

Interacting with Home and Home Appliances in a Hand-Held Terminal

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Abstract

Many remote controlled home appliances exist in homes and consequently, several remote controls lie around tables. We decided to study how to combine these controllers as one and especially, how to provide a unified user interface for all the devices. In addition, we wanted to understand how people perceive their homes in order to navigate between rooms and control devices. As a result of user-centered iterative software design, we created a concept, which is based on a simplified zoomable user interface. The interaction is based on zooming on different levels of information. The lowest level is the hand-held terminal. The next level is the selected device in the room where it is located. Finally, the highest level provides a view of the house and its yard. We began by interviewing a group of potential users and gathered their requirements. After this we studied three different floor plan visualizations in order to create visualization, which is suitable for a small screen of a hand-held terminal and limited interaction capabilities. Based on these results we created a high-fidelity prototype, which was tested further. Currently we have a working prototype – a Micro Java application that runs in any MIDP capable mobile phone.

1. Introduction

A future vision of living often paints a picture of something that happens in a home full of network connected computer-enhanced appliances. These smart devices are always accessible and make everyday life easier and more comfortable. This kind of scenario is a part of late Mark Weiser's (1993) vision of what he called ubiquitous computing. If we want this kind of system to become popular, the usability and the interaction with these appliances is one of the major aspects. In addition, visualizing these appliances and their functionality to the user plays an important role.

Nowadays it is typical that there is one remote control for each home appliance that is usually near the

appliance and this means that tables are overcrowded with remote controls. The interaction with different kinds of remote controls is not very straightforward since each manufacturer has its own symbols and conventions for the interaction. For some user groups, such as kids and elderly users, this is a major problem since they may have to learn to master several different devices.

Another question is that how to locate and control the appliances, which are not in the same room with the user. This requires presenting the floor plan (in a one way or another) with the hand-held terminal, which causes at least two major problems. First, how to present the floor plan of a single-family house on a small display and second, how to enter the floor plan in the terminal with the limited input capabilities of the terminals.

Our approach is based on using a hand-held terminal (either Personal Digital Assistant or smart phone) in order to provide a unified user interface for multiple home appliances in the house.

The rest of the paper is organized as follows. First, we discuss about the related research. Next, we introduce our design drivers as well as the first design. After this, we describe the next iteration cycle as well as the associated user experiment, where we tested three different floor plan visualizations. This is followed by the design of the high fidelity prototype and its user tests. Finally, we discuss about the current version and conclude the paper.

2. Related Research

Using a PDA as a universal (programmable) remote controller for home appliances is not a new idea. For example, Pacific Neotek's OmniRemote for Palm enables the use of PDA as remote controller (Pacific Neotek). There are also programmable remote controls with touch screen and stylus on the market, for example, OneForAll URC-9990 Mosaic (OneForAll). Controlling smart homes via hand-held terminals has been studied earlier (see for example, Chung *et al.* (2003), Kohtake *et al.* (2001), and Nichols *et al.* (2002)). However, these

papers have not focused on visualization and navigation issues considering a home and its appliances.

The visualization of a home is related to displaying a hierarchy that is consisted of rooms and their appliances. There are several techniques that are suitable for visualizing hierarchical data. Perhaps the most common way is to use tree visualization, although other two-dimensional visualizations exist – such as SunBurst (Stasko *et al.*, 2000) and Tree map (Johnson & Shneiderman, 1991). Hierarchical data may be visualized in three-dimensions, (for example, Cone tree by Robertson *et al.* (1991)) but 3D interaction may cause difficulties with limited interaction capabilities of a hand-held terminal. In addition, three-dimensional visualizations are may become computationally demanding for hand-held terminals.

