The Mobile Phone as a Universal Interaction Device – Are There Limits?

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ABSTRACT

This paper reviews the often cited use of personal mobile devices, such as mobile phones and PDAs, for interacting with appliances, such as TVs, light switches, or vending machines. It argues that mobile devices should not be considered tools for general appliance control, but rather a means to assist users in exceptional situations that they do not encounter on a daily basis. To illustrate this paradigm, a prototype implementation for mobile phones is presented and the setup of a user study to verify its value is discussed.

1. INTRODUCTION

Personal mobile devices, such as mobile phones and PDAs, represent an important building block in many of the systems discussed in the ubicomp community. Their widespread use and their characteristics as a general purpose computing platform make them appear as ideal devices for the implementation of many applications. Scenarios involving personal mobile devices range from attaching digital annotations to physical objects, controlling large public displays, and interacting with appliances of all sorts.

While it is obvious that personal mobile devices can provide the technical functionality needed to implement such novel applications, we believe that from a user-centric perspective, their use cannot be justified in some of the commonly cited ubicomp scenarios. In particular, we challenge the notion of using personal mobile devices for universal appliance interaction, i.e., controlling technical equipment, such as vending machines, thermostats, or answering machines, through mobile phones. In this paper, we discuss preliminary arguments supporting our claim and try to answer the question under which circumstances it is appropriate to use a mobile phone for appliance interaction and under which it is not. We also present a demonstrator illustrating our paradigm and discuss the setup of a user study that we will conduct in order to verify our thesis.

2. UNIVERSAL INTERACTION DEVICES

Handheld devices, in the form of traditional, mostly infrared-based remote controls, have long been used as interaction devices for home equipment. However, there are a number of problems associated with this approach. First, given the many remotely controllable appliances typically found in a household, it is not practical to have a separate remote control for each of them. Second, users often need to carry out tasks that involve more than a single appliance. A typical example is switching on the DVD player, which makes little sense without powering up the TV at the same time. Third, remote controls are usually overloaded with functionality that users hardly ever need. An ideal interaction device should be flexible to adapt to its users' preferences and habits.

A number of research projects and also some commercial products (e.g., Philips Pronto[1]) have grown out of these needs. The simple approach taken by commercial products provides users with a conventional desktop application that allows them to design their own remote control by placing button widgets on a canvas mimicking a traditional remote control. The resulting user interface is then downloaded to a PDA-like, pen-based handheld, which uses traditional infrared transmission to communicate with the target device.

The approaches generally proposed in many research projects rely on the appliances providing a software interface that is rendered on the PDA's display for the user to interact with. The handheld is therefore *self-programming*. Using its wireless communication module (e.g., Bluetooth), the handheld transmits the user's commands to the appliance itself, or a proxy that in turn controls the appliance. Systems of this sort are presented by Hodes et al. in [1] and by Ponnekanti et al. with the ICrafter [12]. However, they are still based on laptops as interaction devices. The XWeb [9] infrastructure is similar, but the authors mention an implementation for pen-based devices without going into details. Common to these systems is the notion of abstract user interfaces to allow for device heterogeneity. By combining the abstract user interface description and a design template, the handheld generates a platform-specific user interface that is presented to the user. The concrete user interface is thus decoupled from the appliance.

Nichols et al. developed the idea further in the Pebbles project, where the authors use a PDA as a *personal universal controller* [8]. A similar, PDA-based system termed the *universal remote console* was proposed by Zimmermann et al [15]. Contributions from both projects led to the standardization of the universal remote console framework within the INCITS V2 technical committee [5]. The standard[2] aims to ensure interoperability between devices from different manufacturers.

Other projects like Yates et al. [14] have examined how interaction with household appliances can be extended to support natural language. They therefore propose a system

[1] www.pronto.philips.com
[2] www.incits.org/tc_home/v2.htm

that is based on speech recognition. Another issue in this field is the selection of the active device. In environments with many remotely-controllable appliances, it would be desirable if the system automatically detected the most likely target the user wants to interact with. Kaowthumrong et al. [3] use a Markov model to predict a likely appliance and present the corresponding user interface. This work is extended by Isbell et al. [2]. They try not to predict a single appliance, but to determine the task a user wants to accomplish. Using k-means clustering and Markov prediction, their system is able to adapt the presented user interface accordingly. The personalized user interface resulting from this approach is evaluated in a separate user study [10]. The authors compare it with interfaces that users have created manually in order to make them suit their needs best. Users could freely combine buttons from any device and also create special macro buttons that would trigger a sequence of actions, such as switching on both TV and DVD player at the same time. The study revealed that both approaches have weaknesses. While the interfaces manually designed by users often missed important buttons because people have incorrect models of their own behaviour, the machine learning approach requires a lengthy observation period to discover accurate models.

