Chapter 7
The Proof of the WISE Concept

After the description of the theoretical foundations of the WISE paradigm and the process accompanying the WISE approach in the previous chapters, this chapter presents empirical examples, which shall be considered as a proof of concept. There are three examples given, in accordance with the WISE process model presented in Chap. 6. First we present experiments and studies carried out in lab facilities. The next example, representing the model home stage, is household 37, a real-world living environment which served as a test-bed for most of the last ten years. The final project presented, Casa Vecchia, was a longitudinal field study and represents the stage of field deployment. In the course of this ambient assisted living (AAL) project, the WISE platform was installed in more than 20 households inhabited by elderly people. The socio-psychological and technological aspects of the project were evaluated intensively over a period of four years.

7.1 University Facilities and Research Labs

As has been pointed out in the previous chapters, the goal of the WISE approach is to deploy and evaluate technology *in the wild* [1, 2]. But depending on the stage of development and maturity of the prototype system it is necessary to perform evaluations under experimental and controlled conditions before being able to deploy a system in the field. To that end, a lab facility was established on the university campus where enhancements of the WISE functionality could be developed, tested and refined. The work on smart homes in general and the WISE idea in particular first started with a theoretical contention with the topic and the formulation of research questions. In the next step it was necessary to empirically evaluate the concepts and prototypes that had been derived from the theoretical considerations. A first expansion stage of the lab facility and an initial version of the WISE platform supported this need. The system available at that time can be

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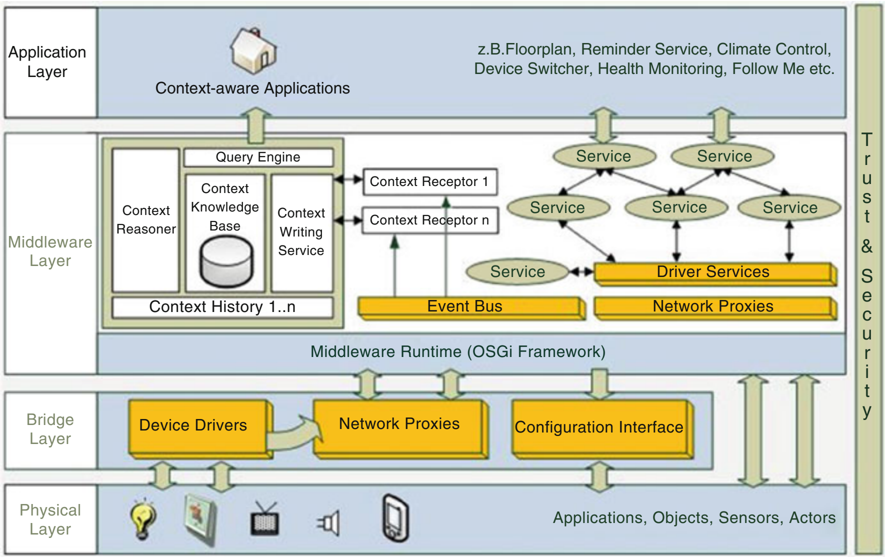

Fig. 7.1 The original WISE software architecture, developed by [3] to support the research group's activities

considered as only being *pre-wise* because it had several limitations. The principal architecture sketched in Chap. 5 was already observable but it was characterized by specifics and limitations on the hard- and software level.

The software platform is sketched in Fig. 7.1 showing the platform and the components the platform consists of. The principle elements of the platform have already been described in Chap. 5, the figure is depicting some more technical details which have to be considered to understand the detailed functionality discussed in the following examples. A detailed description of the platform can be found in [3].

The hardware platform chosen for the first prototype was a system from a German manufacturer, sold online over channels that primarily target do-it-yourselfers. It fulfilled the basic requirements enumerated in Chap. 5 such as being small in size for retrofit, communicating wirelessly, providing an acceptable variety of functions and being available for a reasonable price. Another aspect which was indicative for this system was an active community of professionals and hobbyists who supported the system and were also developing an alternative and open software, FHEM.[1] In contrast to the software that is sold with the hardware that is closed source, FHEM could be customized, and that made it possible to integrate the hardware into the WISE platform. The hardware consists of components such as sensors and actuators, remote controls and push buttons, which communicate over a proprietary

[1] http://fhem.de

Fig. 7.2 The customized central unit running independently on the basis of the Gateway component, a Network Bridge in combination with a harddisk exchanging the PC and a Motion Sensor as example component [3]

radio protocol with a central unit. The central unit is a gateway module, which translates the signals of the proprietary protocol into usb signals, or, in another version, into wireless LAN signals. The gateway did not work independently, but had to be attached to a personal computer running the control software. Although the software did not require much computational power, it was necessary to run the PC around the clock, seven days per week in order to keep the system operational. This shortcoming has been overcome with the development of a proprietary architecture based on a network-attached storage running Linux that was able to replace the PC. The final solution developed by [3], is shown in Fig. 7.2.

The second shortcoming of the initial hardware platform was that the components did not communicate bi-directionally. This led to the problem that the status information of the components could not be trusted. Because of the problems and constraints of the initial platform, it was exchanged by a system with a better technical basis. This hardware is distributed by the same company as the initial hardware platform and sold over the same channels. The new hardware platform already had an integrated gateway component which was able to control and run the hardware and software independently, without the need for an additional PC. The communication was bidirectional, so the status information of the attached components could be considered correct. The system also had other enhancements in regards to connectivity, such as an open software interface specification based on XML-RPC, a better fault tolerance, and better stability. The transfer between the two different hardware platforms was the first practical test for the WISE architecture and it demonstrated that the platform can cope with different hardware platforms and software components. Because the new system had only recently been introduced to the market it did not cover the same range of functionality as the initial one. It was therefore necessary to run the two systems in parallel. Despite the weaknesses of the initial system it was considered better to have some functionality (even with technical limitations) instead of going without it. Being able to run two systems in parallel was another demonstration of the flexibility and adaptability of the platform. Another hardware system that was integrated into the WISE platform was a powerline operated smart home platform from Switzerland developed in cooperation with the ETH Zurich. The system had the benefit of running on the standard electric wiring of a building which would result in several advantages. Compared to wireless systems, no interference with other wireless devices or range problems caused by building structures would have to be expected. Because the signals are modulated on the existing wiring, no additional wires have to be installed, as would have been the case with bus-operated wired smart home systems. These advantages motivated us to use the powerline system in the context of the ambient assisted living project described later in this chapter. However, because of delays in the certification for the Austrian market we were not able to deploy components of the powerline platform in the field. Finally, the WISE platform was adapted to integrate the Arduino® smartboard platform, which enabled the development of customized components providing functionality not available in the other hardware platforms at our disposal. With the release of the WISE platform it was possible to carry out first feasibility studies in the lab facilities. According to the WISE process model presented in Chap. 6, the studies were merely focussed on basic interaction and usability aspects. The central question addressed within the lab facility was: *How could smart home systems be made more usable and useful; supporting instrumental needs such as effectiveness and efficiency*, primarily in cooperation with students, a large amount of research work was carried out to address these problems. For example, a project focusing on indoor location with low-cost components was done by [4], potentials of multi-user support was investigated by [5], and [6] focussed her work on activity pattern recognition, to mention only a few.

The two studies presented in more detail were not performed as initial steps in a development process. They are examples of the possibility to change the sequence, as proposed in the description of the WISE process model in Chap. 6. The need to perform the studies developed from experiences gained in the field projects presented later in this chapter. Based on those experiences and the elicited requirements, prototypes were developed which were to be tested before being deployed to the field again.

The first study presented addressed the question of whether it would make sense to enable the inhabitants of smart homes to perform not only basic control tasks, but even more complex tasks, such as programming their homes themselves [7]. The goal was to evaluate the possibilities in regard to the predictions of [8] who proposed that the orientation of HCI would move from the era of *easy to use* to the era of *easy to develop*, resulting in a higher need for end user development. The feature we evaluated was scenario programming. A scenario can be described as a person's activity which is performed frequently and involves a number of things and devices. These can also be electric, electronic and computerized devices, for example, when a person wants to watch TV. In a conventional home, it would be necessary for the person to separately close blinds or curtains, dim the lights, switch on the TV, and select the correct channel. In a smart home this could be done in a combined way, optimally with the press of only one button. But such a combined control of devices has to be pre-programmed in state-of-the-art smart home systems. We were interested whether naïve users would be interested and able to do this kind of pre-programming.

The study had two stages. In a pre-study, we investigated whether scenarios in general are in the interest of users or if they are just another example of a technological solution in search of a problem. To be able to answer this question 18 participants were interviewed regarding their daily activities in the home, in order to see if there was any routine behaviour that could reasonably be supported by smart home functionality and combined in scenarios. In order to focus the attention of the participants on their behaviour rather than on technical capabilities, we did not, at first, inform them about the real purpose of the investigation. They were just informed that we would be interested in the frequency and regularity of activities that take place at home. In the first phase of the investigation the participants were asked about the activities that take place in general, and if there are any activities or sequences of activities that are carried out on a regular basis. This interview revealed that 100 % of the participants have a morning routine which is the same every day, specifically on weekdays. Around 40 % stated that there are other routine activities which are also characterized by recurring sequences. They are performed when they leave home, come home or do cleaning, receiving guests, preparing a journey, cooking, or preparing to go out.

As routines seem to be quite common, the second phase of the study was devoted to the question of how these routines could be supported by smart home functionality. It was carried out as a card sorting experiment, but not in the usual way, to just stack cards that are considered as having something in common. The cards had to be put in a sequence which corresponded to the routine the devices are involved in. Each of the roughly 30 cards showed an object that is typically present in a home, the majority of which were electric appliances, such as home appliances, entertainment and computing devices. Furniture and infrastructural components (e.g. radiators) were also depicted. Figure 7.3 shows an example of the material provided.

