# *Technology and its Role in the Home*

**Sinem Kuz and Martin E. Brüggemann**

**This paper summarizes the various approaches to Ubiquitous Computing in the home environment. From the theoretical basics, namely the field of Ethnomethodology, we move on to describing the role of routines, pathes and locations in the home. Finally, we describe challenges that must be satisfied before Ubiquitous Computing is commonplace in the home.**

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# *Introduction*

The most recent research in Ubiquitous Computing (UbiComp) suggests that there has long been a wrong focus in the research of *Smart Homes* [11]. For example, Crabtree [1] postulates in [1], that the results from research in the office environment, even though being a subject to research for decades, can not simply be transferred to the home environment. The reason for this, and the approaches that allow research in the home environment, will both be described in the following.

## Ubiquitous Computing

The concept of UbiComp was first articulated by Mark Weiser, he was the lead researcher at Xerox. He understood by UbiComp:

> *"A method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user."* [12]

According to Weiser, the vision of the UbiComp describes the final state of a development in computing.
The first step in this development is called the "Mainframe Era", where many people share one large computer.
The second phase is that of the Personal Computer. The personal computing relationship is personal, even intimate. One has a computer, which contains personal information, and the user directly interacts with it.
The third phase of computing is that of UbiComp. The UbiComp era will, according to Weiser, see lots of small computers used by one user - some of which will be embedded in walls, chairs, even in clothes.

The idea of the UbiComp is that computers will be omnipresent. UbiComp is the method of enhancing computer use by making many computers available in the environment, but making them effectively invisible to the user.

Such UbiComp technologies will bring a lot of changes to everyday life. In fact, research that has been conducted on UbiComp has mainly concentrated on assisting users in home environments - where people spend more time than in any other place.[12]

To this effect, there are representative scenarios for a *Smart Home* [11], that is, a home environment where the concept of UbiComp is embodied. Residential conditions (e.g. light, temperature, moisture) or furniture (e.g. chairs, tables, beds) can automatically adapt to individual users. Phones only ring in rooms where a person is actually present, preventing other people from being disturbed by useless ringing.

But, in the home environment, there are no factors as easy measurable as *Output* or *Productivity.* The main difference to work environments is that these can not be characterized by a common orientation to a shared objective, because in the home we find a diverse range of different concerns, which vary with the number of people living in a household, with their age, stage of life, income, sex or culture.

With the mere transfer of research results to the home environment not being an option, there is the need to replace such terms as “tasks”, “procedures”, “workflow”, “business process”, etc., all of them derived from the vocabulary of business administration, with a concern for the “stable and compelling routines of the home” [2]. This rather new field of research is called ethnomethodology, a term initially coined by Harold Garfinkel in the 1950s [4].

### Ethnomethodology

Routines - in the meaning of “repetitive tasks” are the *glue* of our everyday life: they enable us to perform our daily tasks without constantly having to make new plans of what to do next or how an object is to be used.

Ethnomethodology (literally, 'the study of people's methods') is a sociological discipline which focuses on exactly this perception of action and objects; on how people perceive the world and how they use these environmental stimuli.

## *A new approach: Studying routines in the home*

Now that we saw the transfer of former research results to the home environment being inappropriate, and have laid the methodic basics, we are presenting a new approach of studying routines in the home. The benefit of this is explained at the end of this section.

### Why Study Routines?

In the research community, it is agreed that the home can be augmented by making it more connected, both inside and outside. The “inner” connection means that the UbiComp devices inside the home are aware of each other and do not cluster in “Islands of Functionality”. The “outer” connection allows the home to provide communication options to its inhabitants (For the latter, see [2]). This would lead to an increased feeling of social connectedness, better time management and more entertainment options.

To identify the ways in which an average home can be augmented to become a Smart Home, it is important to gather knowledge of routines, pathways and the types of messages used across them.

### Types of Messages

In the home environment, there are five types of messages: *Reminders/Alerts*, *Awareness/ Scheduling Messages*, *Notices*, *Visual Displays*, and *Resource Coordination Messages.*

1. *Reminders and Alerts*, e.g. To-Do lists or Post-It messages on a desk are used as memory triggers. They are the most common type of messages in the home and are highly time-sensitive.
2. *Awareness and Scheduling Messages* are the second most common message type in the home and are used to know who is currently where. To be able to transform facts like the presence or absence of cars or shoes into useful information, one needs to have knowledge of details about the daily routines of household members.
   Awareness and Scheduling Messages are not as time sensitive as Reminders and Alerts, but they are critical to the smooth functioning and to the coordination of the household.
3. *Visual Displays* are to be shared with other household members. They are pieces of infrequently updated information, for instance, a child's drawing on a fridge.
4. *Notices* provide household members with information about activities or people outside the home. They are often shared between household members and therefore publicly displayed. Unlike Visual Displays, they are more frequently updated.
5. *Resource Coordination Messages* are used to coordinate the sharing of common household resources, like the TV or a car.

