Chapter 5
Theoretical Foundations of the WISE Home

Given the complexity and variety of potentially relevant aspects in the interaction with and within a home in general and a smart home in particular, field-based, longitudinal research is the only chance for appropriately covering the whole scope. This research has to be performed within real world living environments to be able to thoroughly understand *situatedness* [1]; the interplay between characteristics of the home (or better, the house as the surrounding infrastructure), its inhabitants, and the available technology. This form of research has a long-standing scientific tradition in the social sciences and humanities (as will be pointed out in Chap. 6) and has also gained importance in HCI, inspired by respective research activities in CSCW [2].

However, before being able to research technology in the field, specific challenges must be tackled. Given the low dissemination of advanced smart technology, as pointed out in the previous chapters, there is also a low probability of finding facilities that already have integrated such technology that would be required in order to study the triadic relation between house, inhabitants and (smart) technology. In order to make it possible to conduct field research, an alternative strategy would have to be found. Analogously to other approaches in field research, the goal of the attempts to reach the WISE home was therefore to develop prototype systems which could easily be installed and retrofitted. The prototypes have to be flexible and mobile to enable the provision of basic technology to potential users and to be used it in a daily manner under real world conditions. Unlike with single and mobile devices, the difficulty is that smart technology has to be integrated. To succeed at the original experimental design, an unusual amount of additional preparatory work was therefore necessary. In accordance with the theoretical discussion of the last chapters a WISE platform home was established which meets the proposed requirements.

G. Leitner, *The Future Home is Wise, Not Smart*, Computer Supported Cooperative Work, DOI 10.1007/978-3-319-23093-1_5

5.1 Technical Foundation

An indispensable part of WISE is a technological basis which supports a flexible and customized implementation of hard- and software components and in this way enables the thorough investigation of a broad variety of phenomena that are related to technology in the home. It was emphasised in Chap. 4 that the majority of smart home systems available on the end consumer market generally lack compatibility and interoperability. Although there are initiatives and consortia striving for interoperability and standardization, they were either not available or not appropriate (because of technical requirements and limitations) when the work presented in this book was started. The approach followed was therefore to develop an own system that provides the required flexibility and possibility of customization, but also takes into account the compatibility and interoperability issues pointed out in Chap. 4.

Those issues could be addressed with an appropriate architecture which it is based on software components which enable the integration of devices from different manufacturers offering, therefore, a wide range of functionality. The system is based on a service oriented architecture (SOA), which integrates hardware devices either as providers of a certain service (e.g. visual display) or as service users. In the concrete realization the WISE platform is implemented on the basis of an OSGi middleware architecture as a central component. The reason for using OSGi was that the platform is open both in terms of free of charge use and the possibility for customization and, in terms of further development and enhancement. A growing community of developers, researchers and companies contribute to the development of OSGi. As a result, it can be considered the leading architecture in the domain of research-oriented smart homes. Numerous research projects following many different goals are running on OSGi [3–5]. The custom solution to support the WISE approach was initially build and further developed by [6–8]. The high level architecture of the platform is laid out in Fig. 5.1. A more detailed description of the platform is presented in [9] and [10].

The hardware-related layers of the architecture are responsible for the integration of attached devices and their provision to the system in an abstracted form (labelled as systems A, B and C to emphasize their different origins). With this abstraction a user or an external system connected to the platform can handle them as if they were elements of a single system. The platform was sequentially enhanced; first installed and tested in the lab facilities of the university, then transferred to the real world test bed, described in Chap. 7 and related publications such as [11, 12] and [13]. Finally the platform was deployed in the course of a larger scale field project, Casa Vecchia,[1] which is also described in more detail in Chap. 7 and the related publications [9, 14, 15]. Because of its modular nature, the

[1] http://www.casavecchia.at, the project was funded by the Austrian Research Promotion Agency and the Privatstiftung Kärntner Sparkasse in the program line benefit, Project.No. 825889.