3. SCENARIOS AND USABILITY

Virtually all of the papers cited in the previous section name a more or less similar set of appliances that are considered controllable by personal mobile devices. Among the often mentioned appliances are video recorders, DVD players, TVs, video projectors, stereos, answering machines, light switches, home security systems, ATMs, elevators, copy machines, cars, vending machines, heating control systems, microwaves, ovens, and washing machines.

There is surprisingly little work addressing the question of which appliances are actually suitable for this new paradigm of interaction, and under which circumstances they are so. Koskela et al. [4] have studied the use of mobile phones, PCs, and media terminals in a household over six months. However, the handheld device could only be used to control lights and curtains in their setting. Rode et al. [13] conducted an ethnographic study to find out which household appliances users choose to program. Their research gives, however, no indication for which appliances a personal mobile device may be an appropriate interaction tool. Moreover, they do not consider spontaneous interaction with an appliance, but focus on the programming of actions for the future, and the creation of macros to facilitate repeated tasks.

User studies investigating the performance of personal mobile devices for the spontaneous interaction with appliances were carried out by Nichols et al. [6, 7] as part of the evaluation of their personal universal controller [8]. They studied the use of a PocketPC to control a stereo and a telephone/digital answering machine. In particular, they compared the performance of 12 subjects when accessing the appliance either using the PDA interfaces, or the interface on the actual appliance. They used three metrics in their evaluation: time to accomplish a task, the number of errors made, and how much external help users asked for. For both the stereo and the phone, a list of tasks was created that had to be completed by each of the subjects. About two thirds of the tasks on both lists were chosen to be easy, i.e., requiring no more than one or two buttons pressed on the actual appliance. The more complex tasks involved five or more button presses. The time to accomplish a task was defined as the total time users needed to work through the complete task list. The authors found that, compared to the user interface on the PocketPC, interaction based on the physical appliance's interface took twice as long, entailed twice as many errors, and required five times more external help.

4. WHAT ARE THE REAL BENEFITS?

While these results seem very encouraging on the whole, we believe that more research is needed in this area. We recognize that there are three main areas where personal mobile devices prove a valuable tool for user interaction in smart environments. First, it is straightforward to use them to access information services, such as voicemail systems, or online media libraries, which might eventually replace VCRs, DVD players, and stereos. Second, they are the device of choice for users to discover the invisible information services available in a smart room or attached to a smart object. Third, it is clear that handhelds are well suited to control appliances where interaction at a distance is desirable, such as heating control systems. However, it is less obvious whether personal mobile devices should be used to interact with physical appliances that require the user's presence to operate, such as ATMs, elevators, or microwave ovens.

In line with this, we find it somewhat counterintuitive that the use of a personal mobile device for playing back voice messages recorded by a physical answering machine is more efficient than interacting with the actual appliance. It is our contention that, for many of the appliances mentioned in typical ubicomp papers and the ones listed above, it is not advisable to use handhelds as interaction devices in order to replace existing physical user interfaces. In most everyday situations, direct manipulation of the appliance is easier, faster, and more convenient than handheld-mediated interaction.

In *special situations*, however, this approach can be of great value. By special situations we mean processes that are performed irregularly and rarely. In these cases, users often face one of the following problems: First, they lack the practice needed to remember the individual steps that have to be performed in order to achieve a specific goal. Second, functions that are not accessed on a regular basis are often not present on an appliance's main user interface, both to simplify the interface for common tasks, as well as to save costs. Interaction is often difficult, as keys change their meaning in special contexts, or special functions are accessible only by a hard-to-remember combination of keys. As the following examples illustrate, we face this problem with several devices in our daily lifes:

- Many ovens can be programmed to start cooking a meal at a user given time. However, as this function is rarely accessed, it is hard for users to remember the programming procedure.
- Recent washing machines tend to offer several programs for a given temperature. It is often difficult for users to remember the exact semantics of buttons labeled "40°", "40°S", and "40°E", for example.
- Many appliances, such as laser printers or VCRs, show an error code on a small display when a problem (e.g., a faulty network interface) occurs. Without consulting

the appliance's long-since lost manual, this error code (e.g., "F602") is incomprehensible and of little value for a user.

In contexts that users encounter infrequently, just like the ones outlined above, a personal mobile device can facilitate the user's interaction with the appliance in two ways. The handheld can either *provide information* or *provide a user interface.*

Information Provision When an exceptional situation occurs, the appliance can support the user by providing detailed information on his or her personal mobile device. For example, by opening the relevant section in the appliance's manual on the user's mobile device, a laser printer could instruct him or her to check the network cabling instead of just showing an error code on its integrated display.

