Unobtrusive user interfaces for ubiquitous computing: a state of the art of the computer to human communication

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Abstract

In this paper we explore recent research into unobtrusive user interfaces for ubiquitous computing. However, rather than looking into both input and output methods for ubiquitous computing, this paper will concentrate only on the output methods, i.e. the means with which the systems deliver information to humans. To this end, recent papers that present studies into such communication, as well as papers about actual devices implementing such user interfaces are presented and discussed.

Keywords: unobtrusive user interfaces, ubiquitous computing, pervasive computing, HCI.

1. Introduction

“Calm technology” is the term coined by Mark Weiser and John Seely Brown in [12] to describe the type of interface for ubiquitous computing (a term also coined by Mark Weiser in 1988) that would allow a system to pass information to a user without engaging his full attention in a stressful manner. Of course, Mark Weiser doesn’t describe calm technology in this manner, rather he says “Calm technology engages both the center and the periphery of our attention, and in fact moves back and forth between the two”. Still Weiser makes it quite clear that while some information requires the full attention of the user of a system, other information can merely be present, available in an elegant manner when a user wishes for it, without the need to pass by a traditional desktop computer. When we talk about “unobtrusive user interfaces” in this paper, we refer to the idea of calm technology. The idea of the user interface passing from periphery of our attention to the centre and back is the centric idea of unobtrusive user interfaces. Although we use the term “unobtrusive” to describe the interfaces we are interested in, it is not a term that is universally used to describe them. Thus, in the literature terms like “natural” [2], “non-intrusive” - “transparent” [9] or “ambient” [4] are used to describe what we will call unobtrusive. Possibly some authors may even describe their work in other words, while meaning unobtrusive user interfaces.

Ubiquitous computing describes computing anywhere and everywhere, with many computing devices per user. For example a modern car may have about 50 microprocessors [8], but most of them do not provide feedback to the driver. In [9] ubiquitous computing is defined as allowing (some) user mobility and having a transparent user interface (the traditional desktop computer having none of those features). That paper also provides a practical ontological framework, which is reproduced in Fig. 1. What is interesting for us in this figure is not so much its description of what ubiquitous computing is, so much as its examples of transparent interfaces and categories that overlap into ubiquitous computing. Those categories - smart environments, wearable computers and augmented reality - served as a base to choose papers of such systems designed to have an unobtrusive user interface.

Figure 1: The mobility/transparency matrix.

The emergence of ubiquitous computing leads to computers that we interact with either knowingly or unknowingly. When the interaction is obvious, having the user focus exclusively on the output from the ubiquitous device may defeat its purpose. For example in [1]...
the author describes an application of ubiquitous computing (providing important information during paragliding) that must have an unobtrusive interface, else it would compromise the primary activity. However, there is at present no clear definition of how such unobtrusive interfaces may be achieved. The purpose of this state of the art is to give some indication of how current research aims to fill that void, as well as present some of the solutions scientists have developed or imagined.

Even though it is possible to find many papers describing unobtrusive user interfaces for ubiquitous computing, this does not in fact mean that it is a well defined and very active area of research. If one were to search for unobtrusive and novel means to transmit commands to computers, ubiquitous or otherwise, a plethora of information is available (e.g. at least an entire section in [3] is dedicated to such research). However, studies on the means with which a computer may transmit information to humans are much less common, with most output devices consisting of a standard screen, although often one of a mobile phone or PDA for ubiquitous computing [5] [10]. This is probably due to the wealth of information that can be transmitted through visual information, as well as to the familiarity and ubiquity of the medium. However, as [12] may suggest, many of the methods to transmit information unobtrusively are custom-made for a specific function, which limits their re-usability, although not their effectiveness. Studies on the theoretical side of unobtrusive user interfaces (mainly into user acceptance and preferences) for ubiquitous computing are rarer still, but of obvious interest.

In section 2, we present two such "theoretical" user studies of unobtrusive user interfaces, while section 3 is devoted to practical applications and devices. Finally section 4 presents our conclusions on the state of the art.