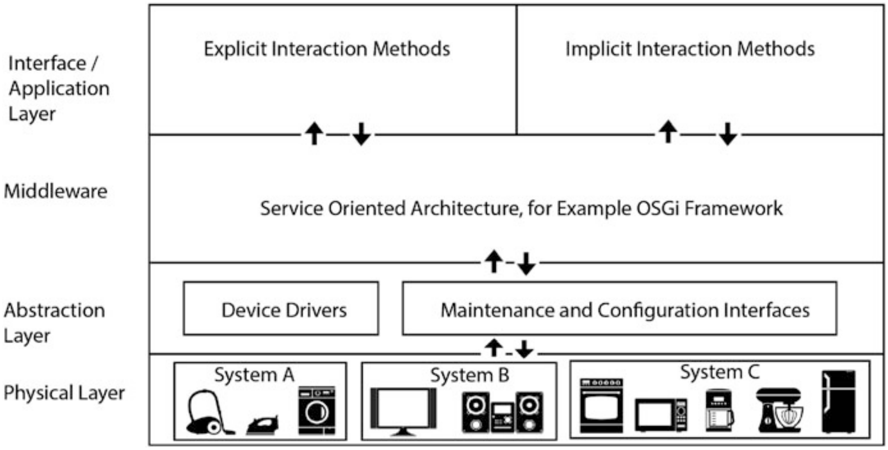

Fig. 5.1 Platform architecture illustrating the integration of devices from different manufacturers (labelled as systems *A*, *B* and *C*) in the base layer, the abstraction and middleware responsible for the provision of services in the middle and the possibilities for accessing devices over these services with explicit and implicit interaction on the top layer

platform supports adaptive and customized integration into different environments and living circumstances and has a functional range that can incorporate features that are typically not available in standard state-of-the-art smart home systems. This includes, for example, health and security functions [15] as well as functions related to energy management [8], entertainment, and comfort [16, 17].

A prerequisite for a software platform to work in the intended way is appropriate hardware which has integrated components that cover the required range of functionality. Investigations were conducted into the availability of smart home systems which would fulfil those requirements. One initial challenge was the inherent difficulty of retrofitting smart technology into real world living environments. After all, the latter are not generally designed and built for the integration of ambient intelligence [18–20]. One important requirement was therefore that a suitable hardware would have to be small enough in size to be integrated even into a very limited amount of space. In order to support interconnection and networking without having to invest high manual efforts, wireless systems were the first choice [9–11]. Another requirement suitable systems had to fulfil was related to costs. In contrast to costs that can occur in research contexts, expenses for the field installations were intended to be within the budget of average private homes – both in terms of initial financial investments and in terms of costs related to the manual efforts for retrofitting and maintenance [21–24]. A final requirement was the potential flexibility that, at that point, could only be estimated on the basis of the features a system already offered. This flexibility should allow the system to be customized in order to suit a broad variety of future requirements that were still, at the time the research attempts described in this book were started, partly unknown; technical requirements such as the possibility to extend the functional range, and, human requirements that had not yet been defined. Even with these constraints, a market survey revealed an almost incomprehensible variety of potentially suitable systems (as illustrated in Chap. 4). As has been pointed out in Chap. 4, systems and devices carrying the label *smart home* are offered through a number of distribution channels with different functional orientations. The final hardware basis (described in detail in Chap. 7) consisted of five subsystems. This was not only the case because no singular system could cover the required functional range. It was also intended as a proof of concept for the flexibility and adaptability of the platform. The hardware covering the biggest range of functionality is a wireless off-the-shelf system from a German manufacturer. The predecessor system served as the hardware basis for the initial development of the WISE platform. It had to be exchanged because of technical limitations, for example, missing bi-directional communication. Another system which could be integrated was a powerline system from Switzerland, which was intended to cover areas in households where wireless communication is impossible or it would not be acceptable because of concerns regarding electronic smog. Custom solutions based on the Arduino® smartboard platform could be integrated supporting the development of custom hardware that provides functionality which was not available in any suitable hardware platform on the market. Finally, it was possible to establish a communication gateway between the WISE platform and another smart home software platform, building brain, which was developed by colleagues from the University of Udine. The focus of building brain is the support of large scale smart environments, such as smart cities. The ability to establish an interface between the two platforms additionally demonstrated the flexibility of our approach.