The result of the pre-study revealed that routines are an important part in the daily activities, and are closely related to devices. If the devices were integrated into a smart home system, their integration into scenarios would make sense. This motivated the performance of a follow-up study in the lab. The study was based on a prototype that was developed in Android to run on a tablet computer. Because the participants of the pre-study reported that they had found the interaction with the cards and the time sequence templates quite intuitive, the goal for the prototype was to simulate this interaction on the tablet in a digitized form. The fact that tablets are operated by touch interaction supported this goal. The prototype was evaluated in a comparative study with the interfaces of two commercial smart

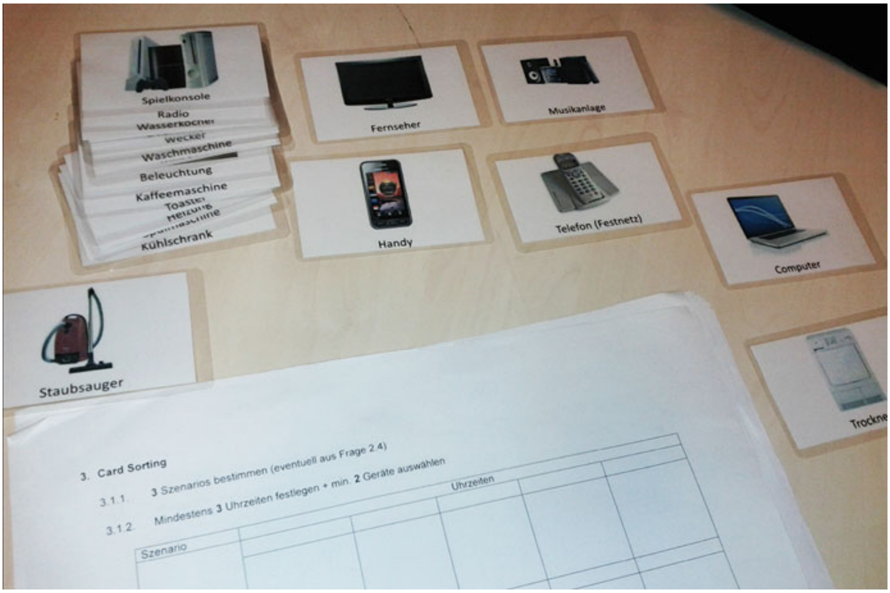

Fig. 7.3 Material provided for the performance of the pretest

home software products. In this study 17 participants were asked to program two scenarios, alternating with the three interfaces. The following questions were addressed. First, we wanted to find the specific characteristics of, and the differences between, the three systems (usability, utility, appeal, etc.) Second, we wanted to find out how well our prototype would perform in comparison to commercial systems. It was of specific interest to see how well people would perform with the three systems without training. The following paragraph describes one of the scenarios the participants had to program.

Scenarios 1: Morning activity.
Please imagine that you want to program your smart home so that it performs the following functions: After you get up (and open the door of your bedroom) the heating in the bathroom is raised to 25° Celsius and 10 minutes later the coffee maker is activated in the kitchen. A screenshot of the study prototype is shown in Fig. 7.4.

Objective metrics such as time for completion of the tasks, number and characteristics of errors and degree of completion were recorded, combined with subjective measures that were collected with the UEQ questionnaire [9]. In summary the objective measures revealed that our prototype was in about the same range as the commercial systems. Complete failures in task completion did not only occur with our prototype but also with the commercial systems. On the subjective level the results also revealed that our prototype system is generally felt to be equal to the others. We had expected that our system, being a prototype and unfamiliar to

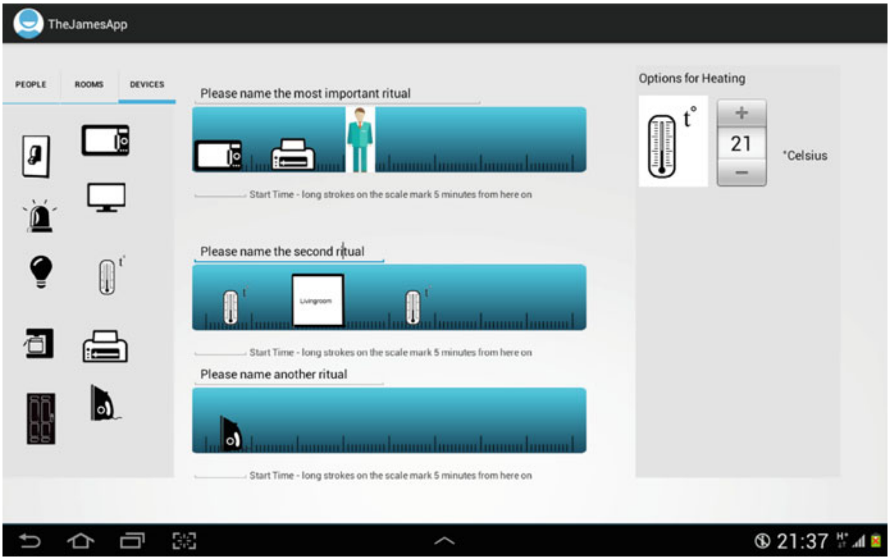

Fig. 7.4 The prototype for the main study. On the left hand side a tabbed container is provided which contains the source elements needed to program a scenario. Most important elements are the devices, but we also provided elements representing two other categories, rooms and people, because these could also be relevant for the configuration of a scenario. With Drag&Drop the elements can be positioned in one of the three containers in the centre which include a time grid to configure three different scenarios as sequences

the participant, would perform significantly worse than the commercial systems, and that it would be perceived as being significantly worse. The fact that it was generally equal in performance and in qualitative evaluation confirms the assumption expressed throughout this book that user needs are not being appropriately recognized and met in smart home products available on the market. Otherwise the commercial systems would have been able to outperform our prototypical solution. We also take this as evidence that the WISE approach and process model are at least pointing in the right direction.

Another series of studies was performed in the lab environment in an attempt to analyse the use of alternative modalities such as speech or gesture to interact with an appropriately equipped home environment. The motivation for these studies is related to the drawbacks of state-of-the-art smart home systems which do not appropriately consider human capabilities. One example of the capabilities being ignored is presented in our discussion of attentional processes, which is emphasised in Chap. 2. Two research activities contributed to the design of the study, both of them related to attentional processes, or more concretely, to the concept of calm computing. One is the work of my colleague JNA Brown [10] who was analysing how interaction with a smart home could be broken down into a generic and intuitive set of commands that can be issued multi-modally and peripherally, for example, by using gestures and voice commands. The other motivation for the studies was derived from the Casa Vecchia project, which is described in detail later in this chapter. The central control unit that was designed for interacting with an ambient assisted living system did not fully address the requirements of the users, such as not having to be in front of the unit to interact with it. Peripheral forms of interactions are not available in current smart homes, but the WISE platform enables their integration and their application to the control of distributed devices. To support the evaluation of peripheral interaction, the WISE platform was enhanced with the possibility of speech and gesture interaction and a trial with 32 participants was carried out. The participants had to control eight functions of the smart home system multi-modally, using a method that focussed mainly on either voice commands or gestures. The tasks were to switch on and off lights or a radio and to control blinds (open, close, open more, open less), and the participants had three attempts to perform them. Because of the requirement that a smart home system should work intuitively, without the need for training, the participants did not receive an introductory training. Despite of that, 55.9 % of the participants could correctly perform the voice-based tasks on the first attempt, and 87.1 % of them succeeded by the third attempt. In the gesture condition, 64.8 % were successful in the first attempt and 91.6 % by the third. For a detailed discussion, see [10]. With the enhancements of the WISE platform a relaxed and peripheral, or *calm* interaction with a future home is possible, as depicted in Fig. 7.5.

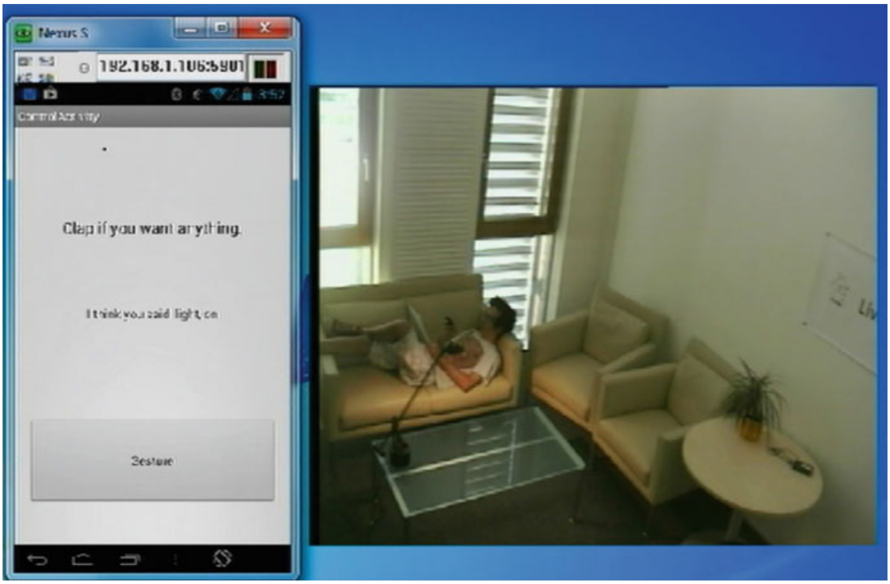

Fig. 7.5 Screenshot of a video record of an interaction study [10] evaluating alternative interaction modalities (speech and gesture) for the interaction with the WISE platform. On the left-hand side a real-time view of the subject's mobile device screen is shown. On the right-hand side is the video in which the participant spontaneously lay down on the sofa to try out the functionality

7.2 Household 37: Bringing Technology Closer to Reality

After having developed the first release of the WISE platform and having conducted initial evaluations under lab conditions, the next logical step was to evaluate its suitability as a real-world installation. As we did not have living lab facilities that would allow participants to stay there for longer periods of time, the major question related to this attempt was where to install the platform. Several challenges and obstacles had to be considered. First, as [11] pointed out, average homes are generally not prepared for the types of devices that constitute a smart home system. There are specific problems and efforts in retrofitting [12], up to an even *tremendous* amount of overhead [13] that would accompany the establishment of a physical smart home test-bed. Expertise and resources are needed to design and install the sensors, controllers, network components, and middle-ware just to perform basic data collection [13]. According to [12] retrofitting existing dwellings is far more expensive and messy. For those reasons, it is easy to understand why only few physical test-beds exist. The second aspect to be considered is the privacy issues related to a potentially-permanent observation of the people living in the test-beds. Both aspects would have made it difficult or even impossible to deploy the system in the home of someone unrelated to our research activities. The deployment of technology *sounds good in theory, but proves to be very difficult in practice* [14]. This is probably also one reason why so many research activities are carried out in artificial environments instead of going into the field. Besides the efforts related to the initial installations, there are also the additional challenges of maintenance and administration of the installation. Research labs typically do have personnel for this task, but this is not natural in a private home. The pragmatic solution for the problem has been to establish the first real world test-bed in a house belonging to a member of the research team. Since I was the driving force behind this research, my house became the test-bed. It is not exceptional or even rare for researchers to conduct experiments in their own homes. According to [11] the same approach was followed in the adaptive home project and also in the pioneering work of Sutherland for the development of the Echo IV. The goal had to be to harmonize living and research, and prevent the impression of *living in a prototype* [15]. This was not always possible, but that also seems to be a trait experienced by other researchers [16].

