Interacting with the Ubiquitous Computer –Towards Embedding Interaction

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Abstract

Computing and communication technology is widely used and integrated in devices, environments, and everyday objects. Even with major advances in technology the vision of ubiquitous computing – from a user perspective – is not yet achieved. In this paper we look at new forms of interaction that will help to interact with the ubiquitous computer. In particular we introduce the concept of *embedded interaction* and *implicit use*. The focus of the research is on embedding information into people's environments. Currently massive amounts of information are available. However, delivering it to the user in a way that is pleasant and not annoying is still a challenge. Observing mobile phone information push services, it appears that endless information is available; however, much of the information is interesting only in a very specific context of use. We investigate how information can be provided to users – exactly when and where it is needed. Our approach is based on a variety of information displays unobtrusively embedded into the user's everyday environment. We place the information displays in context. In contrast to the traditional approach on context-awareness where a context is recognized and then the appropriate information is delivered, we look at providing information already in context. It is up to the user to make use of the provided information or not.

1. Introduction

Processing technologies can be found in many devices, objects, and artifacts of everyday life. Computing has become ubiquitous, people often have several computing devices, many of them are networked and in many parts of the world connectivity is always and everywhere available. It seems that the technological requirements are largely met to enable ubiquitous computing, as envisioned by Mark Weiser [15]. However, looking at ubiquitous computing from a user's viewpoint it appears that these ideals are still far away.

From a user interface perspective, a central vision is that the environment itself becomes the user interface [7]. People go about their daily life and perform their tasks while the computing technologies embedded in the environment are there and support them transparently. People are interacting implicitly with the computer [10], the technology disappears into the background [3]. Such environments provide people with information just where and when it is needed and capture information right at the point when it is created.

In this paper, we first look at implicit and explicit interaction and a resulting new design space for ubiquitous computing applications. Then the concept of embedding interaction is introduced. The aspect of embedding information is investigated in more detail. In a scenario we introduce the basic idea of embedding information. Using the specific example of weather information we outline potential devices and use cases. We then discuss a set of basic design criteria for embedding information. In a further section we show our current developments and present an initial user study.

2. Implicit and Explicit Use

Human-computer interaction research is mostly concentrated on interfaces for explicit use. Most current interactive systems are implemented based on graphical user interfaces (GUIs) and widgets and designed for explicit interaction. This is however only a small part of the design space for interactive systems from a ubiquitous systems point of view.

2.1. Design Space for Interaction

In Figure 1 we depict the extended design space (dark area) for interactive systems enabled by ubiquitous computing. First we discriminate between explicit and implicit use. Explicit use means that a user is operating a system knowingly to achieve a certain goal. In this case the user is fully aware of the tool he or she is using. Implicit use, in contrast, is the use of systems where the user concentrates on his or her prime goal or targeted activity. The use of the tool is intended, but the user is not actually aware of the interaction with the computer system. The interaction with the computer is done implicitly, but on purpose, this is in contrast to the idea of incidental interaction [2].

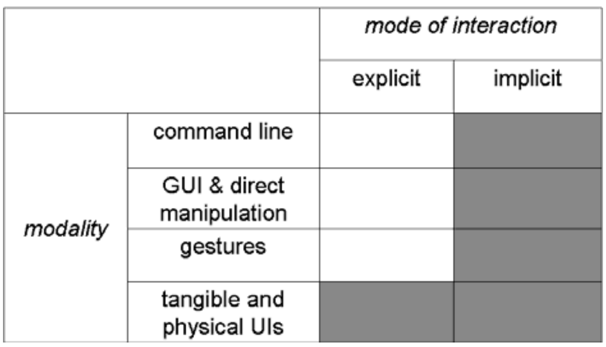

Figure 1: Considering implicit use and physical interaction enlarges the design space for interactive systems.

2.2. Implicit Interaction

Implicit interaction describes a new form of interaction. Implicit interaction can be used in graphical user interfaces, e.g. by observing and analyzing mouse movements and interaction events the system attempts to get some knowledge about the user. Another example for implicit interaction is a command line tool that observes the time a user needs to type a command and, based on this, provides additional information or help to the user.
We use the following definition of implicit human computer interaction (iHCI).

Definition: **Implicit Human-Computer Interaction (iHCI)**
iHCI is the interaction of a human with the environment and with artifacts which is aimed to accomplish a goal. Within this process the system acquires implicit input from the user and may present implicit output to the user.