The integrated hard- and software platform is only a prerequisite for the central goal of the WISE approach – being able to study human computer interaction within the specific context of the home. More concretely, the goal is to be able to study the interaction between users and a smart home system under real world conditions. Two principle forms of interaction with a smart home system could be identified as a result of our own theoretical work and the work of others in the field (as presented in the previous chapters). The first is labelled *explicit interaction*, which [25] called purposeful and direct interaction, and which covers the voluntary and intentional interaction between a user and a smart home system. The second is *implicit interaction* (incidental interaction in [25]'s nomenclature) and is based on the analysis of activity in and interaction with components of the home, for example in the course of rituals and habits. The observation and analysis of such behaviours with AI features can be used to calculate predictions for activities and to derive automatic functions. There are major differences between the WISE platform and state-of-the-art smart home systems. First, standard smart home systems are, in general, not capable of acting smartly in the long term, because they do not have the necessary capabilities, such as a *data or knowledge base* that would make it possible to store data for further analysis. Second, standard smart home systems lack an appropriate algorithmic basis for advanced data analyses, such a *reasoning* and *pattern recognition*, which would make it possible to derive conclusions and to automate functions based on the stored data. Third, the WISE system integrates explicit and implicit interaction features in order to resolve conflicts that result from the different types of intelligences, as has been pointed out in Chap. 2 and [9, 10, 26–28].

5.1.1 Means and Possibilities of Explicit Interaction

The first form of interaction discussed in detail is explicit interaction. As pointed out in Chap. 2 interaction in and with a home has to be observed in a broader sense than in, for example, desktop settings [11, 12, 15, 29, 30]. When considering the interaction between a user and even a conventional home, there are many possibilities for explicit interaction. This could be triggering a wall-mounted switch, a switch on a device itself, or, a button on a remote control. In a smart home, this variety is expanded, because a smart home additionally enables interaction via software interfaces, for example from a desktop computer, a smart phone or a tablet. The result, for a fully-fledged smart home, can be a very high level of complexity. This makes it difficult to define interfaces [31] that appropriately meet user requirements. Figure 5.2 shows examples of possible means of explicit interaction in a smart home. The example is limited to tactile and visual interfaces, but multi-modal interaction, for example with speech and gesture would also be possible.

According to the original understanding of a *smart home*, all devices would have to be integrated into one system to give a user the impression that the home is a holistic entity [32, 33]. This is in clear contrast to the accumulation of stand-alone devices or technology typically present in a home. State-of-the-art technologies are based on an incomprehensibly vast and varied range of distinct interaction

Fig. 5.2 Different forms of interfaces in a smart home and devices that can be controlled by them

principles, leading to an exacerbation of *remote control anarchy* [34]. To overcome the potentially related problems the WISE approach reconsiders basic concepts of human computer interaction and applies them to the context of the home. One of those concepts is the characteristics of interaction introduced by [35], which are, for example, affordances (or their new name – signifiers – [36]), feedback, mapping or constraints. To emphasize their relevance the characteristics of a smart switch are investigated. A smart switch can be considered to represent an *internet of things* (IoT) device [37]. It constitutes a hybrid device that has the look and feel of a conventional wall-mounted switch but is independent from wiring and other physical constraints. The functions that can be triggered by such a switch can be located anywhere and therefore do not cause a feedback in the location the switch itself is located. This can affect the comprehension of mapping (where are the devices located that are triggered by the switch) as well as feedback mechanisms (in what status are the triggered devices). Appropriately considering the accompanying circumstances to avoid pitfalls of incomprehensible functionality, as described by [38, 39] is a central requirement of WISE interaction. Components would have to provide appropriate features to support the mental models of the users. In regards to a smart switch, the mental model of a user is probably more similar to a conventional wall mount switch rather than a remote control (although they might be the same from the technical point of view, as illustrated in Fig. 5.3). The relevance of this difference will be illustrated in Chap. 7.