Before being able to install the platform in a real household, we had to extend the architecture in order to enable a remote connection between the university servers that were responsible for a central data repository, and the remote household systems. The latter were designed to run a redundant local independently-functioning control and backup system in case of connection problems. Figure 7.6 is depicting the principal architecture. The advancements in the architecture were already oriented on future requirements (e.g. considering the accessibility, as available to the trusted persons involved in the Casa Vecchia project, described later in this chapter).

Because of the necessity to ensure privacy, the identification of the field installations was based on code numbers. In order to ease further data analyses, incremental numbers were used to differentiate the households and their expansion

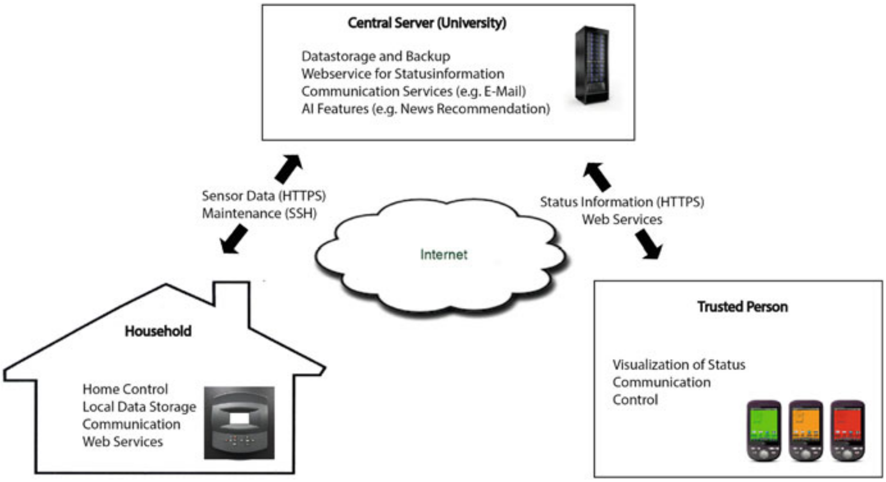

Fig. 7.6 Schema of the distributed architecture, consisting of the household installations, a central backup repository and data analysis platform at the university and a connection to external systems and users

stages. The higher the numbers, the more mature the stages of expansion. This system was responsible for the first field test-bed receiving the codename household 37 (HH37).

The final increment, shown in Fig. 7.7 includes 60 sensors and actuators + infrastructural components such as a server running the WISE platform.

Because of the close relationship between the researchers and HH37, this test bed cannot be considered a pure field installation, but must be treated as an interstage between a living lab and real world deployment. The research performed can be considered a participant-observer-designer approach [11], which means that the researcher has different roles which have to be managed very carefully. These kinds of methods have a long tradition in sociology and psychology, for example in the concept of participant observation [17]. The researcher is not only observing the topic of research from outside, but is himself an integral part of the research context. This has advantages and disadvantages. The advantage is that the natural behaviour of the other persons can be assumed not to be influenced by the presence of the researcher. The disadvantage is the lack of objectivity of the results achieved. HH37 had many different purposes but can generally be seen as a longitudinal case study with the goal of evaluating the technical feasibility and further development of the WISE platform. However it also became possible to evaluate socio-psychological aspects, as shown in the multi-user example later in this section. The experiences that could be gained over the course of almost ten years of investigation provided valuable insights and inputs for the further development and preparation of the platform to be used in other projects. This was especially true for the Casa Vecchia project. On the technological level, one aspect has been of major importance. Household 37 turned out to be extremely useful for applied research in the smart

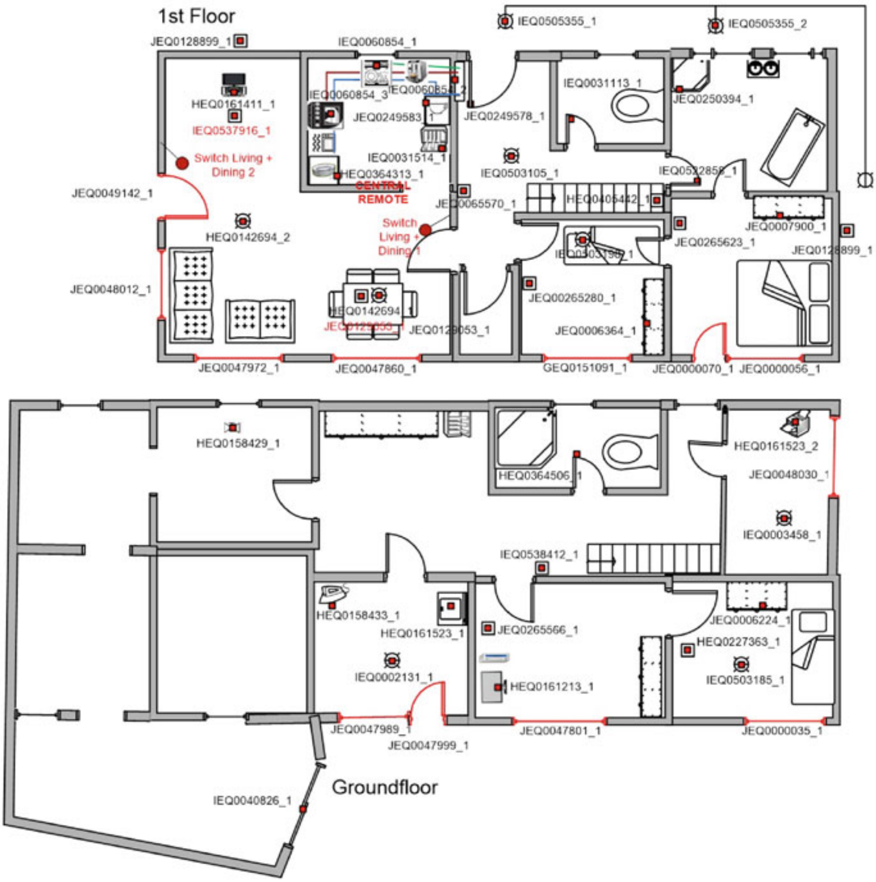

Fig. 7.7 Floorplan of Household 37 showing the latest increment of the smart home platform and positions of sensors and actuators

home field, helping to achieve results on very diverse levels, some of which are illustrated in this section.

The first example shows the problems of deploying smart home systems in real world settings on the one hand, but also shows progress on the other. HH37 was, like the lab facilities, equipped with smart components of the first generation hardware platform. As in the lab, a few years later the components in HH37 were also superseded components of the new hardware platform, because of the technical shortcomings mentioned earlier. Figure 7.8 illustrates the problems related to the retrofit of smart technology in an average home, as discussed in the related literature. The integration of components of the initial hardware platform for the roller blinds, for example, required demolition work which would probably have caused a heart attack in the inhabitants of other households. Over the years, as

Fig. 7.8 The figure shows the changes in component size between the first installation on the *top* and the second version on the *bottom*

illustrated by the lower picture showing the components of the new hardware platform, miniaturization brought smaller form factors, which made components fit into standard junction boxes.

However, as the examples of installation work in Fig. 7.9 show, we are far from having systems that can be technically integrated in a smooth manner into an average home.

Another example from the context of HH37 shows the possibilities to address societal big challenges with smart home components; more concretely, the problem of wasted energy. A side effect of the installation of smart components in household 37 was the ability to observe the power consumption status of devices, though, at first, this could only be done manually. The reasons my family and I accepted the demolition work[2] were that my family supported my intrinsic interest in the research, and that we live in an old house. We had to do some refurbishing

[2] At this point I have to do two thing. First, to apologize for the troubles that my experiments has caused to them and, second, to say thank you a thousand times to the three women who share my life.