Kamba *et al.* (1996) point out that one of the main aspects with hand-held terminals is the limited screen space available for content and controls. One way to tackle this problem is to use so-called focus+context visualizations (see *e.g.* Björk & Redström, 2000). These visualizations enable the user to see an interesting object in detail while having the overview (context) available at the same time. One of the best-known focus+context visualization is the fisheye view (Furnas, 1986). Sarkar *et al.* (1993) continued that work and created a rubbersheet view, which is suitable for small displays. Also combined overview and detail presentations, such as Magic Lenses (Viega *et al.*, 1996) could be used to filter the amount of data displayed on a small screen. Anyhow, the problem in our case is that it is impossible (or at least difficult) to display all the home appliances on a small screen of a hand-held terminal.

Because the hand-held terminals have typically limited interaction capabilities (Rieck, 1996), we wanted to eliminate the need for scrolling and focus manipulation and decided to start studying the use of zoomable user interface (ZUI) for presenting the hierarchy. Zoomable user interfaces have been studied for a while (*e.g.* PAD (Perlin & Fox, 1993), PAD++ (Bederson & Hollan, 1995) and EtchaPAD (Meyer, 1996)). In the current graphical user interfaces the viewable content is limited by the size of the window that it is in. If the content size is larger than the size of the window, the window content needs to be scrolled. A ZUI uses the screen itself and the user can pan and zoom the content.

The benefit of using a ZUI is that it eliminates some of the problems of traditional GUI. It does not have overlapping windows and the scrolling may also be avoided. Although a zoomable UI uses screen space efficiently – the window borders and window controls (scroll bars, minimize and maximize buttons *etc.*) do not consume screen space – it may use the same user interface components (widgets) as GUI applications, which are already familiar to users. Also, as in

focus+context visualizations the zoomable UI may preserve the spatial relationships of the objects.

3. Design Drivers for Our User Interface

As stated earlier, the primary goal of our design was to create a user interface for a remote control for a smart home that could be used for controlling appliances anywhere in the house. In addition, we wanted to keep the design and interaction of the user interface as simple as possible in order to make it usable for inexperienced users, for example, children and elderly users.

In order to identify proper views and hierarchy as well as the appliances that the users would like to control, we interviewed 12 potential users of the system. Six of them were male and six were female. Their age varied from 23 to 54 years (average age was 37 years). Nine of them lived in a single-family house and the rest in an apartment building with a residence of two or more rooms. Based on the interviews, we recognized the following views:

- **Yard and courtyard buildings.** Eleven users (92 %) said that it is important to have an access and control the devices outside the building. Eight users (67 %) wanted to have access to devices in courtyard buildings (*e.g.* for turning off the shed lights).
- **House.** Naturally, all the users wanted to have a view to the house and two thirds of them wanted to see the whole floor plan at once (for example, turning off the kitchen radio while sitting in the living room and watching TV).
- **Room.** Rather self-evidently all the users wanted to have this view; half of them believed that it is unnecessary to have any further levels.

However, four users (33 %) wanted to divide *Room level* further in order to control only the devices that are in *immediate proximity* of the user. Since the meaning of immediate proximity is vague, we defined it as an area which radius is three meters. This is actually caused by the technical limitations of our custom-made proximity sensors that we use. We named this view as the *closest devices*. The following scenario explains the use of this hierarchy level.

The person is sitting on a chair and he decides to stop reading and start to watch television. Since the reading light and the television are near to the person, he does not need to see all the devices of the room, instead he can select the view, which displays only the devices that are right next to him.

Lastly, only two users wanted to have access to recently used devices. They believed that the pool of controlled devices would be so small that after a while, all the necessary devices would fit into this view.

All interviewed persons agreed that the most probable target devices would be entertainment appliances, such as a TV set, DVD and CD players, and radio. However, they felt that it would be very beneficial if they could also control other frequently used electric devices, such as lamps and radiators. Although several other electric appliances – such as washing machine, refrigerator, coffee maker or microwave oven – exist in homes but we thought that need for controlling these devices is rare or linked with safety issues (for example, turning coffee maker on unintentionally).

Based on these interviews we studied the functionality of remote controlled home appliances, which were discussed during the interviews. We found out that in most of the cases the number of the most frequently used functions was eight or less. In addition to these devices, we add heating and lighting devices to the list of controllable devices. Table 1 summarizes the main functionality of the home appliances, which could be controlled by our application.