2. User studies

The first paper [7] presented in this section is a general study on users reaction to the type of non-conventional user-interface that we can expect in ubiquitous computing. The second paper [6] is not directly in the context of ubiquitous computing, being more a study of how people react to an output device that is already ubiquitous in its presence, namely display monitors. It nonetheless provides valuable insights into unobtrusive user interfaces, as will be seen in sub-section 2.2.

2.1. From Everyday Objects to Computational Devices: Understanding the Science behind Ubiquitous Computing Interface Design

This paper was selected as it is one of the few that actually sought the users opinion on the non-conventional interfaces that ubiquitous computers may have, and then draws conclusions in how such interfaces should be crafted. However, even though its findings are not limited to unobtrusiveness, we will focus on that aspect of the paper.

The premise of the paper is to record and evaluate the reaction of people to everyday devices that are computerised to convey information. In doing so, the authors hope to present how everyday objects may be modified to convey information in a constructive manner, in their own words "help guide designers as they go through the rigors of creating new systems". The everyday objects used in the paper, shown in Fig. 2, are the following:

- The infoLAMP, which uses the brightness of the lamp to convey information
- The dataFAN, which uses wind speed from the fan
- The hapticCHAIR, which uses vibration from a cushion

Figure 2: the infoLAMP, dataFAN and hapticCHAIR.

To contrast the novel interfaces to well known systems, two desktop interfaces were also used to convey the same information as the devices: a counter and a progress bar.

The study itself was conducted on a population of 50 undergraduates familiar or very familiar with computers, although only 10 of them knew what ubiquitous computing was. The subjects were presented with the following imagined scenarios: the users where asked to monitor with the five information sources: 1) outdoor temperature while working on the computer, 2) online buddy status for instant messaging (also while working on the computer), and 3) progress in relation to the amount of time left during an exam.

The stated purpose of the experiment is to test four hypotheses about ubiquitous interfaces, namely

- People prefer desktop over ubiquitous interfaces to display everyday information.
- People will be more willing to start using ubiquitous interfaces if they perceive them as trustworthy and intuitive.
The effort required to understand information conveyed by the ubiquitous interfaces inhibits willingness to use.

People who have never heard of ubiquitous computing before will be less trusting of and want to be less dependent on ubiquitous computing systems, impacting their willingness to adopt ubiquitous interfaces.

Of these, only the first hypothesis interests us, as it is the only one which directly deals with the unobtrusive nature of the interface. Indeed, preference was measured over certain criteria, such as if the objects usage was easy to learn, if information was transmitted clearly, and most importantly for us, if the objects were intrusive. Unfortunately, the ubiquitous computing devices were found to be more intrusive delivering information when compared to the desktop options, with the hapticCHAIR being the worst, followed by the dataFAN and the infoLAMP being the best of the lot. As predicted by the first hypothesis, the users preferred the desktop alternatives to deliver the information with the exception of the second scenario, where the infoLAMP was the preferred medium. In that situation the lamp was found to provide the necessary information while not having to focus on the desktop.

These results are unfortunately not altogether surprising for two reasons: the first is that the given devices are rather crude, not specifically designed to minimize their obtrusiveness, while the second is simply that in two of the 3 cases, the users attention is already focused on a computer, which is capable of presenting the information in an unobtrusive manner. Indeed, the two desktop interfaces were sufficiently unobtrusive to displace the augmented devices, and even in scenario 2 where the the infoLAMP was preferred, it was, according to the published results, still considered more intrusive, if not by much. The conclusion which may be drawn is that a same interface may be considered intrusive in some situations while not in others, leading to the authors to conclude that different objects are only good at conveying certain types of information, given their properties. This paper also highlights the importance of user participation to evaluate the validity of an interface, as their underlying hypothesis may be mistaken. This is covered in more depth in the following paper.