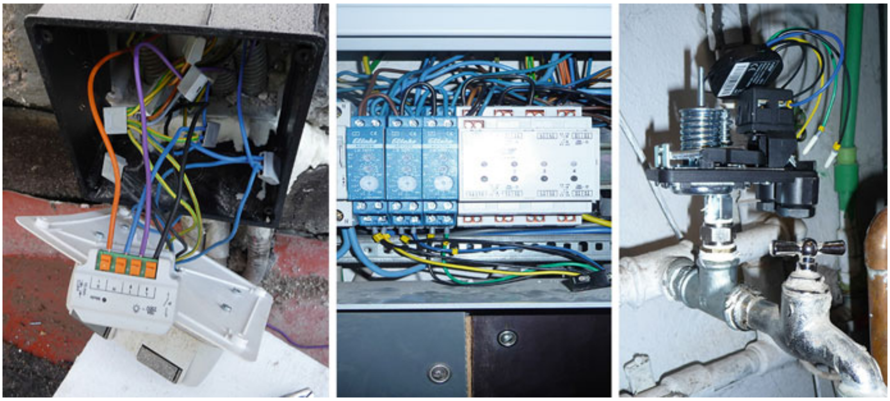

Fig. 7.9 A selection of smart home components that have been installed. On the *left*, an actuator controlling outside lights is shown. In the *middle*, components in the fusebox observing the status of attached devices (e.g. kitchen stove), on the *right*, a sensor that is tracking a water consumption

anyway, and were optimistic that the amount of additional installations necessary for the research would not matter much. Independently from the research goal we were concerned about our energy consumption. We had assumed, along with several experts, that our high energy consumption was due to the fact that the house was not thermally insulated. Sequentially, new windows were installed and some other measures were taken to increase energy efficiency, but according to the information we had, consumption would only decrease significantly once the house was fully thermally insulated. This thermal insulation took place in 2012. The consumption of electric energy dropped around 20 %, but not to the degree we had expected. The energy consumption was still above the consumption of an average, 4-person household. Being sceptical about that consumption rate, and with the smart installations that were now available, I began to investigate the situation. What I found was quite surprising. One of the results of consulting with experts, as mentioned earlier, was that none of the devices present in our home were outdated; meaning that none of them could be unequivocally identified as uniquely responsible for the high energy consumption. This was also the situation after the insulation. All of the devices seemed to be working as intended, and would not waste more energy than needed. The basic problem was a problem of regulation in the heating system that involved the three components shown in Fig. 7.10. Our home uses a wood stove as primary energy source for heating. There is also a solar thermal system which serves as a support system. The heating and the hot water for both personal hygiene and domestic purposes are stored in a combined water buffer. As a backup system, an electrical heating cartridge is installed in the buffer to make sure that the temperature of the water used for domestic water does not fall below a predefined threshold. The reason for the high energy consumption was related to one of the central laws of thermodynamics: corresponding vessels strive for thermal equilibrium. In our case, because of mistakes in the routing of the water piping

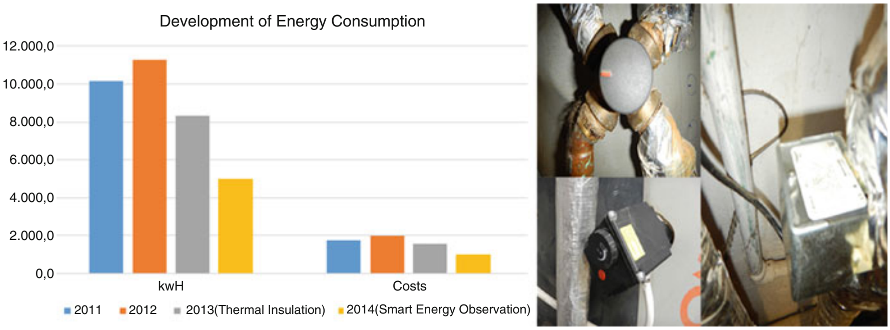

Fig. 7.10 Development of energy costs and the "responsible" components

systems, the hot water in the system was not running past the electrical heating cartridge. Instead, the cartridge was being bathed in cold water, which signalled that the water temperature had fallen below the threshold and constantly needed electrical heating. This problem could not be identified by single measurements but by observing the situation and its development for a longer period of time. With the identification of this problem and its correction, alongwith a few more minor problems, it was possible to reduce energy consumption by another 30 %. The data is presented in Fig. 7.10, as well as the components which were responsible for the problem. The numbers can be verified with energy bills (although this would be a little embarrassing).

The reduction in energy consumption and costs cannot be sold as an unqualified success. Compared to the demands of what a WISE home system should be, the success of the project was only relative. The search for causes, and the recording, measurement and comparison all had to be done manually, which was complex and cumbersome. It produced efforts which would probably not have been in the interest (or within the ability) of average consumers. Obviously, problems do not only occur in regards to the control of smart homes. There are also drawbacks in the observation of operational status. This aspect motivated other research work, the findings of which managed to piece together another piece of the jigsaw of the WISE home of the future. My colleague AJ Fercher [18] analysed the possibilities of energy visualization, in relation to calmness. As pointed out in Chap. 2 devices in a conventional home typically try to compete for the (focussed) attention of the user. But information could also be provided in a reserved and decent way, such as illustrated in the work of [19]. The display of information about energy consumption provides a good example for this. It should be possible to observe energy consumption peripherally, reserving the ability to intervene if necessary, but without any demand for care or concern. The solution shown in Fig. 7.11 is based on the concept of informative art [20] and includes elements of the concept *perceivable energy* [18]. The plant on coffee table illustrates the current level of energy consumption. When the plant is in good shape, this means that the energy consumption is in an average range. A wilting plant shows that energy consumption

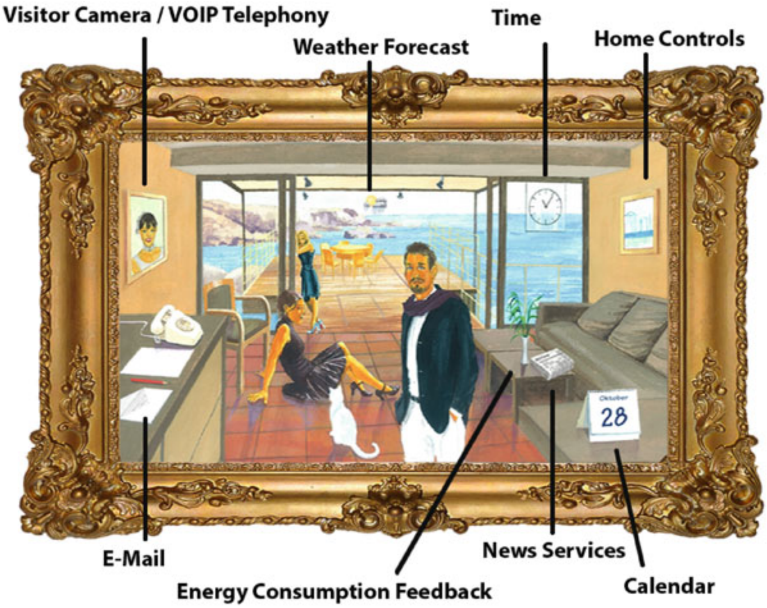

Fig. 7.11 Information Visualisation in a calm way, based on an artwork of A. Fercher (used with permission). The artwork was used in the Casa Vecchia project (described in detail in Sect. 7.3) as the interface of the central unit. Beside other features, it shows the current level of energy consumption. If the plant on the living room table is in good condition, this symbolizes an appropriate level of energy consumption. If the plant is wilted, this shows that too much energy is consumed and symbolizes environmental degradation [18]

is too high, having a negative impact on the environment. Figure 7.11 shows the central interface of the Casa Vecchia project and includes additional functionality. The design represents only one example of energy visualization, other alternatives are depicted in [18]. People could decide the motif for displaying their energy consumption themselves. The interface does not only allow the observation of the current level of energy consumption, but also, for example, a comparison with historical data.

The research presented next was carried out in HH37 with a focus on the recognition of activity patterns of multiple users [21, 22]. For this purpose approximately 500,000 separate pieces of sensor data have been collected over the last two years. The series of studies had the goal of being able to differentiate between the activities of the inhabitants just on the basis of smart home components and observation of individual sequences of activity. The study was carried out in cooperation with [21]. Illustrations of preliminary results are shown below. As pointed out above, within these settings there was a danger of confounding the roles of the different people involved (researcher vs. observed object). In the starting phases this problem was overcome by qualitative observations of the interactions between the installed system and those inhabitants who were not involved in the research. One of the first questions addressed has been if and how the other members of the family are using or accepting smart home functionality. The results were that some of the functions were appreciated. The remote control to close or open the blinds with only one button press was frequently used, specifically in the living room, as shown on the charts that are depicted on the left hand side of Fig. 7.14. The problem was the different modes. Pressing buttons longer activated a different function – programming the duration of the blinds to go up or down. These different modes were difficult to understand and led to involuntary re-programming of components. On a subjective level, the smart home installations and studying their behaviour had the effect that the family members were scared of the installations and had the feeling of being permanently observed (Fig. 7.12).

The studies conducted in later stages strictly separate the inhabitants actively and passively collecting the data from the researcher conducting the analyses (who is not resident in HH37) [21]. The goal of a recent multi-user study was to develop unsupervised learning algorithms that would be able to identify behavioural patterns (in the sense of implicit interaction, as described in Sect. 5.1.2) and to derive individualized automated functionality with the enhanced difficulty of differentiating between the inhabitants. Behavioural patterns had to be learned by the system during the training and evaluation stage. This required additional sources of information (in the form of annotations) in order to achieve *ground truths* as a basis for machine learning; to extract data noise; and to separate activity patterns from different users which the system might have combined by mistake. Annotation methods included diary-keeping with a spreadsheet and with a mobile app, enabling the users to protocol their activities based on icons which had to be pressed when an activity started and again when it ended. The final tool to annotate activities was based on smart cameras, which periodically shot photos of the contexts the users were in. Figure 7.13 depicts some of the impressions from the viewpoint of the persons wearing the camera. Figure 7.14 provides an interesting insight into the progress of research over the last few years. Beside the establishment of the technical infrastructure enabling field-based smart home research, much effort was applied in the first years of research to the development of tools that support evaluations *in the wild*, as described in detail in [23–25]. When the attempt to develop tools to support field research started, we had to develop our own systems supporting these contextual evaluations. Meanwhile, as shown in the lower part of Fig. 7.14, integrated systems (e.g. Autographer[3]) have come into being and the possibilities of data combination and visualisation have improved [21].