Specifically in the context of the home, and because of attentional and motivational aspects (which were addressed in Chap. 2) it is important to ensure an easy, intuitive interaction with a smart home system. In this regard, current movements in HCI question the concepts of *user*, *task* and point out coming changes, such as the *end of interface stability* [29]. Appropriate technology should be designed in a way that would enable users to freely choose which devices to use for interaction, and in what order and combination to use them; selecting the appropriate means and modality with which to perform any given interaction. This freedom of choice occurs naturally in human to human interaction, where the combination

Fig. 5.3 Remote control and wall switch of a smart home system, representing two different designs of one and the same technical component

Table 5.1 The table illustrates the differences and commonalities of the WISE concept and URC

WIse	URC
Application Layer	Controllers
Middleware Layer	UI Protocol Layer
	UI Socket Layer
Bridge Layer	Target Adapter Layer
Hardware Layer	Target

and the change between gesture, tactile, and verbal interaction works smoothly. In contrast to this experience, devices and systems present in current homes are typically concentrated on brand- and manufacturer-specific concepts, which are often incomprehensible for the user, specifically when they have to be used in a combined way. A way to overcome these problems and increase the ease of interaction with technology in the home would some kind of convention which is also found in human to human interaction. Conventions determine what form of interaction is appropriate and what is not. This approach could be used to enhance explicit interaction.

One concept to support such conventions is URC (Universal Remote Console) [40]. The universal remote console strives for a standardization of interfaces to the hardware layers and enables a *seamless* access to the devices integrated in a system (such as a smart home system) from a broad variety of software interfaces. As illustrated in Table 5.1, URC has some parallels to the lower layers of the WISE platform because it is also based on the abstraction of devices in order to make them accessible on standardized protocols or, as it was termed above, conventions.

URC has its focus more on the hardware and back-end software rather than on the interface level. It addresses basic problems of the integration of devices, and so has parallels to the WISE approach. The history of software interfaces has shown that high degrees of freedom in the design do not always have a positive effect. Such a negative development of interfaces in terms of usability is observable in myriad mobile device apps, and has meanwhile reached the smart home field. One could have an app for the refrigerator to check its contents, another app for the kitchen oven to upload recipes for automated cooking, and yet another app to start the washing machine remotely. These apps are typically based on corporate design and brand strategies rather than on standard interaction concepts.

In this regard, the definition of conventions would also make sense. One promising concept to achieve this goal is User Interface or HCI patterns [41]. These patterns were introduced by Alexander who described principle solutions for recurring problems in architectural contexts [42]. The benefits of patterns is their ability to abstract concrete problems to their principle elements. A well-known pattern for interface design is, for example, the shopping cart in online shopping platforms. Although the cart can be quite different in terms of design, location in the website and basic elements (e.g. the available payment possibilities) the principle steps (put items into the cart, change/remove items, check payment and shipping options, finish the process and checkout) are the same. By taking into account such patterns a WISE home would help to solve the problems related to inconsistencies and incomprehensible procedures. For example, the problems related to the VCR clock example presented in Chap. 1.

Most people in the western world have to deal with the problem of resetting their clocks twice a year, when the time has to be changed from winter to summertime or vice versa. It is fascinating to consider the many different ways in which one might set a clock. With appropriate patterns such tasks could be made more intuitive for their users. This is true for generally simple things as clock setting, but also for more complex tasks such as programming procedures (on a VCR, DVD Recorder, Harddisk Recorder, Mp3-Device or NAS), and for procedures that only occur infrequently – such as the decalcification of a coffee maker. All of the mentioned examples are probably that difficult to use, because the focus in their design was on the availability of technical components instead of the tasks, capabilities or experiences of their users.

In the home context the application of patterns need not be limited to virtual interfaces like the shopping cart. Pattern could be applied beyond virtual interfaces and across virtual and hardware interfaces present in the home. On the example of the many different forms of heating controls that are present in the home [15] the respective possibilities are emphasised. On a radiator, there is typically a circular knob to control temperature, and the same applies for room thermostats. But when observing smart home control software, temperature controls are often represented as sliders. Sliders are standard widgets in GUI design and this is probably why they are used for the design of temperature controls on virtual interfaces. The physical knob, however, has a better affordance and is more intuitive to a user. Additionally, its form factor is dependent on the physical constraints of the radiator valve (which is circular). Patterns would have to take into consideration all those aspects and, in the best case, the result would be a collection of standardized, intuitive, multi-modal and cross-platform applicable interaction patterns, that fulfil the requirement that are best described with: "*Don't make me think*" [43].