Table 1. The functionality and the appliances to be controlled with our application

Appliances	Main functions
Tuners – e.g. TV, radio	Power on/off, volume up, volume down, mute, next channel, previous channel
Players – e.g. cassette, DVD, CD, MD	Power on/off, volume up, volume down, mute, next track, previous track, play, stop
Heating Air condition	Power on/off, colder, warmer
Lighting	Power on/off, dimmer, lighter

4. The Initial Version

The physical location of the user is difficult to record and we decided to use the location of the terminal for the basis of the views. If the user controls an appliance with the terminal, the terminal's location is same as the user's location.

As a starting point, we decided to design for Compaq iPAQ (Compaq). Its colour display has 320×240 pixels (¼ VGA resolution) and the display is touch-sensitive. Touch-sensitive displays have been used in remote controllers earlier, for example, OneForAll's Mosaic (OneForAll). Moreover, Enns and MacKenzie (1998) studied the use of graffiti symbols for controlling the television with touch pad and stylus equipped remote control. We also discussed about using other input techniques, such as speech (as e.g. Yates *et al.* (2003)), or gestures.

We were fascinated by the benefits of a zoomable user interface, but we decided to give up the idea of stepless zooming in order to simplify the interaction with the application. We believed that stepless zooming

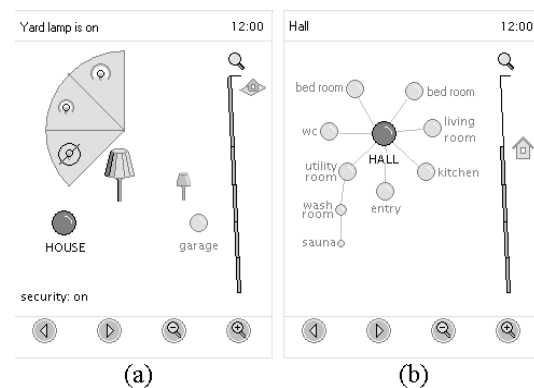
and panning the view might cause usability problems, such as disorientation, for inexperienced users.

Based on the interviews we end up to five discrete zoom levels (views). In our design, the *closest devices view* was for controlling appliances and the other views enable navigation between rooms and devices (Table 2).

Table 2. Zoom levels and their purposes in the initial version

Zoom level	Purpose
House & Yard	Access the courtyard buildings and control outdoor devices. Selecting a device changes the view to the Closest devices view Selecting a building opens the House view for the selection.
House (or other buildings)	Enables navigation between rooms in a building. Selecting a room navigates to the Room view
Room	Enables the access to any device in a room. Selecting a device opens the Closest device view.
Closest devices	A pie menu for controlling devices near the terminal.
Terminal (PDA)	Enables the access to applications (e.g. calendar and messaging) that are in the terminal

The result of our design was a set of sketches that were used to write down the design solutions (Figures 1a–d). The basic screen layout can be seen in Figure 1a. On the top of the screen there is a message area that displays information (name and/or status) about the selected item. The center of the screen is the content area that provides a view to the selected level. The zoom level is indicated with a bar on the right side of the content area. The bottom of the screen is reserved for iPAQ's command button indicators. The first and the second buttons are for changing the selected item and the last two are for changing the zoom level.



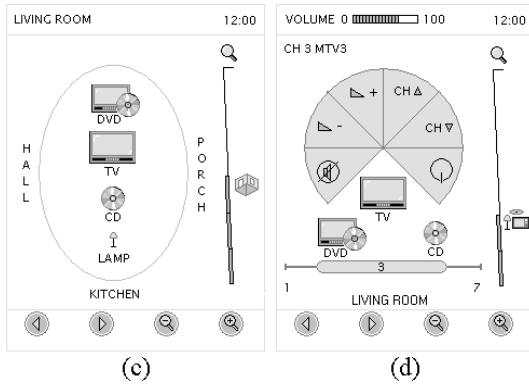


Figure 1. The first set of sketches for the concept: (a) the house & yard view, (b) the house view, (c) the room view, and (d) the closest devices view

Figure 1a presents the *house & yard view*, where the yard lamp is currently selected. If the user selects a house icon, the zoom level changes to *house level*. If the user selects an appliance, an associated pie menu for controlling it will be displayed.