### Pathes and Locations

The different messages types introduced above tend to group themselves along pathways through the home [2]. Along these pathways, household members maintain a type of priority system, a set of places to check for information in a certain order. This "maintaining a priority system" can be seen as a *routine* which itself triggers message positioning along this pathway:
Because household members know about the pathways of others, they can use this very information to decide where to put information, so that it is seen duly. Such places where to put information (in short: *locations*) develop their social meaning over time, but once such a meaning has evolved, they become a strong shared language in the home (Elliot et al.).

For example, the mother knowing that her son will check his e-mails as soon as he arrives at home can deduce from this knowledge that it is best to leave important messages at his PC-monitor, because that is the *location* where the message will reach him on time.

In addition, the prioritization along the pathway can be used to express *information dynamics*: Messages will change their location over time, symbolizing the status of the message thus transported.

Crabtree [1] separates such "locations" along the pathways in the home into three types: *Ecological Habitats, Activity Centres* and *Coordinate Displays*:

1. *Ecological Habitats*: The various media used for our everyday communication exist in certain places where they can be easily retrieved whenever they are needed.
2. *Activity Centres*: Places where media are produced or consumed (e.g. the easy chair where one watches TV), as well as places where information is transformed into messages for other household members.

3. *Coordinate Displays*: Refers to places where media are displayed and made available to others to coordinate their activities (e.g., a pinboard in the kitchen). Such displays are routinely constructed from out of the flow of communication media for means of coordination.

Elliot et al. add, that locations can be *static* (e.g., a desk or table) or *dynamic* (e.g., a wallet). Furthermore, according to their results, the number of locations in a home varies widely, but in general it can be said that the larger the home, the more locations present and the more independent adults in the household, the more locations there are [3].

## Locations and Meta data

Depending on the type of location used, important metadata is attached to a message. Basically, there are three types of such metadata, or contextual data:

1. *Time*: This type of contextual metadata transports information about *When* others need to interact with a piece  information.
2. *Awareness*: This refers to the actions and locations of others, an example of which would be the placement of messages along pathways in the home, as described above.
3. *Ownership*: With that kind of contextual information, the sender of a message can define the recipient(s), or in short: *Whom* information belongs to and what needs to be done with it.

   The *Ownership* attribute can be further distinguished by looking at its different subtypes: In the home environment, the are four main types of:

   - Public Information, which is owned by everyone in the home
   - Public Subset Information, which is public, but only intended for use by a subset of household members
   - Personal Information, that is publicly visible but intended for only one individual and
   - Private Information, this being intended for only one individual and therefore not publicly visible or usable by others.

This ownership, no matter of which subtype, may vary by time or activity.

With this knowledge of message types, pathes and locations in the home, it is possible to approach the placement of UbiComp in the home in a complete new way. This is subject to the next paragraphs of this paper.

# *Using the results for situating UbiComp in the home*

## Identifying Prime Sites: Overlapping Locations

Some locations overlap with others. This overlap is of direct relevance to the design of Smart Homes, because such a location already attracts various kinds of messages, and is thus a *Prime Site* for augmenting a home.
One example for such an overlap is also referred to by "Convergence of Media":

Locations tend to be grouped. One will normally cause others to form nearby, e.g. communication media (e.g. phones) and technology (e.g., computers) also attract non-digital messages.
Since technology is less portable than a sheet of paper or even a phone book, messages typically comes to them, so the phone book will be found near the phone in most homes.

This illustrates that paper-based media are easier integrated into the home environment than digital media. To break the dependence of digital information to a bearer medium (an e-mail being restricted to the PC), users often transform digital media to paper by printing them out or by leaving paper pointers (e.g. a Post-It referring to an e-mail).

## Building on Communication Places: Augmenting Artefacts

Once identified, *Prime Sites* can be augmented by UbiComp. Essentially, digital media need to be more flexible in how they can be moved to and from ecological habitats, manipulated at activity centres, and how they can be placed at coordinate displays to be viewed by others.