2.2. Overcoming Assumptions and Uncovering Practices: When Does the Public Really Look at Public Displays?

As this paper doesn’t directly deal with unobtrusive user interfaces for ubiquitous computing, we will only give a short presentation of this paper. This paper does, however deal with an informational media that is already ubiquitous, namely public display monitors. And although the paper doesn’t describe unobtrusive interfaces, it does, however, give insights into how such devices may capture the attention of a user, especially when the interface is absolutely commonplace and must compete with other interfaces.

The authors of the paper chose to observe the real world interaction between the public and omnipresent monitors displaying non-critical information in order to find out, among others, if the assumption that passersby will engage in public ambient displays is valid. The researchers observed the interaction with 48 existing monitors in 24 sites within 3 mid- to large-sized cities, each for a time of 1 to 3 hours. They sought to observe how exactly the monitors captured the interest of the public, if at all, namely through studying the placement, size and content the monitors displayed. Interest was inferred from the time passerbys watched the screens. Although the authors of the paper make detailed observations, we will limit ourselves to explaining their conclusions here. These are:

- Displays are practically not looked at, either not at all or 1 to 2 seconds, very rarely up to 8 seconds. Apparently people make extremely rapid decisions about the value and relevance of large display content.
- Displays must be at eye level, anything above, or especially below, does not attract any attention, no matter the content.
- Video, especially of an artistic nature attracts more attention then any other content, although not necessarily longer glances, while non-dynamic content like text rarely caught or held the attention. This seems to validate the artistic value of interfaces as in [4] and the dangling string of [12].
- Other items of interest could draw interest to display monitors if they were level and relatively close.
- Monitors in the path of people, especially if they are forced to face them, have greater chance to attract attention.
- Smaller, more “private” monitors that only one or two people could look at would capture the attention longer than a larger screen (if not with greater frequency), even if there was a larger screen nearby that displayed the same content.

The conclusions of this paper give an insight into design principals for how unobtrusive interfaces may capture the attention if necessary, or on the contrary how to “hide” an interface. Clearly, even large dynamic displays may not overly intrude on a user as long as they are pervasive and commonplace enough.
3. Practical applications

This section focuses on existing or planned devices following the ubiquitous computing paradigm that present themselves as having unobtrusive user interfaces. The first paper we discuss [4] is in the smart home category, presenting the ways with which the energy consumption may be gently transmitted to the inhabitants. The second paper [10] deals with augmented reality, and more specifically how an augmented world can be considered a user interface. The third and final paper [11] presents a wearable computer: a belt with an haptic interface used to transmit directional data. As mentioned in the introduction, these papers were selected as they are examples from three distinctive domains that overlap the domain of ubiquitous computing. Moreover, all three papers detail the efforts they made on their user interface.

3.1. Pervasive approaches to awareness of energy consumption

This paper falls into the category of smart homes, more specifically allowing the users of the smart home to monitor their own energy consumption through slow technology. The authors did not develop a unobtrusive user interface themselves, having worked on the software solution to gather the information and then send the information to display devices. Their system is designed to be highly modular, with the ability to add different hardware meters and output devices as long as they provided interfaces written for the framework used for the software system. The software system also provides a mapping component that allows the output devices to change in function of events in the measuring system, a control system and an database interface.

The interest for the state of the art presented in this paper is that a large section is dedicated to the type of interface they imagine to output the energy consumption in the smart house. The authors point out that usually the only output of the electrical status of a house is a counter which is checked once a year. To make residents of a smart home aware of their consumption, the authors propose to use ambient information systems, and more particularly informative art. The authors believe that the dimensions of artworks (colour, space, form, scale, etc.) can represent different classes of data, so that the information is hidden. The authors present three different examples of such artworks that could present information: a digital painting, an indoor fountain and furniture with light effects (Fig. 3). The digital painting (top) is a modification of David Hockney’s A bigger splash, with the palm trees subtly changing heights to reflect values of power consumption. The fountain (middle) reflects current consumption through the intensity of the running water, a system which presents gently the information in both a visual and auditory manner. As for the cabinet (bottom), the colour of the lighting reflects current consumption. The authors point out that similar dedicated devices already exists, but they believe that by using furniture there is no need for additional appliances.

