

Ambient Interfaces: Design Challenges and Recommendations

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Abstract

Ambient interfaces go beyond the classical graphical user interface and use the whole environment of the user for the interaction between the user and the system. In this paper we describe the design and implementation of ambient interfaces to facilitate the easy and smooth cooperation and coordination among geographically dispersed team members. We report on results of user involvement in the design and implementation of these ambient interfaces and user feedback from evaluation. We discuss consequences for the design of ambient interfaces and derive design guidelines.

1 Introduction

Ambient interfaces use the whole environment of the user for the interaction between the user and the system. They present digital information through subtle changes in the user's physical environment such as variations of light, sounds, or movements. They capture natural interactions of the user with physical devices such as switches, buttons, or wheels and translate them into digital commands (Gross, 2002; Wisneski et al., 1998). Ambient interfaces go beyond the classical graphical user interface and do not consume real estate on the computer screen; they make user interaction with the system easier and more intuitive. Their properties of a calm technology (Weiser & Brown, 1996) are particularly useful for situations, in which users want and need permanent background information without being disrupted in their foreground tasks.

Ambient interfaces can be used for any setting or system, where the subtle presentation of information is vital. This is particularly the case for awareness information environments. Awareness information environments aim to facilitate the easy and smooth cooperation and coordination among geographically dispersed team members by providing them with group awareness. Typically, this group awareness comprises information about co-workers such as their presence and availability as well as about shared artefacts such as the creation or alteration of documents (Dourish & Belotti, 1992). Awareness information environments face the trade-off that on the one hand users need up-to-the-moment and detailed group awareness information and on the other hand users want to perform their foreground task without frequent disruptions (Hudson & Smith, 1996). Ambient interfaces have the potential to considerably reduce this trade-off.

In this paper we describe the design and implementation of ambient interfaces that were used to augment an awareness information environment. We report on results of user involvement in the design and implementation of these ambient interfaces and user feedback from the evaluation. We discuss consequences for the design of ambient interfaces and derive design guidelines.

2 Ambient Interfaces

The ambient interfaces were designed and developed to augment the Theatre of Work Enabling Relationships (TOWER) open awareness information environment. TOWER aims to support mutual awareness and chance encounters among geographically dispersed users with sensors that capture information and various indicators that present the information on the users' computer desktop with pop-up windows, tickertapes, and a 3D multi-user environment. This 3D environment presents shared documents as buildings and users as animated avatars wandering through the virtual cities. TOWER consists of an event and notification infrastructure that captures and processes awareness information, a space module that dynamically creates the 3D space according to the changes to shared documents, a symbolic acting module that creates and animates the avatars according to the users' actions, and a docudrama module that can replay past states of the 3D multi-user environment.

Several ambient interfaces were designed, developed, and integrated into TOWER; they can communicate directly with the event and notification infrastructure. In the following we present multimodal ambient interfaces and AwareBots.

2.1 Multimodal Ambient Interfaces

Multimodal interfaces address multiple human sensory modalities and multiple channels, of the same or different modalities (Buxton, 1994). Some examples of multimodal ambient interfaces that we developed are a fan, a lamp, and a fish tank. The fan addresses the haptic sense of the user—it blows air into the face of the user. The desktop lamp addresses the visual sense—it points to the ceiling of an office room and illuminates the ceiling, its intensity can be changed in a subtle way. The fish tank addresses the visual and auditory sense of the user—it can release bubbles in different intensities, these bubbles can not only be seen, but also heard, if their frequency goes beyond a certain threshold (cf. Figure 1a).

2.2 AwareBots

AwareBots are ambient interfaces presenting awareness information in the shape of robots. Several AwareBots were developed with the LEGO Mindstorms Robotics Invention System (The LEGO Group, 2002). LEGO offers several advantages for the participatory design of ambient interfaces: users can easily build and change their AwareBots, users can easily personalise existing AwareBots, and the AwareBots are aesthetically pleasing. For instance, the RoboDeNiro AwareBot (cf. Figure 1b) can lift its hat when another user logs in; it can rotate its body when new email has arrived; and the user can press its arm in order to log into the system.

Details about the multimodal ambient interfaces and the AwareBots as well as about other ambient interfaces developed in our group can be found in (Gross, 2002); some mobile interfaces that were also integrated into TOWER were described in (Gross, 2001).

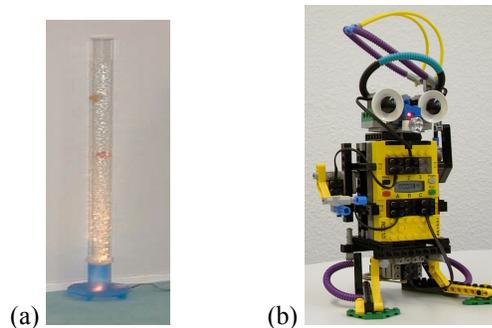


Figure 1. a) fish tank; b) RoboDeNiro AwareBot.

3 Evaluation

The TOWER environment as well as the ambient interfaces were conceptualised and implemented in a multi-national project, which was partly funded by the European Union and started in January 2000 and ended in July 2002. Besides several research partners from academia and industry, two companies participated as application partners.

3.1 Application Partners

Aixonix is a small enterprise with a staff of 25 people working at two sites in Germany and the U.S. Aixonix develops, operates and sells Web-based systems for the transfer of technical as well as scientific knowledge, and provides consulting services in information management. At Aixonix the TOWER environment and the ambient interfaces were used to inform the users at the different sites about each other.