When augmenting an artefact, it is of high importance to do so in a 'natural' and 'intuitive' way. If the change is changing the semantics of what an artefact is or what it is doing, and may therefore confuse the user's mental model of an item: Sometimes, an artefact may even have to be redesigned in order to make its new semantics understandable to the user.

## Augmenting Actions

Opposing to the approach of augmenting artefacts, Crabtree et al. point out that it is instead actions that need augmenting: With the mulitple types of media grouped in a communication place, it is not necessary to further add functionality to the individual media. It would be of higher value to the user, if he or she had assistance in *coordinating the actions* performed here (See [1]).

The risk in such augmenting, no matter of augmenting actions or artefacts is that UbiComp devices intended to provide assistance may disrupt the doing of routine sequences of actions

through supporting them.
One reason for such disrupting can be that a user is forced to switch from routine activities to description activities, which is the case every time a device needs interaction.

This and other challenges will be described in further detail in the next section of this paper.

## *The Challenges*

Recently, a number of trends have increased the probability that the Smart Home can soon become reality.
Settings such as the *Aware Home Laboratory* at Georgia Tech can teach us about what a Smart Home could provide to its inhabitants.
Nevertheless, the idea of the Smart Home raises many questions which have to be answered before the vision of the Smart Home can become reality.
These questions are based on studies, research and analysis of the adoption of other domestic technologies in the domestic life and can influence the design and evaluation of technologies for the Smart Home.

### How will occupants understand their complex and unpredictable home?

Today, the infrastructure for UbiComp does not yet exist in homes, so houses must be explicitly equipped for this new sort of devices.
Homeowners might also want to adapt these technologies by upgrading their homes.
Consequently, old homes will suddenly become *smart* - and this will make the home environment more complex and unpredictable.
For example, when a neighbor's stereo starts using one's Bluetooth speakers. The user will be confused, because he or she does not understand why the speakers do not work the expected way.
The reason for such an "accident" is that Bluetooth speakers, when first installed, connect themselves with the nearest sound source, in this case the original homeowners stereo. The homeowner may not realize that wireless technologies offer such functionality, and can connect themselves to devices in another house just as easily as to devices within the home.

The general question is what might happen when our homes will be filled by this sort of *smart* devices - and if this will make our homes unpredictible.

The challenge for the designers of the Smart Home [11] is to help users to understand questions, like:

- How do we make the system intelligible? (e.g. wireless connections)
- How can I tell what is interacting?
- What are the possible configurations of my devices?
- How do I control the devices and the entire system?

The challenge for homeowners with such devices will be to understand the modification of their house from “dumb” to “clever” and to manage that modification.

### Will we have “Islands of Functionality” in the *Smart Home*?

The Smart Home will be equipped with many devices and softwares. As mentioned above, such systems and devices should be intelligible and should have the ability to interconnect and interoperate with one another without advanced planning or implementation.

Without this, the Smart Home will consist of “Islands of Functionality”: devices of singular purpose which do not connect to other devices or services. The challenge is that every software or device must be programmed to understand every other type of software or device.

For example, an application with printing-functionality should be able to understand the concept of a printer. This illustrates the idea of the standards on syntax and semantic, which is an agreement in the first place. Such standards allow communication with a specific class of devices or services using a standard protocol, such as printing.
Other visions of interconnectivity represent a standardizing communication at the syntactical level (protocols and interfaces) at which the user implements the semantic.
For example, the SpeakEasy project at Xerox PARC uses mobile code to allow devices and services that were not explicitly written to use one another to interoperate fluidly. The end user has the possibility to manage the interconnections among the devices and services.
The challenge for the Smart Home designers is to develop new models of connectivity and interoperability so that systems can work together fluidly.

### How much administration is required for these complex systems?

Nowadays the average computer user has to be able to perform a few administration tasks like installation of new software. The Smart Home will be filled with complex technology.

Such advanced knowledge cannot be expected by “users” of Smart Homes - and two approaches solve this problem:
The first one is to use models of devices without complex administration like single function devices, such as a microwave oven. The challenge for the appliance model is the possibility to convey interactions with other devices without losing the simplicity of the model.
The other approach includes utility models as the phone or cable television network which are maybe more suitable for administration in the Smart Home, since the needed technology is located in the network and not in the home. The user is confronted with the easy functionality to access the network. The challenge of the utility model is to design solutions to protect the network against malicious attacks.
It does not make any difference which model one chooses, some administration, such as configuration or security parameter set-up, will always have to be performed.