The floor plan of a fictional family-house as a hyperbolic tree is displayed in Figure 1b. There were two reasons for discarding actual floor plan visualization. Firstly, constructing a floor plan into system will be difficult and secondly, displaying floor plan on a small screen is problematic. If the floor plan is displayed as the most of the interviewed persons wanted (view all the floors of a house at the same time), it will not fit on a small screen and it requires panning and scrolling. Other solution would be downscaling, but it would throw away details. Therefore, we thought of using the hyperbolic tree (Lamping & Rao, 1994) for displaying the floor plan. It would enable displaying the relationships of the rooms without having to depict the actual floor plan of a house into system. Hyperbolic tree distorts the view, which enables presenting a large house on a small display. The focus – the selected room – would be on the center of the screen.

In order to locate and select a certain device quickly, the *room view* (Figure 1c) should promote visual scanning. The devices are presented as a list of icons. Every icon would have a text label, which could be used to name a certain item. The labels could be based on, *e.g.*, the information accessed via RF-ID tag and the user could edit and personalize them. Obviously, the number of devices in a room would probably be much higher than shown in Figure 1c, but we estimated that at least 18 icons would easily fit to this view. The rooms next to the selected room are displayed in order to provide shortcuts for the user. After tapping the device icon, the view changes to the *closest device view*.

As mentioned, the *closest device view* was designed for controlling the home appliances and we decided to use a pie menu as the main interface for an appliance

(see Figure 1d). In the pie menu, items are placed along the circumference of a circle and each menu item holds an equal portion of the area. When compared to normal pull-down menus, pie menus reduce target-seeking time and lower error rates. Users also considered them subjectively equivalent to pull-down menu style (Callahan *et al.*, 1988).

In our design, the pie menu contains the most frequently used functions of the selected home appliance. Figure 1d shows the pie menu for the living room TV. Below the pie menu there is a scroll bar, which is used for selecting the device to control. The closest devices – previous, selected and the next device – are shown as icons, while the remaining devices are hidden. The scroll bar indicates that three out of the seven appliances that the room contains are displayed.

The last zoom level is the hand-held terminal itself. This terminal may be, for example, a PDA or a smart phone and it may provide other applications, such as a calendar or an address book.

In addition to identifying the proper views and controllable devices, a big issue is how to create actual views based on this information. Although this is out of the scope of this paper we will discuss it briefly. Firstly, our design is based on using short-range radio frequency identification (RF-ID) tags that are networked and connected to a home server. The simplest solution for creating the views would be scanning manually the devices around the house and then generating the actual views with an appropriate manager application. With the application, the user would drag and drop icons depicting rooms and devices in order to create a graphical presentation of a house and its contents. Since the devices that are designed to be controlled with our application have a fixed or very stationary location, the user does not have to edit the views constantly. We also considered a more advanced solution that is based on an automatic, dynamic service discovery and registration. This would probably be easier from the user point of view. This kind of solution would enable registering these devices, their location and current status in the system via a bi-directional link, which in turn would be closer to the ubiquitous nature of the devices.

Some other issues, which are not discussed, are related with several people interacting simultaneously with different hand-held terminals.

5. The Second Version

We had captured most of the user requirements in the first version, but it contained some problems. Firstly, we aimed to simple interaction and navigation, but in our design every view had a different kind of interaction and the views lacked graphical consistency and clarity. We considered this as a major problem, since we believed that the visualization is one of the key aspects when interacting with multi-device smart environment.

Secondly, presenting a house as a tree or a graph has some drawbacks although it may be easier to depict into system as a real floor plan. A graph is an abstract, mathematical presentation, which may be difficult to interpret by the user. In addition, the navigation in a graph may be difficult without pen or mouse. Thirdly, we believed that our initial design was not aesthetically appealing, and we decided to ask for help from our graphical designer as well as look out other solutions.

