Chapter 4
A Focused Survey on Technology: From Hypocaust to Smart Appliances

It is difficult to determine exactly when smartness came to be of interest for humans the first time, but it can be hypothesized that this interest is almost genetically anchored in humans. What is clear is that smartness in general and smart enhancements for living environments in particular are not an invention of the present. This is shown, for example, in the excerpt from Aristotle's politics that opened Chap. 1. Technology-based smartness for the living context was already available in the ancient world. For example, consider the smartness of systems to improve public health (canalisation), to enhance comfort (hypocaust heating, bagdirs), and even to serve as a form of entertainment. The last is seen on, for example, inventions that are attributed to Heron of Alexandria (called mechanicus) [1], who probably lived in the first century B.C. The following figure shows an example of smart technology that was in operation when Heron lived. It is a smart heating system used in ancient Korea that I had the chance to see during a visit to Seoul in 2010. The *ondol* constitutes a predecessor of modern waste heat utilization, intelligently re-using the heat that is produced when cooking (Fig. 4.1).

Centuries later, in the middle ages, da Vinci devoted parts of his innovation work to building technologies, as seen in his concepts for cities which can be considered *smart* in relation to the time in which Leonardo lived, and insofar can be observed as predecessors of today's smart cities [2]. In my observation, the work of de Caus [3] is specifically important in regard to smart homes. He presented a collection of *so wol nützlichen alß lustigen machiner* (useful as well as funny machines) [3] to the german prince-elector Frederick, the fifth. This was an outstanding pioneering work for smart home technology, as it was the first where two perspectives of smart technology were jointly considered – as expressed in the title; technology that supports the utility aspect on the one hand and technology supporting entertainment on the other.

This dichotomy accompanies people in their homes, and is also important in regard to other concepts addressed in this book. For example, in the notion of User Experience (UX), which emphasizes the importance of hedonic aspects in

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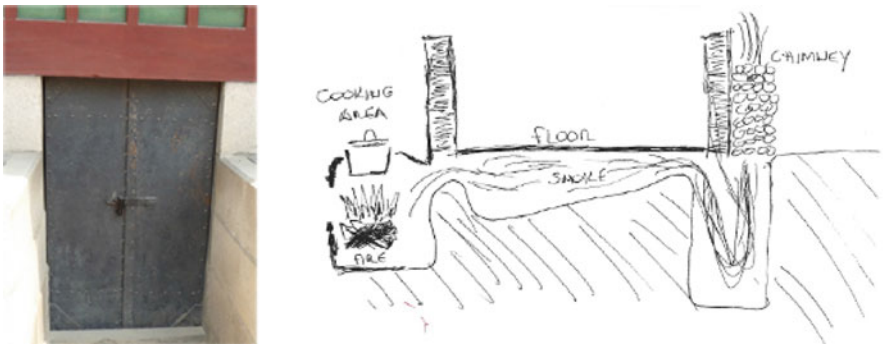

Fig. 4.1 On the *left hand side* the entrance to the ondol is shown. On the *right* a schema of the ondol technology is sketched. The fire on a hearth is used for cooking, the hot smoke is piped under a floor construction and in this way heats the rooms above. The cooled down smoke leaves the building through the chimney on the *right*

combination with instrumental aspects as relevant in the interaction with technology. Technologies supporting both categories of needs are present in a high probability in every home. But in general, they are operated side by side on different infrastructures. Separated in the categories *white goods* and *brown goods* they are typically also operated by different means of interaction.

The societal structures and living circumstances prevalent in the eras of Heron, da Vinci or de Caus are not comparable to those we are typically living in today. Smartness in the illustrated form was merely present in public or religious contexts. If it was available in private areas, then it was reserved for the rich and members of the upper classes and often times required the operation and maintenance by members of lower classes, servants or slaves. The next passages are devoted to the historical developments which can be considered the starting phases of living circumstances that are comparable to those prevalent today.

The modern concept of the home gained relevance after major societal changes. First, the bourgeoisie and later, in the context of the industrial revolution [4], the working class became important parts of society. Societal upheavals were accompanied by new family constellations and the separation of work and life led to new forms of dwelling [5]. In these periods the prototype of the *ideal home* was coined, a detached house with a yard, as described in more detail in Chap. 3. The changes in societies where accompanied by progresses in domestic technology, which became necessary due to changes in demography, urbanisation, and economy. For example, basic needs (warmth, nutrition, light, clothing) could no longer be satisfied by self-production [6]. Whereas rural families in the 1920s still produced 70 % of their own food, urban families could contribute only 2 % to the production of their food [7]. It was necessary to have paid work to afford consumables such as food, firewood and petroleum, to pay rent, and later, to have access to electricity. Because of the need to earn money, the time available for home-based work decreased continually. This resulted in a demand to increase the efficiency