WSAtkins is a global enterprise with thousands of employees in over 90 offices throughout the UK and several other offices in more than 25 countries. The company is among the world's leading providers of professional, technologically based consultancy, and support services. The motivation of WSAtkins to use the TOWER environment and its ambient interfaces was based on a worldwide reorganisation and a newly created concept of a 'one company - one team' culture in the year 1999. The TOWER environment and its ambient interfaces were used to inform employees from the different sites about each other and to stimulate group cohesion.

3.2 User Involvement

The participatory design and development as well as the evaluation of the TOWER environment and the ambient interfaces can be characterised by two iterative circles.

In the *outer circle* users participated in the requirements analysis and in the evaluation of the prototypes. In expert workshops, which started in January 2001 at Aixonix in Aachen, Germany, and at WSAtkins' main office in Epsom, U.K., the prospective users were interviewed about their work practice and gave feedback on early design ideas, mock-ups, and first ambient interface prototypes. Throughout the rest of the project the environment and the ambient interfaces were deployed incrementally and discussed in regular user workshops. Furthermore, we produced and analysed log files for the email correspondence (only with email headers such as sender, recipient, subject, date and time), for the activities in shared workspaces, and for logins and logouts to and from the TOWER environment.

In the *inner circle* the TOWER environment was used among the design team within the project. New features and new ambient interfaces were first introduced at the different sites of the design team. In fact, several members of the design team had their own LEGO Mindstorms Robotics Invention System packages and produced their own AwareBots and defined their own mappings between the input and output of the AwareBots and the represented information and actions. Various application scenarios were tried out to explore the usability of the features and to check whether they provide sufficient benefits for users to justify their introduction into work practice. Upon acceptance the features were demonstrated and discussed in the user workshops.

On a whole we primarily used qualitative measures of user involvement and evaluation, since they are often more adequate for empirical studies in cooperative settings; the evaluation of the log files was the only quantitative analysis.

4 Guidelines for the Design of Ambient Interfaces

The guidelines (cf. Table 1) originate from various sources: basically, the application partners' input from the participatory design activities and the empirical results of the evaluations were combined with findings from literature on usability goals and principles for GUI-based systems from Preece et al. (2002), on interaction design for multimodal consumer products from Bergman (2000), and on guidelines for the design of applications for mobile devices from Weiss (2002).

Ambient interfaces should be <i>effective</i> .	Quality in terms of how good the ambient interfaces does what they are supposed to do. For instance, one basic goal for ambient interfaces was to make use of users' peripheral awareness, not disturbing the user from performing the foreground task.
Ambient interfaces should be <i>efficient</i> .	Way an ambient interface supports users in carrying out their tasks. For instance, pressing the arm of RoboDeNiro for logging in to the TOWER environment relieves users from typing user names and passwords.
Ambient interfaces should be <i>safe</i> .	Protection of the user from dangerous and undesirable situations. For the PC a considerable body of knowledge on hardware ergonomics exists. For ambient interfaces, especially if they are multimodal, little knowledge on ergonomics exists.
Ambient interfaces should have good <i>utility</i> .	Right kind of functionality so that users can do what they want and need to do. Ambient interfaces should be used for easy input for simple actions or for subtle presentation of simple information. They are not well suited for complex information.
Ambient interfaces should be easy to <i>learn</i> and <i>remember</i> .	Ease for the users to learn a system and to remember how to interact with the system. For ambient interfaces this is particularly challenging, because users do not have experience yet; novel metaphors are used; and traditional help systems are not available.
The functionality of ambient interfaces should be <i>visible</i> .	Clear communication to the user at any time which choice she has and what the system is expecting from her. Visibility can be easily achieved through the physical affordances of the ambient interfaces.
Ambient interfaces should give the users adequate <i>feedback</i> .	Information to the users to tell her that her input was received and analysed properly, and that the corresponding actions have been or will be performed. The feedback for the login function of the RoboDeNiro is a negative example: as pressing the arm can mean a login or a logout, the users often were not sure if they logged in or out.
Ambient interfaces should provide <i>constraints</i> .	System awareness of the user's current situation and possible next steps and appropriate actions of a user. For the ambient interfaces we built constraints play a minor role, because the functionality of input and output in quite simple and easy to handle and does not require complex interaction or multi-step interaction.
Ambient interfaces should provide an adequate <i>mapping</i> .	Mapping between controls and their effects should be adequate. This is a particular challenge for a multimodal, distributed multi-client system. In TOWER, the effect of the input often cannot be seen on the ambient interface <i>per se</i> , but rather on other indicators
Ambient interfaces should provide <i>consistent</i> functionality.	Similar operations and similar control elements should be used for achieving similar tasks. In a distributed participatory design and development process, consistency can only be achieved by frequent exchange among the different sites.
Ambient interfaces should be <i>adequate</i> for the target domain.	Adequacy for the target domain such as the environment, in which the ambient interfaces are installed; the users, who will use the system; and the tasks that will be performed on the ambient interfaces. For homogeneous target domains such as in TOWER, adequacy can be achieved easily.
Design and development should be <i>participatory</i> .	Stimulation of users to contribute to the design of the ambient interfaces at very early stages. The experience from the TOWER project has clearly shown that users somehow liked the ambient interfaces designed and developed by others, but that they had much more fun when developing their own ambient interfaces.

Table 1. Design guidelines for ambient interfaces.

5 Conclusions

The design, development, and evaluation of the ambient interfaces as well as the design guidelines derived are only a start into a more systematic exploration of the systematic design for ambient interfaces. The whole area of ambient interfaces is rather new and to some extent still in its infancy. The results and guidelines provided should, therefore, be interpreted as a first attempt in combining knowledge from literature on design and usability of computing artefacts and initial experiences with the design, development, and use of actual ambient interfaces. And we are probably far from a usability engineering theory and practice that is already established for classical graphical user interfaces.

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