User Interfaces for the Digital Home on the basis of Open Industrial Standards[1]

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Abstract. In this paper we describe the design, development and evaluation of user interfaces for a modern digital home based on the ISO/IEC 24752 standard: Universal Remote Console—URC. Two target groups were addressed: seniors aged 65 years and above and people suffering from Alzheimer's disease. Our goal is to design user interfaces (UI) for our target groups that make use of all available modalities, such as, graphics, voice, and video. We provide a set of recommendations and design patterns for developing UIs for seniors and Alzheimer's disease patients. We present the results of tests of user interfaces designed for smart home environment.

Keywords. i2home, intuitive interaction, user-centered design, eInclusion, URC

1. Introduction

In the last couple of years, we could see an increase in the number of networked digital devices in our homes which is why we talk about digital homes. These systems are quickly becoming ambient and thus become a natural part of our life. For young people who are experienced in using computer-based technologies, it is easy to smoothly adapt to these ambient systems. The situation is different for seniors however, who rarely have any experience with computers and who have difficulties to adapt to new technologies. While young people currently drive the economy, seniors are only of small interest to main stream manufactures. However, as the population in Europe is getting older, we expect a growing interest in senior users; the elderly will have a larger purchasing power and attending to the needs of this overlooked group will be a must for the main stream manufactures.

In the EU-funded project i2home, we are focusing on two areas: development of a standards-based technical infrastructure for the digital home and on the implementation of user interfaces for this system for people with special needs. In this paper we report on the results of our efforts in developing user interfaces specially developed for seniors and people with moderate Alzheimer's disease.

Our technical infrastructure provides an integrated environment based on a central hub (Universal Control Hub—UCH) connected to a number of household devices and

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services along with some user interfaces, see section 2. The integration makes it possible to control household devices using a number of different controllers or their combinations.

Our development methodology follows the User-Centered Design (UCD), e.g., [6], i.e. it is essentially the users themselves who are driving the technological development and hence the final user interfaces are tailored to their needs. We understand the UCD methodology as the iteration of a four-phase process. This process will be outlined it what follows. In the **Requirements** phase, personas are developed (see section 3), a STAR for technology established, and appropriate scenarios including a selection of controlled devices (targets) are defined [1,7,5]. In the **Implementation** phase, the basic technological infrastructure as well as the targets get implemented/refined (see section 2), and prototypes of user interfaces are designed and developed in three steps (see section 4): from paper prototypes we move to mockup prototypes and, finally, to fully functional controllers. In the **Testing** phase, the individual prototypes and later the complete integrated environment are tested. Finally, in the **Evaluation** following the testing we use a common evaluation plan, initially using a *qualitative* evaluation to evaluate the different systems, see section 5. The results from one phase serve as the input for the following phase. The project is scheduled for three complete iterations.

2. System Architecture

We base our technical infrastructure on an open international standard ISO/IEC 24752 1–5, the *Universal Remote Console—URC* standard, e.g., [8]. The standard allows for a coherent and standardized low-level interaction with—in principle—arbitrary appliances, devices or services, called *targets*. A *controller* is a device or user interface that is used by a human to interact with the targets via the hub, see figure 1. The standard provides a precise description for how the functions of a target may be described by a *socket description* and a *target adaptor*. The user interface designers/programmers can thus author a UI without the need of implementing low-level interaction, such as powerline, Zigbee or Instabus etc. but can concentrate on conceptual issues. There are several advantages with this architecture: it is easy to replace a user interface with another one since the standard allows for *pluggable user interfaces*. It is possible to share arbitrary resources, such as, socket descriptions, user interfaces, target adaptors, et cetera through one or more resource servers.

For this first UCD cycle, we have integrated the following targets: TV with EPG, a calendar and an HVAC from the serve@home series.

3. Personas

In the first phase of the UCD we have analyzed the target users of the i2home system using Alan Cooper's methodology [4]. We made a number of interviews with the potential users and transformed the results of these interviews into definition of *personas*. Each of these personas represents one target group with a typical set of requirements and properties. Below, we provide excerpts of three personas derived from these interviews:

Blanka (passive persona) is a 73 years old woman who lives alone in a small flat. She has recently moved there so that her daughter Jirina can take better care of her. Blanka has no experience with computers. Her performance with regard to memory, vision and