In this paper, all three devices are unobtrusive, designed to be a natural part of the environment, and require familiarity to know the nature of the information that they transmit. In addition, the information they present can only be read in an approximate manner. However, in the same manner as the dangling string example of [12], it is not necessary to have an exact value, and the nature of the information is such that it never needs to attract attention to itself. These characteristics may in fact be intrinsic to informative art.

3.2. The World as a User Interface: Augmented Reality for Ubiquitous Computing

This paper focuses on mobile augmented reality (AR), presenting the authors’ work in creating such systems, as well as a discussion in the manner through which sophis-
ticated AR systems may be devised. Although AR may involve any of the senses to communicate information to the user, this paper focuses exclusively on using visual information to transmit data to the user. The first part of the paper describes the hardware systems developed by the authors for mobile AR (a backpack computer with a head mounted display and two hand-held systems), as well as various hardware systems for user interface and tracking. Later, the paper briefly discusses the XML models that can describe the relation between the real-world objects and the enhancing digital information. At the end of the document, the methods and logic with which the XML information may be translated to visualisations using input from the real world is discussed.

The part of the paper which interests us is the description of the applications and hypothetical examples which showcase the user interface. Their method is to inject virtual visual information on top of normal vision of the real world, either by creating completely new virtual objects, or by enhancing existing objects to display extra information. The authors clearly state that they sought to make their user interfaces unobtrusive, however, as we will see, the unobtrusiveness of some of the examples they give could be contested, while others are more in line with the stated purpose of this state of the art.

The first application is an outdoor navigation guide for tourism, which provides both navigation cues to guide the tourist and information about cultural artefacts of interest. The navigation works through the means of visual waypoints attached by a virtual line on the ground (top of Fig. 4), along with simple directional information if the user cannot see the next waypoint. The user may also add an arrow pointing directly to his destination. The application also provides cues to the cultural artefacts of interest, indicating them as icons, the user must then simply look at the artefact to have it outlined and have readable information displayed (bottom of Fig. 4). The example provided in the figure is perhaps overly showy, but illustrates well the concept of injecting virtual information into a real world context. One can easily imagine less showy, yet still informative virtual objects being placed to guide the user.

The second application is an indoor guide, which uses a combination of a complete 3d miniature model of the environment with the path to take, along with a virtual path superposed on the users view to guide him (Fig. 5). To better guide the user, the next door to take is highlighted and an arrow shows next door or turn to take. Once again, the example in Fig. 5 is a rather flashy example of augmented reality, filled with jarring colours. And again, one could easily imagine how such a system could be more subtle and we will speculate as to why it is not at the end of the subsection. The third application is an augmented library application, highlighting the book which the user wishes to take, or outlining the shelf to which a book must be put back.

The paper also provides examples of how such augmented reality may be used for pedestrian navigation and for a gas utility company. The pedestrian navigation system would work as in the first and second application. Such a system would seamlessly take over from car GPS navigation when leaving a building using a head mounted display (such as augmented sunglasses) to direct the user to the destination building, highlighting the entrance to use, and if applicable the destinations room window. Within the building, the system directs the user to an elevator, and displays the destinations floor number. Once on the correct floor, the user is directed to the room. With such a system, the user is helped to go to his destination, but he is still free to focus his attention on other tasks, with only a subtle reminder from the AR system.