of household work, which was one of the drivers for the progress in technology. An indicator for this change is, for example, the stove as a more efficient device that has replaced the kitchen oven [6]. A new era was marked by the introduction of electricity, which, depending on the county and area, dates in the period between 1900 and 1940 [8]. After the profound effects of the second world war, technological progress levelled off resulting in a wider variety of white good appliances such as fridges, electric cookers and washing machines and a differentiation of device categories. At the end of this period the majority of households had access to mains electricity and possessed electrically-powered devices. Interesting effects of the new technologies became salient, such as the fact that, despite the availability of electric appliances, the time spent for household work actually increased. This is because – as a side effect of more efficient devices – demands on cleanliness changed and numbers of cleaning cycles increased [9]. In this way, the new appliances increased output rather than saving time [7].

The category of household devices, brown goods, which fulfilled entertainment needs experienced a diversification. Different forms of radio, television and musical equipment entered the mass market. In the following decades this progress continued. The diversification of home entertainment brought devices supporting the individual use of audio and video content. Tape-based devices enabled an independent and flexible replaying and recording of audio and video for private purposes. Devices like the compact audio cassette were the prevalent technologies when I was a boy. At this time we were happy and satisfied with the things that were possible. In regard to the content quality they were far from the levels that we are used to today. In terms of comfort and ease of use, in some aspects the situation could be considered to have been better than it is today. For example, exchanging content was very easy. When one of your friends had bought a cassette or recorded it himself one did not have to care about whether the cassette would fit in your own player, or if the content was in the correct format to be played or even if this exchange would infringe copyrights. This changed with digitalization. One paradox in this regard has been that the same container could include almost any digital content. I remember when a relative of mine came across a DVD the first time which contained a selection of football games. Having been familiar with digital audio in form of the CD, she was very surprised and asked: "*Who would ever be interested to listen to a football game?*" I think she was probably not the only one who was confused about the mixture of containers and contents, not even to speak about the different recording formats (DVD+, DVD-, DVD-RW, etc.) and regional codes. Taking into consideration the potential problems with interaction caused by inappropriate cues, as pointed out by [10], the *silver disks* in this regard were a regression rather than progress. Today physical containers have all but disappeared and been replaced by virtual containers such as Mp3 and Mp4 which have become the new standard. Meanwhile, the variety of digital formats has led to what is now commonly referred to as the format war. Given the number of combinatorial possibilities, it is not surprising that we are often confronted with error messages such as: "*This file format is not supported by your device*"; "*Codec not found*"; "*This file is not available in your country*".

In comparison to the reasonable changes in the entertainment sector, changes in the white goods sector are not as spectacular. Devices which have already been on the market for quite a long time, such as vacuum cleaners, washing machines, dishwashers, or cooling devices, have been further developed in regard to their efficiency, but have not experienced many revolutionary developments. Only a few innovative technologies such as microwave ovens, induction cookers or cleaning robots have been introduced.

In the context of almost each technological advance, we can observe that promises have been made; promises that there will not just be progress in a specific segments, but that the devices in the home will grow together into a fully-integrated smart system in the near future [11]. High definition television really followed devices that carried the label *HD-ready*, but this example is one of very few exceptions to the rule: not many of the promises of technological revolutions in the home have come true, specifically in regard to the smart home. As illustrated in Chap. 1, a fully integrated smart home continues to be the exception rather than the rule. This is astonishing because some of the other technologies enumerated above have disseminated quite impressively, speaking of developed countries. For example, major domestic appliances such as washing machines, which have already been on the market for quite a long time have unsurprisingly, attained a penetration of 95 % [12]. In a similar percentage, around 95 % [13, 14] of homes have a TV. Personal computers, which were introduced at about the same time as the smart home, have attained a penetration of 70 % [15]; and the same applies to the significantly younger broadband internet, which is now also available in around 70 % of households [16].

Despite of the problems that have been emphasized in regard to the digital format war, a convergence is observable in some areas of technology. Analogue audio and video contents and physical containers have transformed into virtual container formats, which originated in the realm of computing. The computer as a device was first brought into the home in the form of the PC. Advances in multimedia were first available only locally: examples being improvements in the quality of sound, colour depth, and display resolution. When the Internet came into private households, and when broadband connections followed, extensions such as in-home WLAN networks became of interest for private households. More recently, the spread of mobile devices such as tablets and smart phones was accompanied by the expansion of broadband mobile networks.