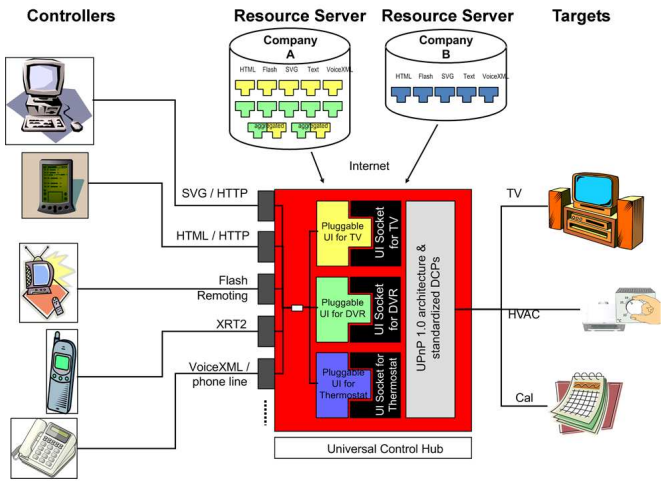

Figure 1. A depiction of the Universal Control Hub. To the right are the targets, in this case a Home Movie Center, HVAC, and a calendar. Possible controllers are on the left side. Note that a TV can act both as a controller and as a target. Above the hub, two resource servers providing, for instance, target adaptors and/or user interfaces are depicted.

hearing is in decline but is nevertheless self-sufficient in her everyday life. TV has become the major interactive point in Blanka's household. She has major problems with new devices like state-of-the-art TV remote control, DVD or digital radio. Moreover, she is afraid to touch unfamiliar devices: as she might be unable to reset it to it's initial state. Blanka feels inferior when she has to ask her daughter for help. More complicated operations will always be done by her caregivers or relatives.

Arnost (active persona) is a 68 years old man who recently retired but still maintains his hobbies and keeps in touch with his colleagues from work. He has gathered some experience with computers during his time at work. He wears glasses, can operate a cell phone and a PDA but has minor problems with small fonts.

Manuela (passive persona) is 73 years old woman who has been diagnosed with Alzheimer'S Disease (AD) three years ago and who now attends a Daily Care Center. Manuela does not take her daily medication but she is still able to perform simple tasks under supervision. She will become progressively more dependent. Manuela can answer the phone when she hears it but as dialing causes her problems she tends to avoid it or wait for somebody to help her. Despite her anxiousness to fall, Manuela still goes out alone to make small shopping. However, she usually goes out with her daughter or grandson.

In addition to the personas above we have defined additional personas that represent care givers and other seniors, who are also potential users of the i2home system but are not the primary users of it. During the recruitment for the evaluation we match the person to be tested to one of our personas in order to get results that are relevant.

4. User Interface Design

For each of the defined personas a customized user interface was developed. For Blanka and Arnost, the selected set of controllers was a graphical user interface implemented

on a touch-screen enabled PDA or a TV. For Manuela, we have designed a speaking avatar running on the TV in combination with simplified remote control. The main requirement from all personas is simplicity. This requirement was especially emphasized by the Blanka and Manuela persona. While Arnost requires a larger number of functions, Blanka needs only a very basic set, see Figure 2 for comparison of the HVAC GUI for Blanka and Arnost. The first version of Manuela's UI is based on the interaction with the calendar only.

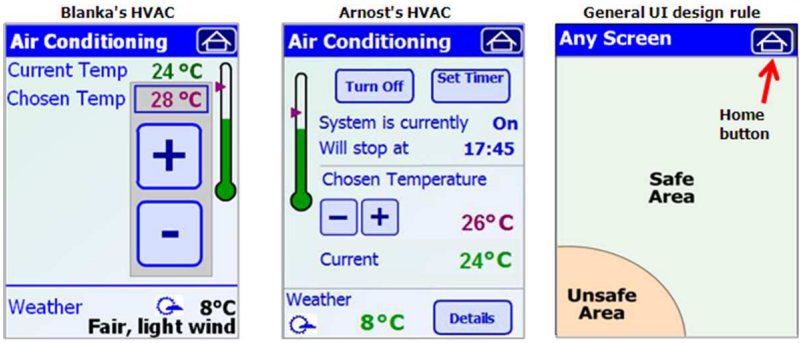

Figure 2. UI design for HVAC for Blanka to the left, for Arnost in the middle. The general UI design to the right.