Definition: **Implicit Input**
Implicit input are actions and behavior of humans, which are done to achieve a goal and are not primarily regarded as interaction with a computer, but captured, recognized and interpreted by a computer system as input.

Definition: **Implicit Output**
Output of a computer that is not directly related to an explicit input and which is seamlessly integrated with the environment and the task of the user

3. Embedding Interaction

Our research is concerned with ways of embedding interaction. Embedding interaction is twofold. On the one hand this is concerned with embedding technology, e.g. Smart-Its [6], which enables integration into artifacts, devices, and environments. On the other hand, on a conceptual level, it deals with embedding the interaction into the user's task or action, see Figure 2.

3.1. Embedding Interaction Technology

In many artifacts, devices and environments, computing technology and user interfaces are included. This includes technical devices such as household appliances and power tools. In these cases including processing and UIs is just a step from providing a functionality electronically that has been mechanical before. By the embedding of technology in everyday objects, new qualities can be achieved. In [12] a wireless locking cylinder is described, that is commercially available. Using a wireless key the user enables the device and can then manually open and close the door lock – similarly to turning a key. A further example is an automated door at a supermarket. Sensors, actuators, and potentially some processing are seamlessly embedded. The technology is hidden and people rarely are aware that they interact with a system when walking through such a door that automatically opens before them. However, when people want to achieve a certain goal they use the technology fully aware of its function. To keep the door open, they explicitly use the controls available (e.g. put something in front of the sensor) to achieve their goals (e.g. keep the door open).
This shows that embedding of technology does not necessarily implicate how people are using the system. Something that is perfectly embedded and hidden can still be used explicitly. Similarly, technology that is not embedded but used often and known very well by the user can by used implicitly – without the user being really aware of it.

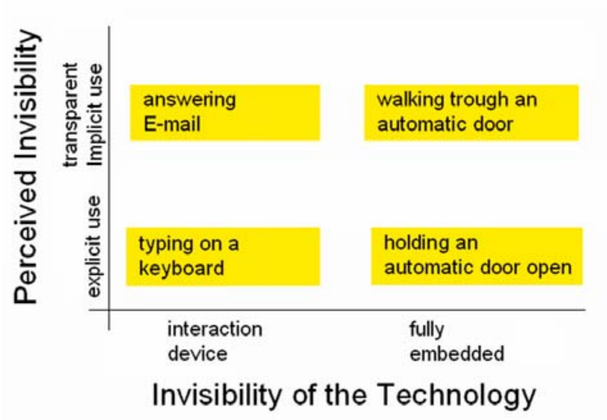

Figure 2: Embedding interaction has implications on the perceived use and is dependent on the technical implementation.

3.2. Embedding the interaction procedure

In most cases in everyday life people are performing actions to achieve certain goals. In work environments these goals can often be directly named, whereas in informal settings and in home environments goals are often more difficult to describe.
Environments, objects, and tools are facilitated in the process of performing actions or when doing a certain job. Depending on the familiarity of the task performed the tools are perceived differently. If one is unfamiliar the objects and tools used are central in the user's awareness, whereas for tasks that are well trained the awareness of the tool ceases (e.g. driving a car for the first time vs. driving to work the same route everyday).

3.3. Humans and Invisible Computing

As motivated above, invisibility is not primarily a physical property of systems; often it is not even clearly related to the properties of a system. In this section the factors that influence the perception of invisibility are discussed. Investigating the effect of making everyday artifacts part of the digital world brings up the inherent dilemma - invisibility vs. added value.

3.3.1. How to Perceive Invisibility

It is not disputed that invisibility is a psychological phenomenon experienced when using a system while doing a task. It is about the human's perception of a particular system in a certain environment. Taking this into account invisibility has four factors that have a major influence: the human, the system, the task, and the environment, see Figure 3.
Only the relationship between all of them can determine the degree of invisibility that is experience. Again, the degree of invisibility is hard to assess. Going along with Normans' argument ([9] p.52) that the system becomes a natural extension to the task the following test can be helpful. The simple question "*what are you doing?*" can help to reveal the basic relationship between the tool, the user and the task. If to

this question the tool is mentioned already the tool is central to the user's attention. If only the task is mentioned the tool has some degree of invisibility to the user. By detailing the question further: *How are you doing the task?* and *What steps are you performing to accomplish the task?* the tool will be mentioned eventually.