All these technological developments could, theoretically, have paved the way for the smart home. Smart technologies should have taken over the part of integration and networking but those integrative features are still missing in an average home. When breaking down the numbers provided by, for example [17–20], the current percentage of penetration of integrated smart systems is in the single-digits. Systems promising to offer *smart* features have entered the market, but the majority of them are still stand-alone devices or cohesive sets of devices which are, at best, difficult to combine or integrate with other smart devices – to say nothing of the integration of conventional devices present in a home. Many of these systems just offer some form of remote control. But as [21] points out, the ability to remotely control a home, even if it is done with a cutting-edge smart phone, does not mean smartness; smartness has to be more.

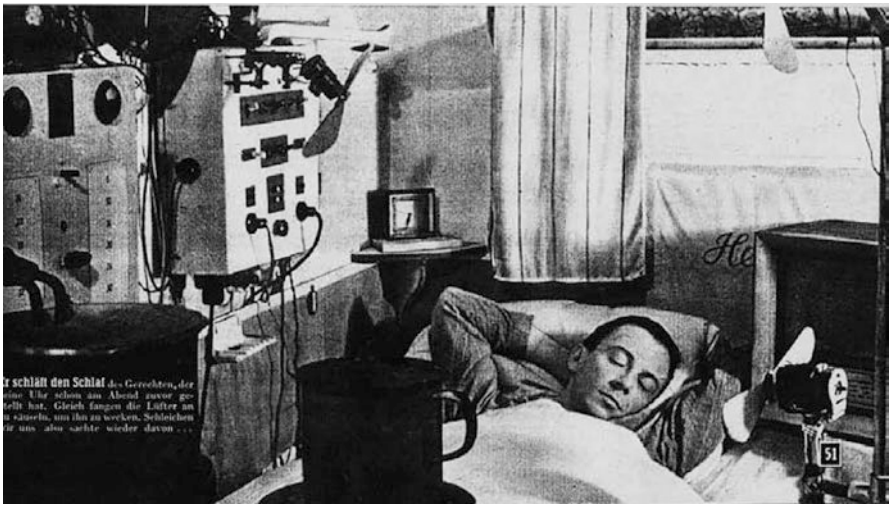

Fig. 4.2 The engineer within his self-established smart home (Taken from [23, p. 13])

To achieve a better understanding of the state-of-the-art the next passages are devoted to the historical developments of technology that can be considered as the direct ancestor of the smart home. According to ([22], p. 75), the smart home was considered a "*... natural extension of current electronic, information and communication technologies*". In the 1960s the first hype, a broader interest in such enhanced functionality can be observed [8]. But even earlier, since around the 1940s [11], related industrial activities can be observed. One example of the technical possibilities of the early days of smart home technology is illustrated in a news article from the 1950s, describing an engineer who developed a self-constructed smart home. The available features included a timer which automatically switched off lights after 10 p.m. and a *toilet occupied* signal [23]. An impression of the system is given in Fig. 4.2. Compared to those available in current smart homes, the possibilities were quite limited.

An important step in home automation was the introduction of computer technology enabling the software based programming of smart home systems. A pioneering work in this regard was the electronic computing home operator (Echo IV) [24]. Computing technology and software programming brought a revolutionary leap in terms of technological possibilities but, as the situation in Fig. 4.2 convey a questionable "*Menschenbild*", putting the focus on the technology and considering the human as an element, that is somewhere in-between. This understanding is obviously still present in the heads of some technicians and developers and one of the central goals of the WISE approach is to change those basic mental models. In this regard, one important example is a product that, according to [25], was not really intended to be a product, but that reflects an understanding of the role and model of technology of the 1960s. This might have been meant sarcastically in the

example of the kitchen computer, but is meant seriously and it is present in different forms of advertisement today. The message conveyed to all of us consumers with each of the different devices is that, if we fail in fulfilling our roles, it is never the fault of the device.

After the pioneer phase, the home automation market also experienced some diversification. Over the last decades a separation between automation technologies for industrial and public functional buildings on the one hand and the residential building sector on the other, is observable. In the functional building sector, wired solutions have been successfully adopted. Consider, for example KNX, which enables the integration of components from different manufacturers and offers a high functional range. However, the complexity of system architectures, the pricing and maintenance models have, so far, impeded broad dissemination on the private consumer market.

In the private consumer market, wireless solutions constitute the majority. The following enumeration is consciously not taking into account those smart systems that originate from other sectors, but focusses on *operational technologies*, as [26] labelled them, approaching smartness from basic components and functionality. But even the variety of systems in this segment seems to be incomprehensible.