Concepts such as URC or Interface patterns could help to overcome several problems that occur in the home; problems which can currently be solved by smart technology, but not in a WISE way. For example, I assume that everyone knows the situation either personally or second-hand, when a TV is still working but the remote control is broken. Specifically for outdated televisions, it is often impossible to get an original spare remote, or it is too expensive and not worth a high investment. The solution is often a universal remote control. Most of the time these controllers are completely different from the original, in terms of look, feel, and handling. Elderly people in particular therefore shy away from changing their remote until it is completely broken. If an exchange cannot be delayed, do-it-yourself solutions to prevent elderly or inexperienced users from pressing the wrong buttons have to be applied. Examples for that can be found on several internet fora, for example.[2]

If remote controls were based more on standardized patterns and interaction conventions, rather than on brand-specific interaction concepts, this would be a step in the right direction and would not make necessary the work-arounds mentioned.

Another development on the level of software interfaces that could support the demand for a higher intuitiveness and more understandable interaction is HTML 5. Whereas interface patterns are focused on the basic building blocks of interaction, HTML 5 provides means for an appropriate implementation and design of the interface. This is possible because HMTL 5 can help to overcome inconsistencies, limitations and specifications of platforms, such as iOS, Android or Windows.

An important addition to HTML 5 to achieve the goal of enhanced interaction is the concept of responsive design [44] which illustrates possibilities to develop interfaces in a platform-independent and consistent way. The central idea of responsive design is that a developer of an interface never knows who the users of his system might be, and, more importantly, what device a user is currently using to interact with the system. The uncertainty of not knowing what devices a user is taking for interaction as well as the need to provide an optimal experience also applies to the smart home. PC, smartphone and tablets are only a few examples of the variety of tools with which a user could interact with a smart home system. The cumbersome solution would be to implement an interface for every platform separately to ensure that every user would have an optimal experience. Responsive design is based on the second alternative. With concepts such as cascading stylesheets and media queries responsive design supports an enhanced level of usability on different devices and platforms.

Taking into account conventions does not have to result in a mishmash of boring and similar-looking interfaces. I would like to use again an example from the automotive sector at this point. Most people would probably agree that the diversity of cars is broad, especially in terms of design. Despite this diversity, each car can be controlled on the basis of more or less standardized patterns. Most cars have a steering wheel, an assembly of pedals, a gear box. These basic elements and conventions that define their design and position in a car ensure that people can drive every car, in principle, even if it was of a brand a driver has never used before. The conventions do not have to interfere with design, because they still leave appropriate degrees of freedom for the design of cars. Those conventions would therefore also be an appropriate approach to increase the quality of interfaces for the home. It would enable interaction on the basis of generalizable principles and patterns but without limiting the creativity of the design of the interfaces and the platforms that are available.

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[2] http://areuxperienced.me/2015/05/15/ux-iota-lifes-short-the-crappy-ux-of-most-of-the-things-you-use-daily-make-it-shorter/, http://i.imgur.com/YMbGp3W.jpg, https://www.pinterest.com/pin/425238389786992973/

Taking into account these aspects opens new possibilities, such as to enable users to develop their own applications and interfaces. End user development (EUD, [45]) is, according to [46] the future of human computer interaction. They expect an evolution from systems that are *easy to use* towards systems that are *easy to develop*. However, the change from using basic functionality and interfaces to developing or modifying them requires either an expertise in programming or alternative forms of programming to allow users to build their own programs without requiring such skills. One solution is, for example, visual programming on the basis of basic elements (primitives), as demonstrated by [47]. Such programming alternatives were also investigated in the course of our own work and are presented in Chap. 7.

There are many reasons why EUD will gain importance in the future. One of them is that the need for EUD will increase due to the shift in the population pyramid, according to which the availability of qualified personnel will decrease [48]. Another argument is that, in terms of cycles and flexibility, conventional software development cannot support the variety of needs that would be required in the home context [46]. A third argument, which, in the context of increasing data abuse is probably the most important reason to support EUD, is the consideration of values, such as privacy, independence and autonomy. By giving users the possibility to take and keep control of their own data related threats and fears can be reduced. In [49] and [50], examples are provided showing how end user programming is (and could be) supported by the WISE platform on both a theoretical and a practical level.