These questions can help to understand how much the tool is on the user's mind and how much he or she is taking the tool for granted and concentrating on the task. But in the same way the weakness of the concept of invisibility becomes obvious. Imagine you ask two people who are writing a text document. One person uses the text based Unix programs *vi* and *latex*, the other one using a graphical word processor on an Apple. Assuming that both have been using the system for a number of years the answers – and also their psychological perception of their tool – will in many cases not differ much. Both will probably have formed a relationship with the tool so that it is used subconsciously.

This gives evidence that the degree of invisibility perceived is strongly related to the familiarity of the tool for solving a particular task. This puts into perspective the notion of a "natural extension" [9] and the idea of "weave themselves into the fabrics of everyday life" [15] as this could be achieved by training the user. For many tasks there are no natural ways of doing it, take manual writing – children spend years in school to learn it. Nevertheless in many cultures writing is considered to be natural.

Invisibility to some degree can be achieved for any tool – it does not matter how awkward it is – if the user spends enough time using it. This notion of invisibility does not relate to the basic ideas of ubiquitous computing. Therefore when considering systems the **immediate invisibility** is an interesting criterion. This is the question about how obviously can the tool be used to solve a task building on the common knowledge a user has.

3.4. The Invisibility Dilemma

The physical disappearance and in particular embedding has also an effect on the user's perception. Especially when digitally enhancing artifacts that are known and used in everyday live, the physical invisibility of the technology plays a significant role.

When building computing and communication technology into everyday objects and environments there are two conflicting goals that pull the design in opposite directions:

Goal 1: invisible integration.
The technology that is needed to make everyday artifacts a part of the digital world should be invisible. The perceived affordance of the artifact should not be changed by technology. With regard to the usage of the object there should be no change to the behavior – the technology should be completely transparent.

Goal 2: added value.
When digitally enhancing everyday artifacts there should be an added value for the user. The added value can be on the artifacts themselves or in the overall system.

As investigated in the project MediaCup [5] these goals appear in the first place not to be conflicting. In particular, assuming the constellation that the artifact is enhanced and the added value is in the backend (e.g. a coffee cup provides the location of the user and on a map of the building activities are visualized). However, the first goal also includes that people do not change their behavior as the technology is transparent. But offering added value will stimulate human creativity to exploit what is available.

Even if an artifact only senses information and provides this to the system it becomes a handle for the user to manipulate the system. As humans are creative to find ways to use technology in a way to efficiently achieve their goals, they will change their behavior to optimally exploit the capabilities of the system.

This does not question the design of transparent and invisible systems but the designers should be aware that people will make use of the added value provided – often even in an unintended way.

In the remainder of the paper we describe a current experiment where we look at the aspect of embedding information into peoples living and office environments.

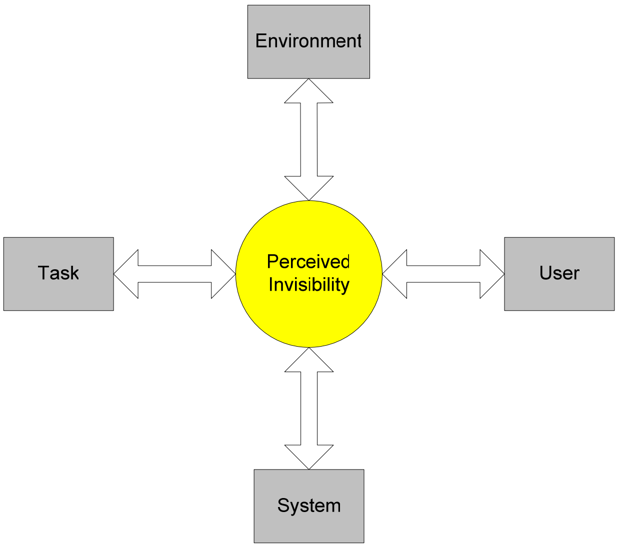

Figure 3: The perceived invisibility of systems and applications depends on several factors. How the technology is integrated into the system is just one factor, the user, the environment, and the task also have a major influence on the perceived invisibility.

4. Embedding Information

Potentially everyone has access to enormous amounts of information nowadays. Much of the information available is, however, meaningless to a specific user at most times. A person driving in Munich city centre has most probably very little interest in information about traffic jams on the motorway around London. Location and context-aware presentation of information is regarded as a general way to tackle this problem [1]. In this area much research is aimed at mobile devices. Different products are available for mobile phones. Here the context is estimated based on sensed information (e.g. the cell-location). A basic problem remains – all these contextual information services share a single device on which they are delivered and they potentially require user interaction – even if the information is not of interest to the user. Recognizing the context and delivering the right information at the right time in the right place is still a difficult problem. And it seems that people are easily annoyed if they get 'wrong' or already known information pushed to their phone.