A simple web search[1] reveals systems from Belkin, Xavax, EQ-3, AVM, RWE, Allnet, D-Link, Coco, Edimax, eSaver, REV, Zipato, Loxone, Somfy, Elro, Brennenstuhl, Taphome, gigaset, BTicino, intertechno[2] and this list is certainly not exhaustive. In the low price segment addressing the end consumer, compatibility and interoperability is typically not present. The strangest example I came across when analysing the market is a manufacturer who has 5 systems on the market. Some of the devices have the same shape, probably have comparable hardware components and seem to operate on the same radio frequency; but they are all branded differently, and they are all incompatible.

There are a few exceptions driven by initiatives and consortia such as Enocean, z-Wave, or Qvivicon, which enable the combined use of devices from different manufacturers. However, the core problem for the consumer is that a decision made in favor of one system and against the others is final. Because of the technical constraints the systems have to deal with, they offer more or less the same principal functions. Technical constraints can be, for example, the wiring standards smart components have to be attached to, and available spaces in households where additional components can be placed. For the average customer it is difficult to find out whether or not a particular system might fulfil ones needs, and whether one system can cover the range of functionality better than the other. Pushing proprietary systems is understandable from an economic perspective, but such a policy could motivate customers to avoid all similar technology instead of adopting one particular brand. In my opinion this has contributed to the current degree of low dissemination of smart home technology (Fig. 4.3).

[1] Because the search is started on a computer in Austria, the hits correspond to this market.

[2] All of the brand names serve as examples and are used courtesy of their manufacturers.

Fig. 4.3 Smart home systems (Adapted from [27])

However, the lack of appropriate interconnecting technology in an average home is only one aspect of the problem. Another aspect which additionally complicates the situation is that those technologies that were successful, such as computing and entertainment electronics – have now developed their own networking and integration facilities. In my opinion, this should have been the responsibility of smart technology. Instead, the number of proprietary and brand-specific infrastructures increases. Standards such as DLNA are present, but not supported by all manufacturers and specifically not available in the low-cost segment. The combination of all of the separate developments and advances, has resulted in a level of complexity on the end consumer market that an average user probably cannot understand. Systems characterized as smart are today offered by global players in the electronic appliance market, focussing on the control of their proprietary appliances (e.g. white goods). Big players coming from ICT are either working on smart home market strategies or already offer their own, mostly proprietary smart home systems, conceptualized surrounding their own key devices: smart phones or tablets. Even car manufacturers meanwhile offer the ability to control technology at home on their in-car systems, though it is, of course, controlled from the perspective of the car. In between these factions one might find the systems I consider to be "*original*" smart home systems. Systems which address smartness from basis of the elementary functions and components enabling the control of lighting, heating, shade, locking, etc.

In general, the different forms of technology present in the home are not integrated. When taking a look at other markets, the automotive sector for example, the situation is different. Most in-car systems are based on integration and the sharing of resources. A state-of-the-art car has integrated around 50 microprocessors and kilometers of cables and is comparable to an average house in terms of technical complexity. The difference is that the integration of the technology is much better than in an average home. This is not a surprise, because cars are compound

products and, as a result, it is much easier to configure them so that all of the technology in place is compatible and integrated. This is a pre-requisite due to space limitations and the need to tune and coordinate the flow of energy. However, many manufacturers are producing components for cars and could obviously agree upon standardization.

All the same, as pointed out in Chap. 3, there is some kind of technological standardization in the home, and it could be further pushed in this direction. This would probably also lead to a better utilization of resources, as can be demonstrated again by the example of a car. In a car there is probably only one central display but this conveys different information about all components of the car. For example, information about the technical status, information related to security issues, and also entertainment information (e.g. the current radio station selected) is displayed in the single, general display area. This principle idea of sharing resources probably could have prevented the situation that was described in the birthday story. One of the challenges for a WISE home is therefore to integrate devices present in the home, whether they serve instrumental or entertainment purposes, into one, holistic home system.

As I have tried to illustrate in this chapter, the paradox is that the basic technology is available. We do not have the problem of missing technology, we face the problem of having too much of it. No universal standards are in sight. One could express it with the words of Tanenbaum, a famous computer scientist. "*The nice thing about standards is that you have so many to choose from*".[3] This quote was clearly intended to be humorous. A potentially serious application of it can be found in the next chapter.

The technology has to assume an integrative role and exploit technical possibilities, such as those based on AI. Consider the example from the birthday story, told earlier. Such situations have to be overcome by the WISE home. This is important, for example, to solve the imminent societal challenges of the triple E (Elderly, Energy and Effectuation) discussed in Chap. 1.

But there could also be other reasons, for example [28–31], refer to the cost aspect (financial as well as effort- and time-related) as a potential hindrance.

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