designing Pleasurable Products. Taylor & Francis.

Leed E.J. (1991). The mind of the traveler. Basic Book.

Lévy P. (1994). L'intelligence collective. La Découverte.

Macleod, M (1994) Usability in Context: Improving Quality of Use. In: G. Bradley and H.W. Hendricks (eds.) *Human Factors in Organizational Design and Management - IV - Proceedings of the International Ergonomics Association 4th International Symposium on Human Factors in Organizational Design and Management.* (Stockholm, Sweden, May 29 - June 1 1994). Amsterdam: Elsevier.

Muller, M. J. and Kuhn, S. (1993). Participatory Design. *Communications of the ACM* (pp. 24-26). June.

Nielsen, J. (1992). Finding Usability Problems through Heuristic Evaluation. *Proceedings of ACM CHI '92*, (pp. 373-380).

Nielsen, J. (2000). Designing Web Usability: The Practice of Simplicity. Indianapolis: New Riders Publishing.

Palen, L., Salzman, M., & Youngs, E. (2000). Going Wireless: Behavior & Practice of New Mobile Phone Users. Paper presented at the CSCW, Philadelphia, PA.

Picard, R., (2000). Affective Computing. MIT Press.

Raby F. (2000). Project #26765 – Flirt: flexible information and recreation for mobile users. London: RCA CRD Research Publications.

Reyes, A., Burch, G. P., Cover, A., Galore, J., Griffith, K., Leiboh, L., Liedgren, J., Linker, B., Mellen, J., Pises, A. M., Reinhardt, R. (2001). Flash Design for Mobile Devices: A Style Guide for the Wireless Revolution. Wiley.

Sanoff, H. (1990). Participatory Design: theory & techniques. Henry Sanoff (distributor). N.C.: Raleigh.

Schuler, D. and Namioka, A. (1993). Participatory design: principles and practices. Hillsdale, N.J.: L. Erlbaum Associates.

Sears, A. (1993). Layout Appropriateness: A Metric for Evaluating User Interface Widget Layouts. *IEEE Transactions on Software Engineering* (pp. 707-719).

Shneiderman B., (1987). Designing the User Interface: Strategies for Effective Human-Computer Interaction. Reading, MA: Addison-Wesley.

Stanton, N. (ed.) (2001). Ubiquitous Computing: Anytime, Anyplace, Anywhere? *Special Issue of the International Journal of Human-Computer Interaction.*

Weiss, S. (2002). Handheld Usability. Wiley.

Wharton, C., Bradford, J., Jefferies, R., Franzke, M. (1992). Applying Cognitive Walkthroughs to More Complex User Interfaces: Experiences, Issues, and Recommendations. *Proceedings of CHI 92* (pp. 381-388).

16 Terms and Definitions

Infodesign: a broad term for the design tasks of deciding how to structure, select, and present information

Microdesign: the process of designing how a user will be able to interact with a small artefact.

Self-usability: sort of mechanisms set by the users (e.g. use of acronyms in a SMS) in order to make more usable the interaction with complex human artefacts.

Multi-access: interacting with a computer using more than one input or output channel at a time, usually suggesting drastically different input channels being used simultaneously (voice, typing, scanning, photo, etc.).

Multi-channel: different interfaces that can be available to the user for data entry in a multi-platform system (iTV, PC, mobile phone, smart-phone, pocket-PC, etc.).

Multi-channel identity: a perceived communicational coherence for each service provided through the whole system of interfaces.

Mistake: an error of reasoning or inappropriate sub-goals, such as making a bad choice or failing to think through the full implications of an action.

Reversible actions: any action that can be undone. Reversibility is a design principle that says people should be able to recover from their inevitable mistakes.