We suggest a different approach for contextual information delivery. Instead of detecting the context, we place the information – by the choice of the information display - in context. The assumption is that in future we can afford environments where there is a massive over-provision of displays. Displays are regarded as very specific information appliances [8]. We want to investigate environments where a large number of displays is distributed and casually available to the user. Our first step is to provide additional information at decision points (e.g. what should I wear, do I go by bike or by car, should I take the umbrella or not, do I have a meeting today) that help to make a more informed decision.

4.1. Scenario

In the following scenario the envisioned concept of embedding information is outlined. This scenario is also the basis for our prototypes described in Section 6. For the prototype we concentrate on a limited number of embedded displays.

Mary is working at an insurance company in Munich. She lives out of town and commutes by public transport. She often spends the evening after work in town meeting friends. It is a day in August.

When she gets up in the morning, the display on the wardrobe shows that the temperatures today will be pretty high and that she has a formal meeting with a customer in the afternoon. Mary chooses appropriate clothes for the day and dresses. The shelf where she keeps her bathing costume is illuminated. She decides to take things for swimming with her – perhaps there is a chance to meet with her friend Anne and go for a swim after work. In the bathroom, the shelf where the sun cream is kept is also is illuminated but she thinks she will not need it today. On her way out Mary sees that the umbrella stand is slowly flashing – indicating that there is a low probability of rain. She thinks to herself perhaps there is a thunderstorm in the afternoon and takes the umbrella with her.

The scenario above illustrates several instances where information is embedded at places where decisions are made. It is not tried to detect the awareness of the user. Hardly any actions are taken to draw the attention of the user to the information device. The displays are unobtrusively integrated in the environment.

4.2. Embedding Weather Information

There are various sources of real-time information on the internet providing information on many different topics, e.g. RSS news feeds. Similarly, information push services are available for mobile phones. In our current research we concentrate on weather information and how to embed this information into the environment of a user.

The following examples outline how weather related information can be integrated into objects and places.

4.2.1. Temperature forecast for one day

The temperature forecast over a single day is currently very precise and can be obtained on a fine-grained town by town level. People use the information about the expected outside temperature when they choose clothing, for planning activities, or deciding on the means of transport they are using.

Typical objects and environments where this information can be embedded into are places where decisions are made that relate to dressing and leaving the home. The following examples illustrate this:

- **Wardrobe Display**
  We extend the idea presented in [17] and add a display to the wardrobe. Information about the weather helps to decide what to wear. If the user knows already what to wear he or she can easily ignore the information without effort.
- **Shelf Display**
  Displays to highlight shelf space and objects in the shelf can suggest to the user to take things for specific activities or in particular circumstances. E.g., if it is going to be hot, the shelf with the bathing costume is highlighted and if it will get cold the shelf with the gloves and scarf is highlighted.
- **Key Display**
  Integrated in a key or a key chain can be temperature information that, e.g., indicates dangerous driving conditions, like below 0°C.

4.2.2. Probability of rain

For many areas information about the probability of rain is available. This information is not as precise as the temperature forecast but gives a good indication whether or not one has to expect rain. Similarly, people use this information when they decide on dressing accessories as well as on the means of transport.

The following objects demonstrate potential objects in which this information can be embedded.

- **Umbrella Stand Display**
  A display on the umbrella stand that visualizes the probability of rain during the day can help the user decide whether or not to take an umbrella. We envision a visualization that gets more explicit but not obtrusive the higher the probability of rain is, e.g. flashing LEDs.
- **Key Table Display**
  Providing the information of rain probability on the key table can help the user to make the decision what means of transport to take. E.g., when instantly recognizing that the rain probably is close to zero per cent the user may take the bike instead of the car.

4.2.3. Sun intensity

In many areas information about current and expected sun intensity is available. Especially when preparing for outdoor activities, this information is relevant to decide on sun protection, an issue that is getting more and more important. Here a mechanism similar to the shelf display can be used.

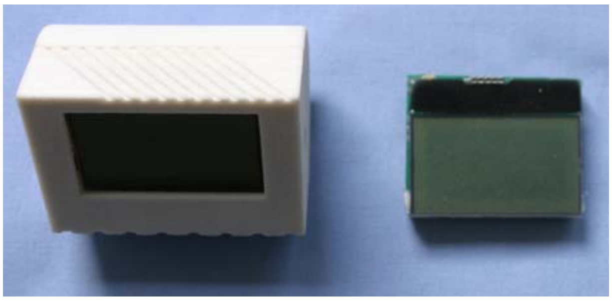

Figure 4: Low cost graphical LCD-displays connected to Smart-Its Particles hardware as basis for experimental cheap wire-less displays environments.