The final example of HH37 demonstrates the relationships between smart technology and complex constructs that drive life at home. If the technology is appropriate, it does not give rise to conflicts with the values of the intended user. This is shown by the small example of the switch depicted in Fig. 7.15. In my younger daughter's bedroom, the light switches are positioned beside the entrance doors, as is quite common in houses of a certain age. This is a disadvantage when one

[3] http://www.autographer.com/

Fig. 7.12 Business in different rooms in the morning

Fig. 7.13 Scenes recorded with the necklace camera Autographer which periodically shoots pictures from the perspective of the user who wears it

Fig. 7.14 Multiuser tracking and pattern analysis, in the *upper part* the initial, custom made, status and in the *lower part* the current systems in use [21]

Fig. 7.15 Switch that has been customized by a girl to fit in her environment

would like to turn the lights on or off from some other location. For example, the bed is often located in the middle of the room, where no light switch is available. The conventional approach to solving this problem would be to do demoliton work, and install new wires and a wired switch near the bed. This would be cumbersome and it would also be anachronistic. If the bed were moved, then the position from which the lights are switched would have to be changed again, and the entire rewiring procedure would have to be repeated. As HH37 is fully equipped with smart components, another solution would have been to provide control for the lights. The problem that could be observed specifically with the children in the household was that they had some difficulties in mentally mapping different devices to the different buttons of the remote control. The preferred solution was therefore to install a wall mounted but smart switch right above my daughter's bed. The switch had two rockers and we could therefore not only enable switching lights but also the blinds, the original switch of which was near the window. The smart switch seemed to work, but it turned out that it was not as un-intrusive and intuitive as expected. One day my daughter asked me if she was allowed to re-design the switch a little bit. I did not know what she meant by that, but allowed it. The result is shown in Fig. 7.15. When asking her about her motivation she told me that the blank white switch seemed to her to be too out-of-place between her cuddly toys. It also occurred to me that, since she was not able to read at that time, the animal stickers on the switch served as memory aids, reminding her of the meanings of the different rocker positions. For example, the kangaroo jumps up, and therefore rocking the switch towards the kangaroo means that the blinds go up, too.

Although the experiences gained with HH37 are idiosyncratic and not representative, they proved to be of great help in the follow-up projects that were based on field deployment. Remember the German colleague who admitted that he would not want to live in his living lab? Many other researchers do not have the long-term experience of living in a smart home and so cannot use this experience to estimate, understand and solve problems that can occur in projects. Some of our experiences were interesting in terms of application to research, while many others served only to point out the boring reality of day-to-day life at home. In terms of installation and maintenance the work in HH37 was sometimes quite cumbersome. Sometimes that seemed understandable, others not. The troubles with the first installation was very annoying. Quite often it occurred that the system did not work, but because of the complexity of the system (gateway, PC, drivers, software components), searching for the problem was fatiguing. Fortunately, this changed with the new platform, where all mechanics and the control software were concentrated in one device. The weakest components in all stages of expansion were the batteries. In the context of studying activity patterns, some of them had to be exchanged preventively on a weekly basis. Components such as door contacts were very sensible for slamming doors, not maliciously, but simply as a typical way to close them. The door sensors stopped working because batteries became dislocated. But as was demonstrated with the generational changes of the roller blind actuators in Fig. 7.8, this problem has since been solved by components which integrate solar cells that produce enough energy to keep them operational for years. Other components, such as smart switches, can store the kinetic energy that is produced by pushing the rocker to load the battery. The experiences and results that could be gained in a setting such as HH37 could not have been achieved elsewhere, specifically in terms of be of realism of the collected data. The research itself brought interesting insights, specifically on the qualitative level.

7.3 Active and Assisted Living: The Casa Vecchia Project

The project presented in this section illustrates an attempt to overcome the limitations of lab experiments on the one hand, and the idiosyncratic perspective of a case study on the other. Experimental research has the benefit of objective and quantitative data, but the outcome often lacks external validity, due to the artificiality of the setting. A case study based on participant observation is biased by idiosyncratic and subjective elements and therefore the generalizability is questionable. In response to these issues, we designed a research project to combine the benefits and overcome the shortcomings of both types of study. The WISE platform was used as the basis of a possible solution to the difficulties involved in using Ambient Assisted Living (AAL), a concept which was recently renamed into Active and Assisted living, which is, in my opinion, emphasizes the goal to achieve in a much better way. The goal of the project was to address the threats of an ageing population, within the specific contextual conditions. AAL is based on the idea of applying any technology to support the elderly in their living contexts and to enable them to stay for a prolonged period within their *own four walls*. If any technology can be applied, then smart home technology should be applicable, too. With the help of appropriate technology, the elderly should be able to lead an independent life and to stay in their accustomed homes longer and in an enhanced quality than would be possible without such technology. Numerous AAL projects have been carried out all over the world during the course of the last decade. For examples of an overview see [26, 27]. Promising results were achieved, but a significant percentage of those projects followed the approach of moving elderly people into newly-built or refurbished care facilities equipped with AAL technology. Within these settings [12] only see marginal benefits of technology. Many surveys show that the majority of seniors want to stay at home in their old age [28]. In consideration of the proverb which exists in many languages: "*You cannot move an old tree without it dying*", the goal of our attempt was to bring appropriate technology to the people and not the other way around. Relocating the elderly can have dramatic consequences. Statistics show that the majority of people moved to nursing homes die within the first 6 months [29]. The reasons can be manifold, but probably are strongly related to the fact that people lose their feeling of being home, their familiarity with the environment, and confidence in their own abilities. Taking into consideration the meaning a home could have, which could only be superficially touched in Chap. 3, the consequences are understandable. I recently heard a sad story from a friend who knew about my work and was interested in using the WISE platform for her grandmother. However, because of the grandmother's condition and her living circumstances, it was not possible to support her with our solution. Although the grandmother in question was over 90 years old at the time, she still was able to manage her household, cook meals, independently manage her personal hygiene, and dress herself. She was supported by the family, who arranged frequent phone calls and at least two personal visits per day. The main responsible person was her son, but when he became sick and had to move into a hospital, his mother had also to be moved to a nursing home. My friend described the vast problems that her grandmother had in adjusting to her new living situation. For example, when she woke up at night and wanted to go to the bathroom, she stumbled or knocked things over as she felt her way in the dark. Clearly this happened because she was not familiar with the environment and was disoriented. This loss of familiarity had a deep impact on her. She passed away shortly after being transferred to the nursing home.

One of the central goals of *Casa Vecchia* was to protect the elderly from such dramatic experiences. Casa Vecchia is the Italian translation for *old house* and the name should emphasize the intentions of the approach; retrofitting new technology into *old houses* to enable an enhanced quality of life. This constituted an optimal way to approve the concept for the WISE home idea, the flexibility and adaptability of the platform and the process model described in Chaps. 5 and 6. The experiences and results that we could achieve in our lab experiments and in the context of HH37 built the basis for the project. Because of the inherent flexibility of the approach we could take into account the ample literature and resources available in the smart home field in general and in the AAL field in particular. We could easily integrate methods, concepts and software components without having to re-examine the whole development cycle from lab, model homes, field deployments. Instead we were able to integrate results directly with little effort [30].

Besides the main focus of the project on bringing AAL technologies to the ancestral homes of the elderly, the secondary focus of Casa Vecchia was to bring that technology to rural areas. The central methodological goal, field deployment and research of the WISE platform had to correspond to the availability of opportunities. Carinthia, Austria where our research institution is located is mainly made up of rural areas with only a few small to middle-sized cities. But this was not the only reason to focus on rural areas. Rural areas have a high socio-political relevance, because a significant percentage of the world's population lives in rural areas. Speaking from the EU member states, for example, this means that 125 million people live in rural areas, which is about 25 % of the entire population of the European Union [31, 32]. In terms of topography rural areas even represent around 80 % of the territory of Europe. Although the concrete numbers differ from country to country and from region to region, the relevance of rural areas can be considered comparable all over the world. Rural areas will play a specific role in the context of the big societal challenges in the future. Demographic change will have a higher impact on those areas, because phenomena such as rural escape have seen to it that rural areas are already currently characterised by a disproportionately high percentage of the elderly. In regards to economic developments to increase efficiency and reduce costs, rural areas will probably suffer to a higher extent from savings in infrastructure and supplies. People who need increased support, such as the elderly, would be disadvantaged by such developments if no countermeasures are taken. As has been already demonstrated in the past, technology can help to compensate for the consequences of such developments, if it is appropriately designed. A central goal of the WISE approach followed in the Casa Vecchia project was therefore to design supporting technology in a WISE way. The technology should not overrule and overexert people by turning their lives upside down, but enhance and strengthen their existing way of life with technology only where this is appropriate. It was therefore of high importance to carefully analyse not only the immediate living circumstances of the elderly but to additionally involve their social network, and local organizations and craftsmen. This was realized by involving a *trusted person*, a relative, neighbour or friend, together with each elderly person that participated in the project.

One problem related to the dissemination of home technology emphasized in the earlier chapters of this book was the understandable reluctance of average end consumers to adopt such technology into their homes, and to adapt to it once it was there. The relevance of this problem was also confirmed during the Casa Vecchia participant acquisition phase. The target group for the project, elderly people living at home in the region of Carinthia, constitutes around 50,000 people. The prerequisites to participate in the project were that the seniors were living independently and did not require professional support or permanent care. No knowledge in handling computers was required. Although we used channels for advertising the project such as popular newspapers and local radio stations, which are known to have a high penetration among the target group, only around one thousandths of the target group responded to our announcements. Some of the people who contacted us had to be excluded because of incorrect expectations about the project, or because of their being in a status (e.g. in a health condition) which would not have made possible to participate for ethical or security reasons. Of course we do not know the exact motives of the more than 49,000 people who did not contact us,but we did get feedback from around 200 elderly people in the course of senior days where we presented the project. Additionally a questionnaire survey was carried out addressing nursing and healthcare personnel. About 150 completed questionnaires were returned to us. The outcome of both evaluations was, in summary, a strong fear of having to install complicated technology in the home and becoming dependent on it, or even being at its mercy. Bad experiences with, and ignorance of, technology were obviously the biggest hindrances to potential participants. This hypothesis was confirmed by the characteristics of the persons who finally participated in the project. All of the participants had previous experiences with computers and therefore seemed to be kind of open to new technologies or at least less reluctant than the majority. The range of computer literacy in the sample was broad. One elderly woman, for example, had an outdated PC on which she only played solitaire from time to time. The other extreme was an elderly woman who told us that she had some experiences with computers but did not consider herself a knowledgeable computer user. During one of our first meetings she showed us her favourite video on YouTube and informed us that she frequently does Skype calls with her grandson who was currently on study stay in Australia. Between these two extremes, we also found every level of computer literacy, and many examples of computer usage for very specific purposes (e.g. to arrange the instrumentation of musical pieces). Although the general access to technology in the group of participants was positive, this did not mean that they were naïve in this regard. They also expressed concerns in regards to the technology, for example, the *youtube woman* was concerned about increased electronic smog caused by wireless technology. Other participants mentioned their concerns in regards to data collection and privacy.