User Interface Provision Functions that are rarely needed and are thus not easily accessible through the actual appliance's user interface are offloaded onto the user's personal mobile device, *without* completely replacing the traditional user interace. In this way, a GUI based on familiar widgets can be built to, for example, program an oven's timer, while keeping the haptic user interface for the everyday tasks of switching the oven on and off.

5. PROTOTYPE IMPLEMENTATION

We are currently preparing a user study to test our thesis that it is in exceptional situations where personal mobile devices are most valuable for interacting with appliances. Using the example of a coffee maker (Impressa S70 by Jura), we will have participants perform various tasks using either the appliance's user interface as designed by the manufacturer, or our own interface rendered on a handheld device. We plan to evaluate three distinct use cases. First, we will test the impact of offloading the everyday task of brewing a cup of coffee onto the handheld. Second, we will examine how the user interface influences users' performance in adjusting the water hardness — a task which is performed only infrequently. Finally, we will compare how difficult users find it to replace the coffee maker's filter when they are given either the appliance's printed manual or a software assistant explaining every step needed.

In preparation for our user study, we have already built a Java MIDlet implementing these three use cases. The user interface for adjusting the water hardness is shown in Figure 1, while Figure 2 illustrates the interface assisting the user in changing the water filter. The user is guided, step by step, through the task. In every step, the system highlights the part of the coffee maker the user must operate next. As soon as the user pushes the right arrow on the phone's keypad, the assistant advances to the next step.

The MIDlet runs on a Nokia 3220 mobile phone. We chose this particular model because it is a very simple phone that offers just the basic features found in most mobiles today. Unlike the devices used in evaluations done by others, the Nokia 3220 does not offer pen-based input capabilities, but has a simple keypad instead. In addition to that, its color display is considerably smaller (128 x 128 pixel). The phone has an integrated Near Field Communication (NFC) module, which allows it to read RFID tags. We use the phone's

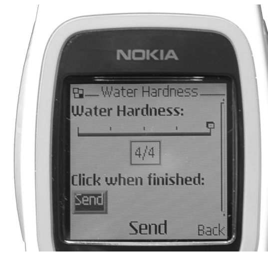

Figure 1: Adjustment of water hardness.

Figure 2: Change of water filter.

NFC module and an RFID tag on the coffee maker to implement the *touch me paradigm* [11], which we feel is ideal for users when interacting with appliances in their proximity. Another advantage of NFC is that it is possible for a device like a coffee maker to transmit status information directly to the mobile phone. However, we do not make use of this feature yet, but employ NFC merely for the phone to identify the appliance. Based on the received identifier, the phone downloads and execute a Java MIDlet containing the appliance's user interface.

Preliminary experiences indicate that the system offers significant benefits to users. As changing the water filter consists of about ten steps and involves the manipulation of physical parts, such as valves and latches, it cannot be easily automated by manufacturers and inevitably requires user participation. For this purpose, the assistant seems to be a very intuitive, yet cost-effective way to facilitate this fairly complex process.

6. CONCLUSION AND OUTLOOK

Personal mobile devices have become an important cornerstone of many ubiquitous computing systems. Apart from fulfilling other functions, they allow users to interact with their environment. While they are undoubtedly an important tool to access both information services and appliances from remote locations, their value as a means to locally interact with physical appliances is less clear. We argue that appliance interaction through personal mobile devices is most effective when it is utilized to assist users in carrying out tasks that are infrequent. Consequently, personal mobile devices should not be seen as a complete replacement for existing haptic user interfaces.

We believe that this hybrid approach of a traditional, haptic user interface, combined with an extended user interface on a mobile device, offers many benefits. Users can continue to directly interact with appliances, which is desirable in most everyday situations. However, in special situations where users would have to remember complex and clumsy sequences of pushing buttons or manipulating the appliance, it is much more intuitive to use a mobile device with its powerful and versatile user interface for interaction. For user interface designers, this is an interesting approach, as it allows them to make use of the full range of possibilities offered by modern GUI toolkits, without the physical and monetary constraints of adding such complex functions as a separate physical control.

Finally, the paradigm presented in this paper is economically attractive for manufacturers. Improving the traditional user interface of an appliance can be very costly. It involves adding means of providing feedback to the user (e.g., LC displays), which, on the one hand, entails additional hardware expenses and might not even be possible due to space constraints. On the other hand, it requires the development of software for an embedded system, which is comparatively expensive. Contrary to these drawbacks, offloading rarely used tasks instead of redesigning traditional appliance user interfaces is a relatively simple endeavor. It is sufficient to develop an application running on widely used and well-supported platforms, such as J2ME or Symbian. Moreover, a software interface can be easily personalized and adapted to the user. A casual user could, for example, be offered a simplified version of the user interface that is presented to a regular user.

We believe that this paradigm is very powerful and will thus continue to evaluate it's utility in a comprehensive user study.

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