The final, but not least important form of explicit interaction that can be considered specifically promising in the context of home is *peripheral*, or *calm* interaction as [51] labelled it. As has been emphasized in the previous chapters, activities in the home are different to those taking place in the workplace. They are often performed in parallel to one another, many of them even not in the focus of attention. However, the electronic devices in general and computerized devices in particular demand focused interaction of their users, as is observable with both mobile devices [52] and with devices in the home [51, 53]. In times of information overload it would specifically make sense to provide alternatives; supporting human capabilities such as peripheral attention or speech and gesture control to communicate with the environment [15]. The WISE platform supports this form of interaction – as is demonstrated, for example, with the design of the central interface of the platform, and alarm and information features available for smart phones, both described in detail in Chap. 7 and [9]. Conveying information on a peripheral level is also possible with pieces of furniture, as illustrated in [8] and [15]. Other forms of peripheral interaction have been conceptualized [54] and evaluated experimentally [55] for gesture and speech interaction, enabling a sort of *laid-back* interaction, as observable in Fig. 7.5, in which a study participant is totally relaxed while interacting with a smart home system. The interfaces in the WISE home platform are designed with a focus on an enhanced level of user experience by using alternative interface concepts such as informative art [56, 57].

5.1.2 Means and Possibilities of Implicit Interaction

The next category of interaction, *implicit interaction* is also happening peripherally, but with the difference to peripheral interaction that it is not requiring explicit triggers from users. To identify a need for a change to the system, AI is used. AI constitutes an appropriate basis for smartness, but according to [58] its relevance in ambient intelligence systems is still too low. Specifically in the segment of affordable systems, the provision of customized AI features fails in terms of appropriate infrastructures (such as databases or advanced analysis features) but also in terms of costs which would be required for their implementation. The WISE platform overcomes these limitations by using the open OSGi architecture which enables the integration of devices from different manufactures (as illustrated in Fig. 5.1), and implements AI features on an abstract, device-independent level. With this approach, enhanced levels of smartness are possible, even on the basis of low-price smart home components or systems. Smartness realized with AI is, for example, able to analyse activity that takes place in the home as *implicit interaction* and derives automated functionality from this activity without the need for the user to explicitly triggering a function. An example for that could be that the system observes that a user is frequently getting up at night and moves from the bedroom to the bathroom. On the basis of data analysis the system could provide a light corridor when this situation happens the next time. This kind of functionality would support a requirement of [25] who demands that a system "... *should get on with its job with little or no communication with the human*". There are different levels of smartness, which are imaginable. Figure 5.4 shows a conceptual model including different levels of smartness which served as a basis in the conceptualization of the enhanced smartness features for the WISE platform.

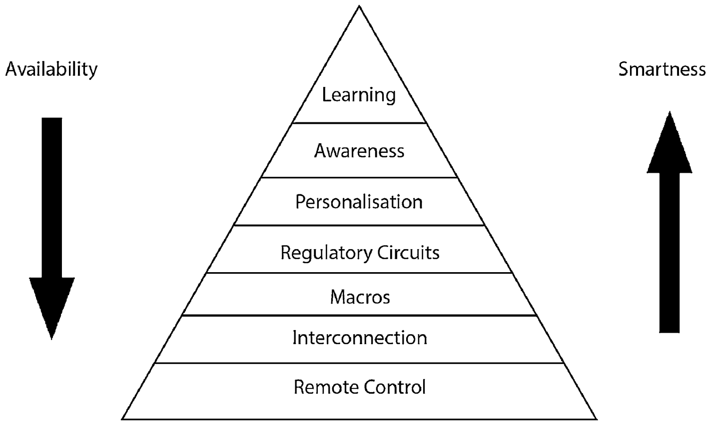

Fig. 5.4 Stages of evolution of smartness in the home starting with remote control on the basic level, followed by the possibility of networking and macro programming and representing personalization, awareness and learning as the highest levels of smartness [10]