As a result the screen layout was changed to a set of nested circles that present the zoom levels. The currently selected view has icons on its circumference, presenting the content of the level. A sketch for the circular layout is shown in Figure 2.

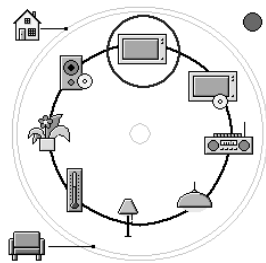


Figure 2. The sketch of the *room view* in the new design

Although the look of the new design was very different compared to the initial design, the interaction in and between different views remained the same. However, the main advantage of the new design was that it provided a coherent look and feel between the different zoom levels. We were pleased with the new design, but we were worried whether the users were able to navigate in the house with it since the new design did not explicitly show the relationships between the rooms. Hence, we decided to conduct a user experiment with low-fidelity prototypes before the implementation.

5.1. User Experiment

In our experiment, one test session with a subject consisted of three phases: drawing a floor plan, testing an icon set, and navigating in a house by using a different kind of visualizations.

In the drawing phase we asked a test subject to draw a floor plan of his/her own home. This was done because we wanted to study how the test subject perceived his/her house. In addition, we wanted to observe what items (*e.g.* doors and furniture) are drawn in the floor plan and how these items are presented. We emphasized the fact that the phase was not a drawing contest. Only the issues concerning presenting a floor plan and room order were important.

In the second phase we presented the users a set of icons on a paper and asked the first impressions about

the icons and what particular room or appliance a certain icon represented.

In the last phase, we presented three different visualizations of a room order: a floor plan, a graph, and our circular layout (see Figure 3). The floor plan worked as a reference to the other visualizations because it is a well-known and common way to present room order in comparison with these two other choices. The visualizations were presented as paper prototypes and the order of presenting them was systematically varied.

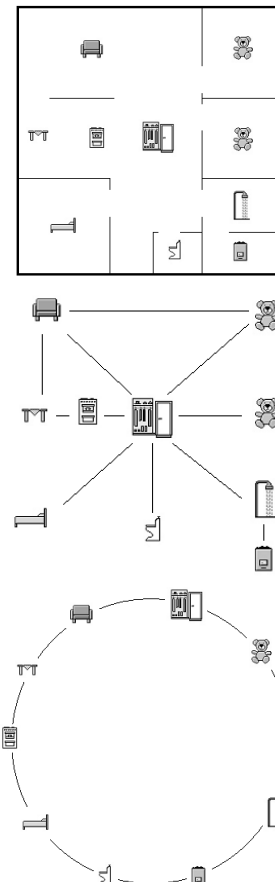


Figure 3. Three visualizations (the floor plan, the graph and the circular) of a room order of the same house

The purpose of the last phase was to study the subject's first impression about the visualizations and how (s)he navigates when using one of these visualizations. Especially, we wanted to found out, if displaying the relationships of the rooms has any significance to the user. Furthermore, we asked the subject to rate the best way to visualize his/her own home.

In the beginning of a session, we made a brief background interview with the subject. A session took approximately 30 minutes per user including the interview.

Prior to the actual user experiment we conducted a pilot test with one subject in order to see whether our test set-up was working properly. Since we did not have any problems we started to conduct the actual study.

We had 18 test subjects (10 male and 8 female) in our experiment, aged between 23 and 62 years. The average age was 33 year. The subjects were from various professions and backgrounds.

5.2. Results

As a result of the drawing phase, almost all of our subjects drew a so-called *quick & dirty* floor plan. They started the floor plan by drawing exterior walls and continued by drawing the interior walls. This resulted rooms, which shape was roughly correct but the room sizes were mere approximations. In almost every case, the subject drew doors, but surprisingly none of them drew windows in their floor plans. There was no particular order in drawing different rooms. Only three out of eighteen subjects drew furniture or other details in the floor plan. The function of furniture was to indicate the purpose of the room. Also, four subjects (one of these users belongs to the group that marked other items to floor plan) indicated the purpose of the room by text or abbreviation.