Although the participants had a certain similarity in regards to their experience with computers, they were very different on other characteristics. The spectrum of former professions, for example, ranged from farmers, workers, and drivers, to nurses, entrepreneurs, and managers. Their level of education was generally higher than in the average population. Occasionally persons of lower social classes were interested in the project. In one case a retired lady being dependent on a wheelchair would have been interested in participating in the project but, in the end, she and her family were too sceptical about the real intentions of these scientists (us) and about what they might really be asked or tricked into doing. Such misunderstandings did not only occur with members of low societal class. A retired medical doctor, who was obviously a very prosperous member of the upper class, had a completely false impression of how we might conduct our research, and to what end. He wanted the smart home equipment, support and maintenance for free, but with no balancing contribution from his side; no participating in interviews, no allowing data collection, and no filling in of questionnaires.

It was only later in the project that we came to realize that there was another, probably more important, similarity in the motivation of the participants that finally stayed in the project. All of them had direct or indirect past experiences with severe health problems. The range of experiences were broad, and included problems with one's own personal health – such as heart attacks and strokes, or other severe problems that had to be treated with complex surgeries. Others were motivated to participate by indirect experiences such as observing the beginning cognitive impairments in their partner or being responsible for care-dependent relatives. In the interviews all participants had expressed the fear that sooner or later they would have to leave their current home if their own health conditions or the condition of their partner should change. However, if and when this would happen was unclear and unforeseeable, and this uncertainty was a burden to them. They therefore welcomed any research on technology that could provide security and support features-hoping for alternatives to moving into nursing homes. Moving into a nursing home was not seen as a *natural* option in the rural areas, in which the majority of the Casa Vecchia participants were living. The topographic distribution of the participating households is shown in Fig. 7.16

About half of the persons participating in Casa Vecchia were elderly singles, the other half of them were living in a partnership. The majority of trusted persons involved in the project were adult children or other relatives. In single cases they

Fig. 7.16 Topographic distribution of participating households. The *white circles* represent the participating households. The *blue rectangles* represent the bigger cities in Carinthia (ranging between 10,000 and 60,000 inhabitants); the polygon shows the location of the university (where the server infrastructure is hosted) in the capital of Carinthia (which has around 100,000 inhabitants [30])

were neighbours or close friends. Details on the demographic data, taken from [30], can be found in Table 7.1.

Concrete AAL functionality had to be designed and developed in order to achieve Casa Vecchia's goals to support the elderly in staying in their own homes in old age. Two categories of functions were developed which correspond to what the related literature identified as the most important needs to be supported with AAL. The first was to enhance the security of the elderly. Due to the fact that elderly people are, with an increasing probability, living alone and – in our case – additionally in remote areas, we investigated possible ways in which technology could enhance their security. Also based on the consideration of bridging distances to the outside world, the second category of functions had the goal of enhancing the variety and quality of communication.

One of the major challenges in the preparatory work for Casa Vecchia involved the technical installations. Given the experiences with HH37 these difficulties were kind of expected. Our approach had to bear in mind the potential but understandable fear of being overruled by technology on the one hand and Mark Weiser's idea of unobtrusive and *disappearing* technology on the other. The consequences were that we installed the components of our system in a way that it did not influence the existing infrastructure and devices but that, rather, worked in parallel to them. If the smart system did not work in the expected way, the conventional components were still operational. As a second important feature the system was optimized to provide the highest possible level of stability and self-healing functionality. This meant, for example, that after a power outage (which frequently happened, specifically in remote areas) the system rebooted itself automatically. Achieving those features was not an easy task because of the vast range of households participating in the project,

Table 7.1 Overview on the demographic characteristics of the Casa Vecchia sample

Age	Gender	Persons in household	Marital status	Former profession	Trusted person
73	m	1	Widowed	Worker, farmer	Son
62	f	2	Married	Hairdresser, housewife	Son
64	f	2	Married	Nurse, office clerk	Daughter
64	f	2	Married	Translator	Partner
66	m	2	Partnership	Social insurance clerk	Son
73	f	1	Widowed	Teacher	Son
64	m	2	Married	Kindergarden nurse	Neighbour
50	f	2	Married	Branch manager, clothing	Partner
71	m	2	Married	Mechanical engineer	Son
63	f	2	Married	Primary school teacher	Daughter in law
69	m	2	Married	Company owner, consultant	Son
66	f	1	Divorced	Nurse	Daughter
60	m	2	Married	Company car driver	Neighbour
61	f	2	Married	Hospital manager	Neighbour
70	f	1	Widowed	Hospitality industry	Son
71	f	1	Widowed	Owner of transport company	Sister
62	f	1	Widowed	School janitor	Daughter
64	m	2	Married	Highschool teacher	Sister
67	f	1	Widowed	Office clerk	Daughter, grandson
69	f	1	Divorced	Support for crime victims	Daughter
70	m	2	Married	M.D.	Partner
83	f	1	Widowed	Office clerk	Daughter

Mean Age	66,45
Age Standard Deviation	6,39
Main Persons in Project	
Female:	14
Male:	8
Sample size Main Persons:	22
Sample size with Partners (without Trusted Persons)	35

in terms of their age and their infrastructure. We installed our system into a 300 year old farm house, into several detached family homes from the second half of the twentieth century, into apartments being part of a bigger electrical infrastructure, and into a low energy house which already had a highly-sophisticated technical system for heating and climate, but no other smart features. We were even able to install and run the WISE platform in a completely energy autarchic farmhouse in which all electricity was supplied by photo-voltaics.

Fig. 7.17 Smart phone of trusted person with different background colors and alerting signals (Picture taken form [30])

To support the first category of AAL features – to enhance the security of the elderly – a selection of different solutions was developed corresponding to the two major forms of interaction provided by the WISE platform: *implicit interaction* and *explicit interaction*. As pointed out in Chap. 5, implicit interaction is based on artificial intelligence (AI). In the Casa Vecchia project AI supported the observation of the activity of participants and to determine whether or not an activity was regular [30]. If the activity deviated significantly from the norm, the system could automatically trigger an alarm to the outside world. Typically, this alarm was used to signal the trusted person who had previously been assigned to the role by the participant. According to the experiences that were learned from other projects [33], devices that have to be triggered manually or worn on the body have a high level of errors. Our approach was fully based on environmental sensors and actuators and, because it did not depend on explicit triggers, can be seen as a form of calm or peripheral interaction. The signals of deviating behaviour were sent to the trusted person's smart phone, as shown in Fig. 7.17. If a certain threshold was exceeded, the background of the smart phone (based on a traffic light metaphor) turned from green to yellow. If the probability that an incident had occurred was high, the background of the smart phone turned to red and the phone also sent acoustic signals.

The integration of potentially dangerous devices such as the kitchen stove into the WISE platform was another way to enhance the security of the elderly participants. The basic problem which could necessitate an intervention in this regard is the increased probability of forgetting things with age. The stove has the potential to be one of the most dangerous devices in an average household. It is responsible for a high percentage of burn accidents [34]. The technology-oriented approach (which is represented by products available on the market) would be to install an additional device, typically consisting of a switch coupled to a timer which has to be pre-programmed. If a person wants to cook, she or he has to press the additional switch or to activate the timer. Although these systems have advantages in terms of enhancing security, they bear several problems. It is difficult specifically for the elderly to change procedures they have been familiar with for a long time. Adding steps or components to a procedure could lead to a discontinuation of routines. This contradicts the demand to keep the elderly mentally fit, to support their independence and their dignity. The WISE approach we followed was therefore not to install a hurdle in the path of familiar interaction with familiar devices, but to try to enhance security in another way. The result was a custom component in the fuse box of the household coupled with a smoke detector. The usage of the kitchen stove stayed as it was before installing the smart components. But the automatic coupling with the smoke detector enhanced the security of the participants without interfering in their behaviour, and without the need for additional programming. I have to admit that our approach also had some drawbacks. For example, there were some false alarms. When people cooked pasta and poured the hot water in the sink, the steam was sometimes detected by the smoke detector, which immediately shut off the stove. However, this showed that our intervention did work. The difference in the approach is small but important. The additional switch might represent the easiest technological solution, installing a security level on the interface between the user and the technical system. The WISE approach is to leave the interface as it was, because it is familiar to the user. The security level is not put on the interface between user and the system, but in the back-end of the technical system.

Another security feature we tried to provide shows the limitations of current smart home system components. With the same type of switches that was depicted in Fig. 7.15 we tried to provide a central point of control for the enhancement of security. We installed a smart switch on the entrance door of the participating households in order to fulfil several purposes. First, the switch should prevent the system from triggering false alarms. When people left their homes they should press the switch to inform the system that they are not at home, so perceived deviations from regular activity patterns should not trigger an alarm. Second, all potentially dangerous devices such as the kitchen stove, a socket plug for the iron, and other hazards are automatically disconnected from the power mains. The final benefit was that when the system was aware of the absence of residents, it could simulate their presence in order to scare away potential burglars. The advantage of such a WISE presence simulation, in comparison to simple timer based solutions, would be that algorithms based on AI can use a random generator for the simulation and this would make it harder for somebody observing a scene to find regularities. However, despite of all of our intentions, the switch did not meet our expectations, because it did not fulfil the fundamental requirements that devices from an HCI perspective should have. As emphasized in Chap. 2 these are, for example, appropriate feedback, mapping, and affordances (signifiers). The switch was smart because it didn't have to be connected to the wiring of the household and therefore could be put anywhere. This advantage has a drawback, which is the energy supply. To be able to design such a switch in a slim and attractive form, only a small battery can be placed inside. In order not to have to change the battery often, energy consumption has to be reduced. Switches of the first series solved this problem by not providing any feedback at all (such as an LED flashing when the switch was triggered). A typical feedback mechanism from conventional switches was missing too, which is the position of the rocker. I know many people who could tell the status of an attached device based on the position of the rocker of the switch. Unfortunately, the smart switches which are part of many smart home systems have only a single resting state. Rocking the switch sends a binary actuation or deactivation impulse to the system. But the rocker does not stay in a position that might be used as a visual sign of whether the device is on or off. Instead, it always moves back to the original position so as not to continue sending a stream of impulses to the system. The result was that this switch had the same problems that had been criticised about technically oriented solutions. People did not integrate it into their *mental model* of the home and, because of missing feedback mechanisms, the switch did not remind them of its functionality. The reason to describe this problem at this point is to show that even the smallest details can have a high relevance and impact, and, such real-world insights could never be achieved in artificial settings or under lab conditions.