Figure 5: Graphical display, LEDs, and sensors included into a coat hanger as embedded weather display.

5. Design Criteria for Embedding Information

When embedding information, the possibilities and opportunities seem endless. In contrast to a single mobile device that delivers information always to the person, we deliver information always into a context. The basic principle behind our approach is over-provision of information displays. The following design criteria are central when embedding information.

- Embedding information **where and when it is useful**
  It is central to provide information in such a way that the user can benefit from it. Usually information is embedded at points where decisions are made or where the user has choices. The information provided should increase the user's ability to make an informed choice.
- Embedding information **in a most unobtrusive way**
  The information provided should not be forced onto the user's attention. If possible, it should be embedded in a way giving the user the right clue without becoming an annoyance. Concepts of ambient media [12] and calm technology [16] are considered as a basis.
- Providing information that **no interaction is required**
  It is essential that there is no action required from the user when information is provided. This requires dedicated information displays that are only used for providing a specific type of information.

6. Prototyping Embedded Information

At the moment we are building different prototypes of embedded information displays (see Figure 4). We are in particular interested to use technologies that would be extremely cheap, especially in larger quantities. Therefore we limit ourselves to wireless display modules with little processing power (PIC18F6720 Microcontroller), small wireless network bandwidth (about 128 kbit/s), and a variety of displays ranging from simple indicators (LEDs) to small graphical LCDs (96x48 pixel), see Figure 4. The prototypes of the wireless display units are built on top of the Smart-Its Particles platform [5]. We deliberately chose not to use PDAs (or disguised PDAs) as we anticipate, in the long term, systems with hundreds of displays and we want to explore what minimal displays are useful for.

We are currently working on the following specific displays:

- Wardrobe Information Display (see Figure 5)
  The wardrobe information display is a wireless LCD display. It is a graphical I2C-display connected to a Particle module. It can be used to display short texts and small graphics.
- Shelf illumination display
  This is a simple display that can draw the user's attention to a specific location in an unobtrusive way. It consists of a Particle with LEDs connected. It can be used as binary display or to display a level (percentage).
- Umbrella stand display
  The umbrella stand display is very specific for visualizing the rain probability in context. Here we experimenting with using different LED colors and patterns to be unobtrusive and still able to catch the user's attention.

A further concern with a large number of distributed displays is that they have to be maintained or at least powered. Our designs here – even at prototype stage – take this into account and we look at how to create information displays with minimal power consumption. A first and important step to achieve this is to recognize activity in the physical vicinity of the display. For this we include cheap sensors that detect the presence of people (e.g. passive infra-red, light, distance).
The general architecture we assume is that the displays are receivers and that there are one or more senders that provide information. Currently we implemented a web server that allows sending information to named display via a http-get interface. Another possibility is that the displays select from the provided information that is broadcasted the information they are designed or registered to display.
The system setup we use in the first prototypical implementation and for deployment to users in our study will consist of a notebook-computer connected via a DSL-modem to the internet. This will retrieve information from web pages and RSS news streams and from our database. Information is sent to the Particles via a RF-LAN network bridge (Particle XBridge) that wirelessly broadcasts the information received as UDP packets. Each unit consists of a Particle that has a display unit attached. The displays receive the broadcast messages and select the information that is of interest to this particular display, e.g. based on the Particle ID or the data type in the messages. For more information on the used hardware see **Error! Reference source not found.**.
After completing the system and extensive tests we plan a two

to four weeks study in people's homes investigating the potential of embedded information. We want to compare embedded information to information that is pushed to a mobile device using SMS/MMS. In particular we are interested in:

- Where and how do people want information to be embedded?
- How well informed are people when using embedded information?
- How do people rate the added value of such a system?
- How annoying do they find embedded information compared to pushed information?

7. Conclusions

We suggest the idea of embedding information as a form of achieving contextual information delivery. In this paper we have presented our initial idea of putting information in context and we outlined the basic principles of embedded information displays – embedding information where and when it is useful, in an unobtrusive way, and in a form that no user interaction is required. We also have already designed and build the necessary hardware components and implemented the basic infrastructure for the deployment to real environments.

Currently we are improving on the software that will be used in a user study in people's homes. We hope to get new insights on how to make useful embedded information displays from this study.

Acknowledgements

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