4.1. UI for Arnost and Blanka

For the first prototype we have designed a graphical user interface (GUI) running on the PDA which should be controlled with the finger. With this GUI, Blanka and Arnost can, for example, browse the EPG (Electronic Program Guide) or control the HVAC on their PDA while watching the TV. Although the PDA with a touch screen is not a perfect controller for neither Blanka nor Arnost, we have selected this for it's availability and capability to easily make functional prototypes for the first phase of the project. When designing the UI we have considered the following rules as a result of the user interviews.
Depth of UI structure. The depth of the UI structure should be restricted, that is, any screen in the UI should be reachable through a limited number of preceding screens, see Figure 3. In Blanka's case the limit is set to two since she will not remember more than one step back. In Arnost's case the limit is not given but it is recommended to be set to three.
Safe and unsafe areas are defined on the GUI. The GUI is controlled by the fingers and not the stylus. When holding the PDA by left hand and touching it by right hand fingers, there is a danger of accidently touching the screen by the left hand. Therefore, an unsafe area was defined where no active UI elements should be placed, see Figure 2.
Home buttons are always leading to the main screen. For both Arnost and Blanka there is a home button in the upper right corner of each screen (except, of course, for the home screen itself), see Figure 2. Blanka expects an immediate reaction from the system, as she is used to from other hardware devices like white goods, and so the number of confirmation dialogues is kept to a minimum. This also reduces the depth of the UI structure. The confirmation dialogues are a design pattern overtaken from computer UI and it is not understandable to Blanka. In case Blanka needs to go through a more compli-

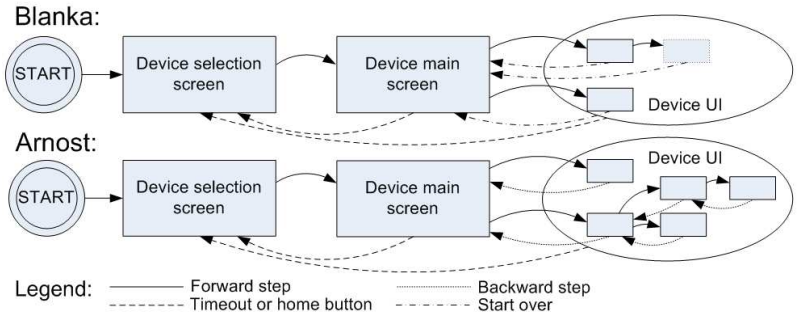

Figure 3. Example of User Interface structure for Blanka (top) and Arnost (bottom).

cated dialogue, leading to a wizard, there must be a "Start over" button on each screen of the wizard which resets the whole process, see Figure 3. The GUI will automatically transmit into the main screen after a given time of inactivity.

Size of all touchable elements on the screen must be big enough to be easily accessible for elderly people. The size of the elements limits their number on the screen. All text, labels and symbols must be big enough to be easily readable for people with vision impairment— remember that both Blanka and Arnost wear glasses.

Affordance each UI screen must be self-explanatory, making both its purpose and its functions obvious. Blanka suffers from short-term memory problems and should be able to operate the GUI despite the fact that she might have forgotten how she got to the particular screen.

4.2. UI for Manuela

Manuela interacts with the targets via the TV, where a speaking avatar announces different reminders and notifications. The interaction with the system is purely system initiated and Manuela reacts on yes/no queries by pushing a particular button on the remote control, see figure 4. The avatar has been chosen because it is an interface that Manuela can easily interact with, see [2] for more details. Based on the results of the user interviews

Figure 4. Manuelat's user interface - speaking avatar on the TV and a simple remote control.

we have taken the following points into consideration when designing the UI.

Personification Since it is very unnatural for users represented by Manuela to communicate with any kind of electronic device, we have decided to use 3D-modeled avatar which looks, behaves and speaks like a human.

Speech synthesis of a high quality in combination with lip synchronization should make the user experience as realistic as possible, see [3].

Simplified remote control enables Manuela answer question asked by the avatar quickly and easily. She can answer simple yes/no question by pressing the appropriate buttons. In order to change the settings on some devices, i.e. the HVAC, she can press +/- buttons. The range of values is however still limited to for example +/- 2 °C.

More advanced settings of the i2home system are dedicated to Manuela's caregiver.

5. Evaluation

The goal for the current study is to perform an evaluation on the feasibility, accessibility and usability of the first prototypes. A data analysis from both a quantitative and a qualitative perspective has been performed. From a quantitative point of view, frequencies of right-wrong answers and response time have been measured. The qualitative analysis helped to determine why the participant answered in a wrong way, record his/her feelings with regard to the presented UI, gather whether or not he/she has understood the meaning, etc. Prior to the evaluation, the participants agreed to take part in this evaluation by signing a consent form and the test supervisor filled out a questionnaire in order to record factors like age, gender, education, and previous experience with information, and communication technologies.

Blanka and Arnost: The purpose of this study was to determine the usability and accessibility of the user interfaces previously described. 14 participants conforming mostly to Arnost persona were hired at the University of the Third Age. The tests took place at the usability lab at the Czech Technical University. 14 participants mostly conforming to the Blanka persona, were tested at the Recovery Center in Motol, Prague. Several iterations of tests were performed starting with the initial interview, moving on to the paper prototype and the mockup prototype, and ending with a functional prototype.