The other type of functionality provided in Casa Vecchia was communication features. The function to inform the trusted persons via their smart phones about the status of the elderly they care for is kind of a mixture between security and communication function. The other functionalities we provided had the focus of providing easier access to features of the Internet. As mentioned earlier, all of the participants had some experience with computers and some of them, such as the *youtube woman* did not need to be supported in their communication with new media. For the others, such as the woman who had only used her computer to play solitaire, we thought about how to provide the benefits of improved communication, but in a WISE approach focusing on their needs rather than on the technical possibilities. This required a change of perspective and a deconstruction of the state-of-the-art. Consider, for example, current E-Mail functionality. A frequent computer user is familiar with the steps involved in writing an E-Mail. Before being able to do that, they have to overcome the hurdles of the operating system such as logging in and selecting the appropriate E-Mail client program. The structure of a conventional E-Mail client program is complex. Many things have to be selected and defined, which make sense in formal correspondence, but maybe not in informal communication. Whoever remembers the time when we wrote paper letters and physically brought them to the letter box, probably also remembers the structure of the letters. Did anyone ever write a *subject header* on the birthday greetings for grandma? The approach that we followed was to throw away all the unnecessary stuff that should not bother a computer layperson and thus reduce the concept to what [35] would have called a *minimalist design*. Due to our team's knowledge and skills in regards to alternative interface concepts such as informative art [18, 20], we designed the E-Mail interface as a symbolic chalkboard where the participants could

Fig. 7.18 Picture of the simplified E-Mail client

directly write notes on the touch display of the central unit depicted in Fig. 7.11 and send them to the preprogrammed E-mail address of either the trusted person they had previously identified, or of others they would like. With the possibility to carefully approach technology without being overwhelmed by it we could awake the interest in some participants to do more (Fig. 7.18).

Combined with the attempt to provide appropriate functionality to the people it was also a goal to deploy the technology used for communication and information purposes in a similarly unobtrusive form as the security function. However, those features are based on *explicit interaction* and insofar they required appropriate interfaces and devices to interact with. What we tried for several reasons was to design them in a way that they are not in the foreground and integrate them into the environment (in the sense of Weiser). Figure 7.19 shows examples of the positioning of the central units that provide those functionalities.

The previous discussion of Casa Vecchia may have drifted too far towards technical details and as a result, the difference between smart and WISE that has been addressed throughout the book may not yet be clear. But this is the reality. To be able to research the use of new technology it was necessary to conceptualize and install it. As pointed out in Chap. 5, we were only able to thoroughly investigate the potential impacts that the technology would have in the home once the infrastructure had been prepared. As was emphasized in Chap. 6, the real difference in the WISE approach, the difference that has hopefully also been demonstrated in the previous passages, is the variety of accompanying methods that can be applied in the phase of field deployments. In the course of Casa Vecchia, a mixture of methods was

Fig. 7.19 The central units of the WISE system placed on different places in Casa Vecchia households. As it is shown, the devices integrate themselves into the environments unobtrusively

applied – as described in detail in [30, 36]. In the following discussion, only a few examples of findings are provided. The investigations in Casa Vecchia started with interviews addressing the status of the potential participants and the trusted persons in regards to their living circumstances, their typical daily routines, their access to technology, and their social network. Based on this initial information the concrete installations of the WISE platform were conceptualized and customized to the individual circumstances. We built a customized evaluative instrument for the next phase of the project by combining aspects of three methodological concepts [37]. The central component of the approach was the technology acceptance model (TAM) [38]. The TAM has been used in numerous studies to investigate factors that are relevant to the use of technology, subsumed in the dimensions of *perceived ease of use* and *perceived usefulness*. These dimensions include many of the aspects that were presented in the theoretical parts of this book. For example, the motivation to show a behaviour is influenced by the self-assessment of being able to do so. The perceived ease of use dimension covers usability and user experience aspects of technologies. Perceived usefulness covers the utility of a technology, the purpose it fulfils. Other factors such as the subjective norm, considering the influence of relevant persons from the social network are also addressed. For our purposes, we adapted the TAM model to the home context and used it as a basis for the investigation of motivations and needs. The second central component of our evaluative instruments was the concept of contextual inquiry [39], focussing on the identification of relevant characteristics of the context within which a technology is used. Because the method had originally been developed for use in the context of work, it had to be adapted to the home context. The final concept included in our inventory is the social network analysis of [40].

In the course of four waves of evaluation, we collected information about the described dimensions and subsumed them into categories. The categories were:

- access to technology
- features of the social network
- life experiences and general life satisfaction
- demographic data and professional background, and
- private interests, engagement in associations, etc.…

Combined with analyses of sensor data (in the course of the project we collected 2.5 million real-world datasets) we were able to form very interesting insights into what has to be done to make AAL technology a success. Details on the data analysis can be found in [21, 30], the following examples are intended to emphasise the ways in which situated research can be carried out in a WISE manner. It has been pointed out in Chap. 6 that a central element of an appropriate evaluation process is to *understand* the circumstances under which life takes place. This understanding can be achieved by observation, but this observation will be biased by the viewpoint and interpretation of the researcher. Our goal has been to find a more direct way of understanding what is important for our participants. Towards that end, we used the method of cultural probes [41]. We provided disposable cameras to our participants and asked them to take photos of situations and things that are important to them, things to which they have positive or negative associations, and other things they are immediately concerned with or about. In addition to written comments regarding the photographs, we asked the participants to put sticky notes on each scene, specifically writing things that would help us to categorize them. Sticky notes with a “+” on them meant that the situation is associated with positive thoughts, a “–” was telling us, that the situation had negative connotations. The colours of the sticky notes were also used to help us to associate the pictures to the different categories enumerated above. Because of the quality the disposable cameras provided, lighting conditions, and size of the photographs, the details are not as clear as we would have liked. The overall results that could be achieved from the cultural probes are that people enjoy being with family and friends, engage in activities such as playing cards or meeting in a choir. The majority of negative associations were related to technology. A washing machine, for example, supports important needs of hygiene, but is too complicated. The same applies to computers and mobile phones. Figure 7.20 includes a selection of the provided photographs.

Another methodological detail which might be considered to be kind of WISE was the way in which we recorded our interviews with the participants. It is typical that interview data should be digitized for the sake of efficiency and effectiveness. The problem is that devices to take notes such as laptops create a barrier between the interviewer and interviewee. Other technical devices such as smart phones, tablets or even dictaphones attract too much attention and disturb the setting. The alternative, conventional note taking, has the drawback that documents are available

Fig. 7.20 Cultural Probes – we gave disposable cameras to the participants and ask them to take photos from things in their lives that are relevant to them, in different categories. Relationship, Technology, Non-Technology, Happyness, etc. The photos can represent positive or negative aspects, or other aspects which we asked the participants to describe. The figure shows a snippet of the photos we got

in physical form, but then have to be digitized for the reasons referred to above. A nice technical solution (which is not an achievement of our own work, but is still kind of WISE despite that) is the system named Livescribe (TM). It consists of a notebook that looks like a conventional notebook and a pen which looks like a fairly conventional pen. The pen actually digitizes the writing in real time, and also captures an audio recording of the conversation. In this way the flow of communication is not disturbed by the obvious presence of technology. Everyone is used to a conversational partner who takes notes. The digitized contents are automatically generated and easily distributed within the team for further analyses.

The major insight from the project is that a WISE home system has to handle different requirements and motivations of the inhabitants on at least two different levels. Basic needs, such as those related to nutrition (representing lower levels of Maslow's needs hierarchy) have to be fulfilled without having to overcome additional obstacles. The elderly, but assumably also other users of smart technology, are not interested in pseudo-enhancements in the control of basic functionality, just in the end result. It should, for example, just be warm in the home, how this does happen it is not of interest. Interaction that is too complicated is not needed, nor is configuration. This would be an ideal area in which to apply the principles of implicit interaction based on AI features.

On the second level, it must be certain that interaction with the system is appropriate to the needs of the user. As [42] pointed out, things should become simpler in a smart home not more complicated. Additional remote controls to perform simple tasks are not appropriate. Other alternatives, such as speech interaction are therefore supported by the WISE platform. The example of the smart switch shows that many so-called smart devices are smart in terms of technology but do not appropriately meet basic requirements of interaction. Consider Weiser's [43] original idea that technology should convey all the necessary information to be used and not require *light switch literacy* [44].

As it could be observed in Casa Vecchia the use of technology is not continuous but undergoes phases. In the first phase of the project, when the technology was new and unknown, an euphoric contention with it was observable. This is not surprising and is, in fact, probable for all new things. When the technology became familiar, the quality and quantity of usage settled to a level which allowed a more realistic estimation of the acceptance of the technology and the influence it has on daily life. Although the goal to deploy the technology in an unobtrusive manner could be achieved to a reasonable extent, the technology still changed behaviour and effected interpersonal relationships, frequency and quality of contacts with people taking care of each other. A clear gender difference in regard to the access to technology was also observable. This is addressed in more detail in [36]. In short, men proved likely to be intrinsically motivated to use the technology, whereas women typically wanted to have functionality that would support them in overcoming concrete problems or limitations.

Another outcome that could probably not have been identified in laboratory settings is that there is not an overall level of acceptance and level of intrusion of the provided functionalities into daily life. Instead, there is a difference related to functionality. Life- and health-critical functionality should not – for several reasons – depend on explicit input from the user. First, in real emergency situations people may not be able to actively trigger an alarm. Therefore this kind of functionality should be automated. Second, active triggers based on a single device may lead to a higher probability of false alarms. With the possibility of interconnection provided by the WISE platform, the accuracy of differentiating between a real emergency situation and false positives can be enhanced by integrating the information of more than one sensor.