The gas utility companys example is a little more
complete, again based on the navigation systems from the first and second application and taking it further. The example is of a worker that has to find and repair a gas leak in the field. The system would guide the user, while indicating the location of the pipe within a model. The system would highlight access points that lead to points where the worker could perform measurements to find the leak, and once in place, it would also show the planned excavation volume and additional structures within it. Those that are above the pipe (and therefore most relevant) would be highlighted in bright colours, but rendered translucent to enhance the perception of the main structure, while lower structures would be darkened as they are not important. Dangerous areas would also be specially highlighted and marked with appropriate signals to indicate the nature of the danger. This example illustrates best how AR can provide information unobtrusively, subtly giving greater importance to relevant structures, while decreasing the visibility of unimportant ones. Yet in situations such as dangerous areas, the system can still force the attention of the user to the dangers (as it should).

In the last two examples the paper describes user interfaces that are far more sophisticated and subtle then the first three, especially given the examples in Fig. 4 and Fig. 5. In the figures the virtual artefacts clearly clash with the real world and there are at least two possible reasons for this. The first is that the authors wished to make sure that the reader of the article could distinguish the virtual objects to show their intent. The second, more likely, is that the existing technology could not support a more subtle rendering of virtual objects, either through lack of processing power on the mobile devices, or due to the lack of sufficiently advanced software (or maybe both). Still, the paper earns its place in this state of the art for both showing the state of unobtrusive interfaces in AR, as well as describing the direction in which they wish to take it.

3.3. ActiveBelt: Belt-type Wearable Tactile Display for Directional Navigation

Our interest in this paper resides in two points: the first is the methods that the authors used to make its kinetic interface as unobtrusive as possible, and the second is that they tested their concept with subjects in order to refine their ideas. As such, it provides a solid basis for an ubiquitous unobtrusive kinetic user interface.

This paper itself describes a belt augmented with 8 vibration motors and a GPS (Fig. 6). Its aim is purely direction, guiding the wearer to his destination, or providing other directional information. The authors are of the opinion that such a device provides relatively unobtrusive information, and moreover is suitable for daily use in mobile environments. To make sure that the device isn’t too intrusive, the researchers chose to have a variable intensity from 33Hz to 77 Hz, which is perceivable but far under the band of 200Hz to 250Hz to which human skin is most sensitive. For the navigation, the direction is provided by a specific vibrator, while distance is provided by pulse information of the vibrators (as the user becomes nearer, the intervals become shorter). Application-wise, the authors propose four uses:

- FeelNavi, a simple navigation application
- FeelSense, a location-aware application that vibrates in the direction of locations that the user has expressed an interest (e.g. boutiques or restaurants)
- FeelSeek, an application that detects if the user has forgotten to take important RFID-enabled objects (e.g. a wallet with an RFID chip), and first activates all vibrators to warn the user, then guides him to the lost object
- FeelWave, an entertainment application that transmits rhythmic vibration in sync with music.

The FeelNavi application was tested by six subjects, aged 21 to 30, that had never used the belt before. Through the tests, the researchers were able to validate the functions of the belt, and receive calibration information for the length of the vibrations pulses. Other conclusions that the authors received from the test subjects are the following: vibrations on the back are less well perceived than on the abdomen, four vibrators may be sufficient for direction, and finally that the application should only transmit information when the user is lost, as otherwise it is not desirable.

4. Conclusion

As was suggested in the introduction, papers on this topic are few and far between. This indicates that while a promising avenue of research, work in unobtrusive interfaces for ubiquitous computing is not commonplace. The papers presented in this paper confirm this view, as clearly recent user studies only begin to delve into the opinions of users on ubiquitous interfaces. The papers on existing devices also reflect this opinion, as no two, whether those presented here or those not selected, have a common methodology or an existing pattern to conform
Fortunately, some general trends seem to underline the papers: the necessity to keep the user interface discreet, even invisible when not needed, the idea that it must be "natural" or intuitive, or even the concept that it should be, if possible, artistic. Still, these trends are not clear and have not yet, to our knowledge, been validated in studies, possibly due to the prototype and exploratory nature of the ubiquitous devices themselves. The final conclusion of this state of the art is thus that despite the time since [12] and the work done in ubiquitous computing, research into unobtrusive interfaces is still in its infancy.

5. References