The icons that we plan to use for indicating rooms and devices were generally considered easy to understand and 92 % were recognized correctly. Only the TV and microwave oven icons were mixed with each other; further, one user interpreted the sauna stove as a safe deposit box. Common icons – such as a flower (we thought of using this icon for *e.g.* a green house) – were ambiguous and thus difficult to map to a certain room. The high recognition percentage backed up the fact that the recognition of the icons will not affect the navigation study in the last phase.

The first impression of the test subjects was that the floor plan is the best way to visualize the room order, because it is the most common and they are familiar with it. However, after the navigation tests, also the circular layout was considered a good way to visualize room order. The graph did not get endorsement at all in comparison with other two ways to visualize the room order. A majority of the subjects felt that the relationships between the rooms need to be shown. Thus some of them said that there is no need to display them explicitly (like in arcs in a graph) because they know where the rooms are in their houses. In navigation between the rooms, there were no particular differences between any of these three visualizations and not a single user made a mistake in navigation. Few test subjects pointed out that it might be much easier to visualize room order on the PDA display with the circular layout than with the floor plan, because it may be quite hard to visualize all rooms as such.

5.3. Conclusion

Based on the drawing phase, we noticed that generally the test subjects did not draw any details (*e.g.* windows or furniture). If furniture was drawn, it acted as an icon that indicated the purpose of the room. The subjects were familiar with the room order of their own home and therefore they did not need any additional cues for recognizing the room. This is a reason why a single icon is enough for presenting a room.

The subjects recognized the icons remarkably well – the overall result was that 92% of the icons were recognized and when the flower icon was left out the percentage rose to 96%. Hence, a basic set of icons for future use was selected as such.

Because the subjects did not make mistakes in navigation with these visualizations, it seems that the biggest issue was how intuitive the icons were. The test subjects liked the circular layout (although they admitted that they were used to the traditional floor plan) and they said that it provides adequate cues for room relations.

Some subjects said that a room order might be easy to convert to the circular form (see Figure 4).

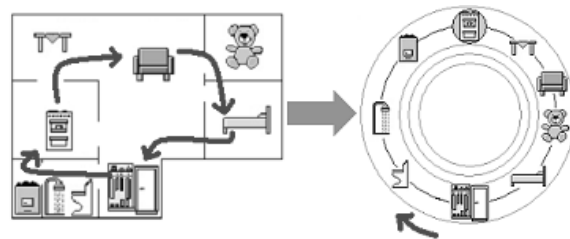


Figure 4. An example of converting a floor plan of a house to the circular layout visualization

We felt that the relationships between rooms had to be taken into account in some way in the floor plan visualizations, because it will help the person in using his/her visual-spatial memory more effectively. The visual-spatial memory is one way to aid the users to use the circular representation similarly than the floor plan.

As a conclusion, we were confident that these results encourage us to implement the circular layout further.

6. The Third Version

Based on the previous user experiment we decided to make adjustments to our design. Because of the lack of the screen space, it may be impossible to display all the home appliances of a room in a single display, without scrolling or panning the view. We decided to make a rule that if the number of devices in the room was higher than eight, some of the devices are to be hidden. Figure 5 presents a part of the *room view* as an example in a situation when all of the devices of the room cannot

be shown. Five items are hidden, which is shown as a number at the bottom of the circle.

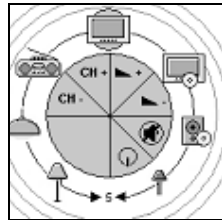


Figure 5. An example of a room view when all of the devices in a room are not displayed

If the user needs to access a hidden device (s)he can click the number at the bottom of the circle and after the click, the circle rotates clockwise and these previously hidden items became visible while some icons became hidden. The devices to be hidden are selected by using the information gathered with the proximity sensors, which actually means that the *closest devices view* and the *room view* are combined.