When the model depicted in Fig. 5.4 (which is described in detail in [10]) was established we considered the possibility of remote control as an early stage and prerequisite of smartness. This stage does not, according to [59], provide real smartness, because it is just an alternative form of control that requires explicit interaction. The next stage, which already has some form of smartness, is the possibility of networking devices which would enable combined programming (e.g. in the form of macros). The following stage is self-regulatory circuits, on the basis of which automated responses to recurring events can be generated. The stages of highest smartness are personalization, awareness and learning and in this regard similar to the model of [33]. Only these latter stages would support the derivation of real smart functionality. The initial step to achieve them is the analysis of stored historical data to identify regularities and significant deviations. Regularities can be used to automatically trigger functions, deviations could be used to trigger alerts. When the model depicted in Fig. 5.4 was developed, we considered regularities as a specific form of implicit interaction and labelled them *ritual based interaction* [10]. Rituals could serve as a basis for the derivation of automated functions as an alternative to explicit pre-programming of complex functionality such as scenarios. These kind of goal would have a high correlation to wisdom, because one central characteristic, or as [60] puts it *the heart of wisdom*, is tacit, informal knowledge [60, 61, p. 157]; a form of knowledge that is currently under-represented in smart home systems – especially outside of academic research.

Examples of features based on implicit interaction in the form of pattern recognition and pattern matching algorithms have been implemented by [62] and as well as in the part of our own work presented in Chap. 7 and [9]. Recommender and configurator technologies are one area of AI that have been applied in different forms in our work to enhance the quality of interaction with a smart home [63, 64]. Another area of application is multi-user scenarios which have been studied in the context of the real world test bed based on the WISE platform described in detail in Sect. 6.1.2 and [13].

5.1.3 An Integrated Interaction Model

The essential advantage differentiating the WISE home from a *smart* home is that explicit and implicit interaction are smoothly integrated in one system. Recommender and configurator technologies, described for example in [26, 27] and [28] play a central role in this regard. These instantiations of AI technologies are responsible for the pre-processing of complex data, combined with dialogue features to enable the user to communicate decisions and preferences to the system [65]. It is important to ensure that AI and automated features do not overrule the user, as was pointed out as a potential danger in Chap. 2 when different forms of conflicting intelligences meet in the home. The alternative is to enter into a dialogue; proposing or recommending alternatives, and negotiating the best solution. Possibilities of how different forms of recommender systems could be integrated to assist in a variety of tasks in a home are discussed in more detail in the Chap. 7, and are also described in [26]. An example of the implementation of a recommender system enhancing the access to news services by reducing the contents based on historical interests is given in [9]. Possibilities of adapting technical systems in an advanced manner to human capabilities are discussed in [11, 27] and [28]. Persuasive technologies, as one example, can help to compensate de-skilling and demotivation problems that are often associated with the introduction of technology. In the sense of [66], who demands *smart people* instead of *smart homes*, users can be motivated (or persuaded) to actively change their behaviour, for example, to save energy or to engage in mental and physical activities [66]. Technology that requires and supports human effort appropriately can help to keep people mentally and physically healthy [66]. In combination with configuration technology providing adequate interfaces to the users – as discussed in detail in [50] – this constitutes an optimal basis for a WISE behaviour of the system. The combination of HI (human intelligence) and AI helps to avoid problems that occur with conventional smart technology, in which automated procedures sometimes overrule the users [67, 68]. It is not that the technology itself should take over intelligent capabilities of the human; smartness emerges from the smooth interaction between the system and the users [69]. This also means that a system has to be able to act beyond immediate problems (e.g. by considering historical data) and to apply implicit (tacit) knowledge, converging ubiquitous computing and user-friendly interfaces [70], and ensuring that the level of automation is not so high as to give people the impression of being dominated by technology [68, 70] or of being haunted [23].

A model of how explicit and implicit interaction are smoothly integrated, and how tasks could be distributed between the technical system and the user is presented in Fig. 5.5.