Manuela: The purpose of this study was to access whether the interaction of a person with Alzheimer's disease and an avatar on TV is possible via the use of a remote control. 20 participants with mild to moderate Alzheimer's disease (GDS 3-5) conforming to the Manuela persona participated in the evalution which took place at the INGEMA residential home in San Sebastain. The participants were evaluated with a neuropsychological screening evaluation, according to UMA (Memory and Alzheimer Unit) procedures providing measures for perception, language and memory capacities, and task performance time.

6. Results

Below we provide a subset of the result of the qualitative usability tests of UI prototypes designed according to the design patterns introduced in section 4 followed by a discussion and when possible also by proposed solutions.

6.1. Arnost and Blanka

The design of the UI based on interaction with PDA touch screen in combination with the TV screen was very well accepted by most users. As a positive aspect we consider the fact that almost all users were able to fulfill all given tasks without the need to be trained in advance. All users experienced a steep learning curve and most of them reported an intention to use the technology in their home environment.

We are now focusing on aspects causing problems that can be generalized to other controllers, not just the PDA used.

Multitasking – Four users conforming to Blanka and two confirming to Arnost were confused by the fact that it is possible to interact with other targets, say the HVAC, while the TV is still running. Consequently, as soon as these users were instructed to switch to the HVAC, they switched off the TV and then navigated to the HVAC GUI. Our recommendation in this situation is to synchronize the two devices as much as possible: the GUI shown on the PDA should also be shown on the TV.
Distribution of UI across multiple devices – Four users conforming to Blanka and three to Arnost were confused in situations where different devices displayed different information content at the same time. For example the user switched to EPG on the PDA and expected the information to appear on the TV screen which did not happen. This problem is similar to the multitasking problem and can by solved in the same way.
Status and action areas – Users often confuse areas that are displaying the current status of the system with areas that may change the current status. An example of this problem can be seen in Figure 2 where both users conforming to Blanka and Arnost tend to click on the status (28 °C resp. 26 °C) rather than on the + and - buttons. There are several possible strategies to avoid this. First of all the action areas—in this case the buttons—should be displayed in a more plastic way including shades and having dedicated coloring. Second, the usage of touch screens should be kept low since most users are not generally used to handling them. Instead, we recommend to use devices with physical buttons.

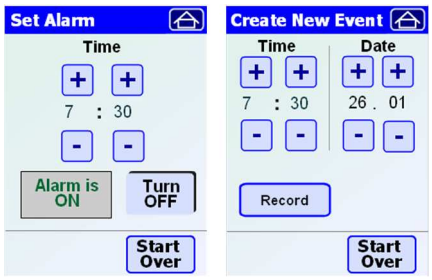

Figure 5. Blanka's UI for setting the alarm and for creating new event

Immediate and confirmed operations – Especially Blanka expects all settings to be accepted as soon as they are modified. For example, in the alarm UI, users conforming to Blanka expected the alarm to be set after modifying the time see Figure 5. The button actually setting the alarm to ON or OFF (functioning as a confirmation button) was mostly overseen. The recommendation is to omit the confirmation buttons whenever possible. Arnosts in contrast understood the confirmation metaphor very well thanks to their experience with PCs.

6.2. Manuela

The user interface based on a speaking avatar was very well accepted. 100% of the test persons completed the tests. The following findings will be taken into account while preparing the next version of the UI:
Timing issues – The black screen before the appearance of the avatar caused user reactions ranging from indifference to insecurity (wondering if the TV set is broken). In order to maintain the users' attention, the presence of the black screen should be reduced

to a minimum. Also, the time interval between the avatar's appearance and 'her' speech should be reduced.

Explicit instructions – If the avatar does not explicitly say "press yes *on the remote control*", some users do not know where they have to press.

Speech input – Almost 80% of the users anwered the avatar by speech although the user can only interact with the remote. This suggests that future versions of the user interface should include this modality.

7. Conclusions and Future Work

We have designed and implemented a set of customized user interfaces for two groups of users with special needs: elderly people and people suffering from Alzheimer's disease. By following the user-centered design methodology, we made it possible for these user groups to interact with a modern digital home equipped with main stream technology. We provided basic design rules for different types of interactions based on a qualitative investigation of user tests. Our users have shown a steep learning curve and a fast acceptance of the introduced UIs.

7.1. Future work

In the next round of the UCD cycle, we will improve our personas, include more targets, extend our scenarios and improve our user interfaces accordingly. We will investigate in greater detail the inclusion of the WII controller as a possible extension of user interfaces, social networking, speech and multimodal interaction.

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