The fact that the pie menu could be shown on the *room view* level made the *closest devices view* useless in the circular model. Therefore, the *closest devices* level was changed to display the most *recently used devices* in order to provide shortcuts for controlling these devices. A need of this view was also mentioned in the first interviews with the users. Table 3 summarizes the levels and their purposes.

Table 3. The zoom levels of the high-fidelity prototype

Zoom level	Purpose
House & Yard	Access courtyard buildings and control outdoors devices. Selecting a device opens a pie menu. Selecting a building opens the <i>house view</i> .
House	Navigate between rooms. Selecting a room opens the <i>room view</i> .
Room	Control a device in a room. Selecting a device opens a pie menu associated with the device.
Recently Used Devices	Access up to eight appliances and their pie menu that are recently being used.
Terminal	Access to applications of the terminal

Based on these results, we created a high-fidelity prototype with Borland C++ Builder (Figure 6). The prototype runs in a normal laptop-PC and the interaction with the PDA's touch screen was emulated with the mouse.

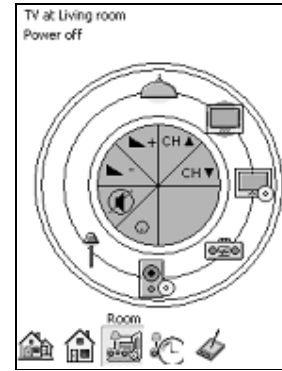


Figure 6. A screen shot of the high-fidelity prototype, which is showing the pie menu for the living room TV

In the high-fidelity prototype, we removed the zoom indicator that we used in the initial version in order to save screen space. Instead of it, the zoom levels are displayed with as push buttons with icons at the bottom of the display and they can be used for navigating between the zoom levels. Since the tests with the low-fidelity prototype were encouraging and no other changes for the design were needed, we decided to conduct a smaller user study than the previous experiment. The main objective of this study was to find a trend that validates our work.

6.1. User Test

The high fidelity prototype was tested with 9 users (5 male and 4 female) and their ages varied from 27 to 55 years. The users were divided into three categories (three persons in each group). The first category – novice users, were people that were not aware our concept. In addition, these people do not use computers for their work nor do they use computers in their spare time. The second group contained so-called immediate users; people that use computers for their work as well as for their hobbies. However, these people were not familiar with our design. The last group was experts, which means that the users are information technology specialists and also familiar with the concept.

The tests were made on a laptop PC-computer. Before a test, only minimal information was given in order to study the immediate usability of the concept. We just told that the concept was an application for controlling the electric devices in a home and it would run in a hand-held terminal and the mouse is used to simulate the touch screen and stylus. The test contained eight tasks, which were focused on two aspects:

- navigation within a room (*e.g.* in a previous task the user has interacted with the living room TV and in the next task, (s)he has to turn the dome lamp off in the same room), and

- between the rooms (for example, in order to complete a task, the user must navigate from the *room view* to the *house & yard view* and again back to the *room view*).

After the tasks were completed, a brief interview was made. One test session took approximately 20 minutes per subject.

6.2. Results

We had two dependent variables that we studied in our experiment: task completion times and mouse clicks needed for completing a task. These variables were calculated based on the log files created by the prototype.

For the novice users, it seemed that the orientation to the user interface took two tasks (generally, under one and a half minutes) and they started to perform as well as the intermediate users. After the task five, even though the test sessions were quite short and the concept of using a single remote control for all the home appliances was not familiar to the majority of the users, the difference between the user groups virtually disappeared (Figure 7).

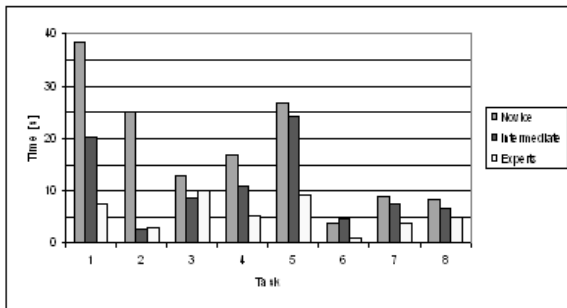


Figure 7. The average task completion times by the user groups

Figure 8 presents the difference between the number of average and minimum number of mouse clicks that were required for completing task grouped by experience. The number zero represents the optimal performance in terms of mouse clicks.