Figure 5.5 encompasses the two forms of interaction, *explicit* and *implicit interaction*. Implicit interaction works bottom up and can cover the control and automation of basic infrastructural components available in a home. The lowest layer (building components) includes, for example, wiring and piping, and heating components. Based on past behaviour it would be quite easy for an AI-enhanced system to learn preferences in terms of temperature and apply them considering the delay times of the heating. It is clear that such systems would not currently be able to deal with multiple users. Not yet, but the WISE platform provides a basis to build upon. The next category (installation components) includes electrical sockets or switches. These can also be accessed by automated functions, such as separating sockets from mains power when it is most probable that nobody is in the room any more. However, it is necessary that human users always have the possibility to overrule automatisms. Built-in devices, representing the next layer, include water boilers and stoves, for example. Attached devices are dishwashers, refrigerators, freezers, coffeemakers, TVs, and hifi equipment. With an increasing variety of devices on the market, the variety in the combination of explicit and implicit interactions has also increased. The final group (networked devices) includes computers, printers, smart phones, and tablets. With these devices automated functions have to be applied cautiously. It could, for example, be in the interest

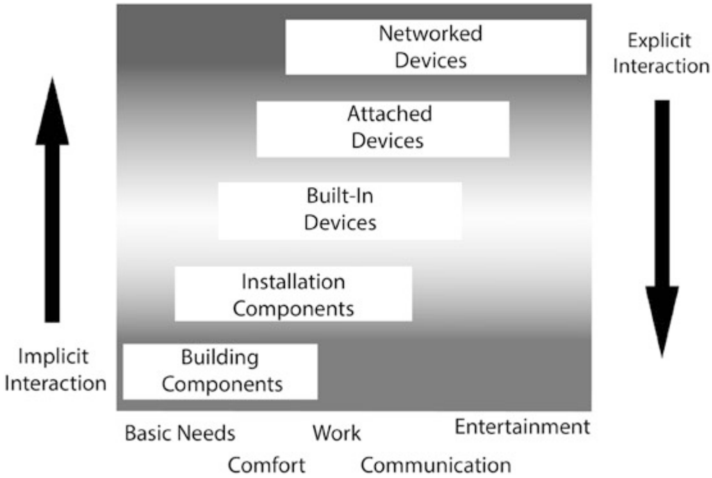

Fig. 5.5 Integrated interaction model based on the model put forward by [19], emphasizing the interplay between implicit and explicit interaction. Implicit interaction works bottom-up and focuses on basic components that are integrated in a household (such as wiring, switches, sockets, household appliances). Explicit interaction works top-down, with a focus on complex, integrated devices such as smart phones, tablets, and computers – but also enables the control of devices of lower layers of the system. Devices of the lower layers of the model support the fulfilment of basic needs and comfort (e.g. warmth, nutrition, hygiene), whereas devices in the upper layers support work (e.g. household work or office work), communication (e.g. phone, e-mail, social networks), and entertainment (e.g. music, video, gaming, TV)

of users to automatically mute or redirect phone calls when a person is most likely to be taking a rest. The borders between the device categories are fluid, because conventional appliances meanwhile have also the possibility of being networked. However, devices in the lower categories are well-suited to the application of automatic procedures based on AI, such as those derived from the analysis of user behaviour. The higher the complexity and functional range of a device or a subsystem (symbolized by a higher category), the more probable it is that people will prefer to interact explicitly. Explicit interaction works top-down and has a higher priority than implicit interaction, which means that it is always possible for a user to access and change the state of any device and subsystem present in the home.

The final goal is that, in the future, the integration of all the devices present in the home and the technologies behind them works as in a car, where automated technologies and explicit user interaction are smoothly integrated. Just think about what happens if a driver pushes the brake pedal. It is in the responsibility of the driver to decide when to push the brake, but the ABS system and stability programs in the backend enhance the efficiency and effectiveness of the brake procedure. The difference is, that, in general, cars are not designed to be technically customized by their users after the purchase. This is somewhat understandable. This is somewhat understandable, but it would be also beneficial for people to have the option to shape the environment, as long as security and safety are not affected. There might be, for example, areas in the home, specifically in regard to entertainment where it would make sense to enable users to adapt functionality by themselves. My understanding of WISE is not to imitate or even supersede the human. What I want to emphasise is that a broader view of HCI in the sense of a *MABA MABA* (man are better at, machines are better at) approach [71]. Each part should concentrate on the abilities and capabilities that it is best for. As it has been displayed in the history of computing, computers are very good at storing information, at processing complex data, at scanning big and complex amounts of information, and at doing repetitive tasks, but they do not have an idea of what could constitute a *good life*.

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