### Are the devices really reliable?

People who decide to live in such a Smart Home will expect reliability. The devices that are used in present homes like television or the telephone afford high reliability, even though they are of great complexity. To reach reliability in the Smart Home, designers have to understand the reasons why these never crash unlike desktop software systems. Some reasons include:

- *Differences in development*: By developing domestic technologies, designers try to avoid system crashes which are intractable to repair or update. By skillful and hard work reliable systems can be realized. For instance, telephone switches by Lucent technologies are aimed to have only 10 seconds downtime a year. Such objectives require time and resources. This affects the system design and should therefore be observed while developing the Smart Home.
- *Differences in technological approaches*: Another difference that should be observed is the different technological approach between the domestic environment and desktop technologies. Telephone and digital television systems are present domestic technologies, in which the bigger functionality lies in the network and not in the devices. Nevertheless, devices do not have to be patched or upgraded to take advantage of new functionalities available in the network. For UbiComp applications, one design challenge will be to decide what kind of balance of intelligence to maintain between the edges and the center of the network.
- *Differences in expectations of the market*: The expectations of the various marketplaces is the next big difference between the domestic and desktop technologies. Consumers want to have running appliances in their homes. Based on this expectation magazines offer also information about the reliability of domestic technologies. There are also some organisations that test these technologies before they enter the market.
- *Differences in regulations*: Finally, there are differences in the level of regulations. For example, some utilities have to deliver a certain standard of service and security.

So the designers should create a development culture that can produce reliable devices, should accomplish the wishes of the users, and should work towards regulations.

### How can we manage the social impacts?

One cannot always predict how a technology will develop. For example, inventors of the telephone foresaw a social role for it whereas the providers did not. Nowadays the telephone serves not only for purposes such as emergency calls, but also for the purpose of communication with friends and the family.
The same is valid for wireless telephones. These instances confirm the need of conducting studies of domestic settings and the need of relying on analysis of the fixed routines of the home. It is important for designers of the Smart Home to analyse how new technologies fit into daily routines.
Technology also has other aspects which should be examined, such as social effects. These effects are not as widely analysed by UbiComp members as the challenges that need to be

overcome.
Based on studies of the influence of televisions and washing machines it is not difficult to recognize the social impacts of technology. For example, the idea of washing machines was to reduce the labor of washing day. Therefore these kinds of technologies are called labor saving devices. In connection with other technologies like hotwater heaters, people changed their attitude to hygiene and washing. They do not limit themselves to washing themselves and their clothes once a week.
Thus it can not be said that these devices reduced labor, because the changing attitude caused only a rise of the amount of work. Another example is the social impact of televisions. Many studies of the television show that it has swayed parents to think about the parental care such as good parenting. With the television parents have begun to think about how much and what kind of programs children may watch. In the United States, here are always debates about the content of television programs. Thus "rating schemes" for programs and new technologies like the "V-chip" followed from this discussion. The V-chip is a feature of a television, that support parents to manage their children's television viewings.
These examples underline the truth that technology can have different social impacts when it is placed into the home setting. The designers of technology have to be aware of these consequences and have to recognize that even simple technologies can cause expanded changes like on society.

### How *smart* does the Smart Home have to be?

Some current computer systems, such as *ClippIt*, the Microsoft Office assistant, offer unrequested context sensitive suggestions to users and access to relevant parts of the help system. This machine inference is seen as an advantage for the Smart Home. Some of these systems are based on sensor technology and other systems are based on presumption to conclude the right intention of the user. These sort of devices embody the "Human Intelligence". It is a new form of intelligent signal processing. It is characterized by processing hardware that is inseparably connected with a human being to function as a true extension of the user's mind and body.
One vision of UbiComp is a system in a physical world to ease the daily work of users. The idea is to design a system that can notice the environment and the user. Either of these visions require intelligence in the physical space, which can have different modes. Some of these modes are:

- Based on the sensor data, the system presumes that a person is in an room, because of the "Active Badge" in the room.
- A system can presume the intention of a user from its view of the state.

These modes can make different mistakes, such as a sensor data which assumes that a person is in a room, because of the active badge that is forgotten on the desktop.
But errors like this are more drastic, when a system makes uncertain inferences and acts on them. Systems which are only possible through inference will make mistakes, so the occupants have to know how the system acts, such as how the system knows that a person is in a room.
All these problems affirm that the developers have to design systems, that support users to

understand the semantics of sensors, devices, and machine actions. The inference that is used in the systems should be intelligible and predictible.

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