The users experienced problems with the pie menus only in the task number five. The problem that they encountered was that they did not turn the TV on before they tried to change the channel. Otherwise the test subjects said that the pie menu was simple and easy to use.

Another reason for the higher number of mouse clicks was unnecessary navigation steps. For example, the user moved via the *house view* to the *house & yard view* although he could have selected the *house & yard view* directly.

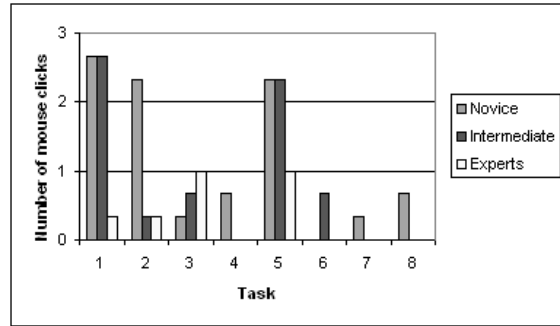


Figure 8. The difference between the minimum and the average number of mouse clicks that were required for completing a task by user group

These results were promising, because the performance of the novice and intermediate users started to approach the performance of the expert users both in the terms of the number of the steps and the task completion time.

A few other observations were made during the test. We found out that the conceptual model of the zoom levels that was used in the high-fidelity prototype has to be changed. Rather obviously, the *recently used devices view* should not be one of the zoom levels. Instead, it should be totally separated from the zooming concept. In order to emphasize its different nature, it could be displayed as a list in association with the pie menu. Also, some of the users wanted to use circles directly for navigation instead of the push buttons in the bottom of the screen.

7. The Current Version

Using the user test results with the high-fidelity prototype, we started to implement the next version, which is a working prototype as a MIDP (MIDP) application in Nokia 9210 Communicator (Nokia).

Because the Communicator has a different display size (a MIDP application can use an area of 463×168 pixels) than the iPAQ, the screen layout is slightly changed. The Communicator does not have a touch screen and therefore we had to make slight modifications to the interaction model of the application. Now, the interaction is based on using the cursor keys and so-called command buttons.

We use custom-made short-range RFID tags for identifying devices and their proximity. The idea of using these tags is two-folded. Firstly, if the terminal recognizes a new device with an RF tag, it fetches the user interface (pie menu) for it. After this, it proposes a room for the new device in order to put it on a right place in the hierarchy. Secondly, this proximity information is used in situations when the room

contains more than eight devices and some of the devices must be hidden in the *room view*.

Currently the prototype can control only devices – such as table lamp, via X-10 protocol (X-10), but we are studying what other appliances could also be used via this MIDP version.

8. Conclusions and Future Work

After the user studies and iteration cycles, the current prototype provides a simple user interface for navigating between the rooms and devices in a home. The user interface enables an access to any (networked) device regardless of its location. The pie menu – the main user interface for the main functionality of home appliances – provides a unified look and feel for any device. In other words, the interface of the device looks always the same regardless of device manufacturer and the interaction with it is always consistent. In addition, the hand-held terminal where our application runs can be used as it was intended, which enables personal computing and communication.

The most of the future work is aimed at enhancing the usability of the concept, but we have also discussed about some new features. For example, one of the guidelines that Robertson *et al.* (1996) suggested for multiple-device interaction was that the information should be distributed across the appropriate devices because they differ in their strengths. Therefore, we have thought of enabling the information distribution via the application. For example, if the terminal is capable of receiving a digital image, the user could distribute this information from the terminal to the TV where it could be more conveniently viewed. Also, the unauthorized use of devices could be prevented with the concept. If the personal terminal does not have appropriate access rights for some device or service, it may not be accessible through the user interface. We have also discussed about the personalization of the user interface. For example, the room and the device icons could be replaced with small digital images of actual rooms and devices, which could make them to more familiar and thus easier to recognize for special groups, such as children and elderly people.

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