Third, a person in need may not be willing to trigger a call for help because, as we have heard in numerous interviews, they do not want to be a burden to their relatives or to generate unnecessary service costs (e.g. for professional care providers). This example has a clear relation to socio-psychological aspects, the value system of the respective persons which neither can be evaluated nor solved on a technical level alone. In contrast to that, people would not accept that a technical system automatically controls entertainment and communication features. These features require appropriate interfaces to enable and motivate users to use them frequently. Neither short term evaluations (conventional and periodical usability evaluations) would have discovered such phenomena, nor would short-term stays in living labs have been able to reveal the whole range of influential contextual aspects.

We could not have learned what we did over the course of the four years we spent accompanying our participants in their very own living circumstances, if we had had to rely on laboratory settings and short term investigations. For example, we would not have observed the different phases of highs and lows in the motivation of our participants. It was interesting to see how their attitude to technology changed – and not always in a positive way – once they understood what smart technology could and could not concretely do in their own environment. Some of the participants were quite disappointed with the limitations of the new technology, especially, for example, in regards to stability and reliability. Others were at once fascinated by and scared of the possibilities to track a person's activities and behaviour without having to fully equip him or her with a bunch of sensors, just by observing the usage of electric devices that just were intelligently coupled with smart home components.

References

1. Brush, A. J., Lee, B., Mahajan, R., Agarwal, S., Saroiu, S., & Dixon, C. (2011). Home automation in the wild: Challenges and opportunities. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2115–2124). New York: ACM.
2. Mennicken, S., & Huang, E. M. (2012). Hacking the natural habitat: An in-the-wild study of smart homes, their development, and the people who live in them. In *Pervasive computing* (pp. 143–160). Berlin/Heidelberg: Springer.
3. Felsing, D. (2009). *Eine erweiterbare Smart Home Plattform auf Basis des FS20 Systems*. Diploma Thesis, Alpen-Adria Universität Klagenfurt, Klagenfurt.
4. Samselnig, R. (2012). *Ein Smarthome lernt Ortsabhängigkeit*. Diploma Thesis, Alpen-Adria Universität Klagenfurt, Klagenfurt.

5. Florian, M. (2010). *Spielregeln zur Beherrschung von Konflikten zwischen Benutzerprofilen in Multiuser-Smart-Homes*. Diploma Thesis, Alpen-Adria Universität Klagenfurt, Klagenfurt.
6. Grötschnig, B. (2011). *Erkennung von Verhaltensmustern in Smart Homes zur Unterstützung älterer Menschen*. Diploma Thesis, Alpen-Adria Universität Klagenfurt, Klagenfurt.
7. Leitner, G., Fercher, A. J., & Lassen, C. (2013). End users programming smart homes – A case study on scenario programming. In *Human-computer interaction and knowledge discovery in complex, unstructured, big data* (pp. 217–236). Berlin/Heidelberg: Springer.
8. Lieberman, H., Paternò, F., Klann, M., & Wulf, V. (2006). *End-user development: An emerging paradigm* (pp. 1–8). Amsterdam: Springer.
9. Laugwitz, B., Held, T., & Schrepp, M. (2008). *Construction and evaluation of a user experience questionnaire* (pp. 63–76). Berlin/Heidelberg: Springer.
10. Brown, J. N. A. (2014). *Unifying interaction across distributed controls in a smart environment using anthropology-based computing to make human-computer interaction "Calm"*. Ph.D. Thesis, Erasmus Mundus Doctorate Program in Interactive and Cognitive Environments (ICE), Alpen Adria Universität Klagenfurt.
11. Hindus, D. (1999). The importance of homes in technology research. In *Cooperative buildings. Integrating information, organizations, and architecture* (pp. 199–207). Berlin/Heidelberg: Springer.
12. Barlow, J., & Gann, D. (1998). A changing sense of place: Are integrated IT systems reshaping the home? http://139.184.32.141/Units/spru/publications/imprint/sewps/sewp18/sewp18.pdf.
13. Cook, D. J., & Schmitter-Edgecombe, M. (2009). Assessing the quality of activities in a smart environment. *Methods of Information in Medicine, 48*(5), 480.
14. Eckl, R., & MacWilliams, A. (2009). Smart home challenges and approaches to solve them: A practical industrial perspective. In *Intelligent interactive assistance and mobile multimedia computing* (pp. 119–130). Berlin/Heidelberg: Springer.
15. Takayama, L., Pantofaru, C., Robson, D., Soto, B., & Barry, M. (2012). Making technology homey: Finding sources of satisfaction and meaning in home automation. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing* (pp. 511–520). New York: ACM.
16. Horx, M. (2008). *Technolution: Wie unsere Zukunft sich entwickelt*. Frankfurt am Main: Campus.
17. Atkinson, P., & Hammersley, M. (1994). Ethnography and participant observation. In *Handbook of Qualitative Research* (Vol. 1(23), pp. 248–261). Thousand Oaks: Sage.
18. Fercher, A., Hitz, M., & Leitner, G. (2009). Pervasive approaches to awareness of energy consumption. In *Ami-Blocks*, Salzburg (pp. 3–8). Erlangen, Germany.
19. Weiser, M., & Brown, J. S. (1997). The coming age of calm technology. In *Beyond calculation* (pp. 75–85). New York: Springer.
20. Redström, J., Skog, T., & Hallnäs, L. (2000). Informative art: Using amplified artworks as information displays. In *Proceedings of DARE 2000 on Designing Augmented Reality Environments* (pp. 103–114). New York: ACM.
21. Ayuningtyas, C. *Activity modeling for multi-user environments*. Ph.D. Thesis. Erasmus Mundus Doctorate Program in Interactive and Cognitive Environments (ICE), Alpen Adria Universität Klagenfurt. Work in progress.
22. Leitner, G., Melcher, R., & Hitz, M. (2012). Spielregeln im intelligenten Wohnumfeld. In *Vernetzung als soziales und technisches Paradigma* (pp. 189–206). Wiesbaden: Springer VS.
23. Leitner, G., & Hitz, M. (2005). The usability observation cap. In *Proceedings of the 5th International Conference on Methods and Techniques in Behavioral Research* (pp. 8–13). Wageningen: Noldus.
24. Leitner, G., Plattner, S., & Hitz, M. (2006). Usability evaluation of mobile applications in leisure-oriented contexts. In *Information and communication technologies in tourism* (pp. 158–169). Vienna: Springer.
25. Leitner, G., Ahlström, D., & Hitz, M. (2007). Usability of mobile computing in emergency response systems: Lessons learned and future directions. In *HCI and usability for medicine and health care* (LNCS, Vol. 4799, pp. 241–254). Springer: Berlin/Heidelberg.

26. Chan, M., Estéve, D., Escriba, C., & Campo, E. (2008). A review of smart homes – Present state and future challenges. *Computer Methods and Programs in Biomedicine, 91*(1), 55–81.
27. Yamazaki, T. (2006). Beyond the smart home. In *International Conference on Hybrid Information Technology, 2006 (ICHIT'06)*, Cheju Island (Vol. 2, pp. 350–355). IEEE.
28. http://assets.aarp.org/rgcenter/general/home-community-services-10.pdf.
29. Kelly, A., Conell-Price, J., Covinsky, K., Cenzer, I. S., Chang, A., Boscardin, W. J., & Smith, A. K. (2010). Length of stay for older adults residing in nursing homes at the end of life. *Journal of the American Geriatrics Society, 58*, 1701–1706. doi:10.1111/j.1532-5415.2010.03005.x.
30. Leitner, G., Felfernig, A., Fercher, A. J., & Hitz, M. (2014). Disseminating ambient assisted living in rural areas. *Sensors, Special Issue Ambient Assisted Living, 14*(8), 13496–13531.
31. Eurostat Yearbook. http://ec.europa.eu/eurostat/documents/3217494/5726181/KS-HA-10-001-15-EN.PDF/5499ee07-b61e-4615-9631-ed76e2a31f81?version=1.0.
32. Jonard, F., Lambotte, M., Ramos, F., Terres, J. M., & Bamps, C. (2009). *Delimitations of rural areas in Europe using criteria of population density, remoteness and land cover*. JRC Scientific and Technical Reports, European Commission, Joint Research Center, Institute for Environment and Sustainability (EUR, 23757).
33. Hirsch, T., Forlizzi, J., Hyder, E., Goetz, J., Kurtz, C., & Stroback, J. (2000). The ELDer project: Social, emotional, and environmental factors in the design of eldercare technologies. In *Proceedings on the 2000 Conference on Universal Usability* (pp. 72–79). New York: ACM.
34. Ahrens, M. (2009). Home fires involving cooking equipment. Quincy: National Fire Protection Association.
35. Nielsen, J. (1994). Heuristic evaluation. *Usability Inspection Methods, 17*(1), 25–62.
36. Leitner, G., Mitrea, O., & Fercher, A. J. (2013). Towards an acceptance model for AAL. In *Human factors in computing and informatics* (pp. 672–679). Berlin/Heidelberg: Springer.
37. Koskela, T., & Väänänen-Vainio-Mattila, K. (2004). Evolution towards smart home environments: Empirical evaluation of three user interfaces. *Personal and Ubiquitous Computing, 8*(3–4), 234–240.
38. Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences, 39*(2), 273–315.
39. Beyer, H., & Holtzblatt, K. (1999). Contextual design. *Interactions, 6*(1), 32–42.
40. Scott, J. (2000). *Social network analysis: A handbook* (2nd ed.). London: Sage.
41. Gaver, B., Dunne, T., & Pacenti, E. (1999). Design: Cultural probes. *Interactions, 6*(1), 21–29.
42. Hamill, L. (2006). Controlling smart devices in the home. *The Information Society, 22*(4), 241–249.
43. Weiser, M. (1991). The computer for the 21st century. *Scientific American, 265*(3), 94–104.
44. Dourish, P. (2004). *Where the action is: The foundations of embodied interaction*. Cambridge: MIT.