Smart Home Technology and Architecture

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ABSTRACT

The recent decades have witnessed the widespread manifestation of intelligent building design development around the world. Meanwhile, the concept of smart housing as one of the main issues of intelligent building design development has stimulated various architects and designers to make use of it for the sake of sustainable housing. However, we review an emerging type of dwelling, indicated as Smart Home, with a focus on future user lifestyles, needs and preferences. Researchers envision a future information society stemming from the convergence of ubiquitous computing, ubiquitous communication and intelligent environments, especially residential environment. Smart Homes have noble aims; they are said to be able to support different ranges of activities such as tele-working, tele-shopping, tele-communicating, tele-educating, tele-caring, etc. In this paper, we investigate the major challenges of Smart Homes as a new dwelling concept. Surveys have shown that user acceptance of any changes in personal spaces is linked to user needs and preferences. In turn, user preferences are directly related to user lifestyles. Therefore, inspired by research in the field of user centered design and future lifestyles, we redefine the concept of housing to increase the acceptance and marketing of Smart Homes as future housing. Which architectural conditions may promote acceptance of these new technologies by users. The presented research framework is not only relevant for academic researchers but also for real estate investors, because it highlights the risks that need to be managed when developing smart real estate.

KEYWORD

Smart housing, lifestyle, Virtual Space, intelligent building designs

INTRODUCTION

What is a Smart Home?

A smart home is one that has highly advanced automatic systems for controlling lighting and temperature, multimedia equipment for monitoring and activating security apparatus (alarms and alerts) associated with windows and doors and many other functions. A smart home appears "intelligent" because its computer systems can monitor many aspects of daily life. For example, the refrigerator may be able to inventory its own contents, suggest menus, recommend healthy alternatives, and order groceries. The smart home systems might even take care of cleaning the cat's litter box and watering the plants [1].

The idea of a smart home sometimes seems like something from Hollywood. Indeed, a 1999 movie Smart House presents the comical antics of an American family that wins a "house of the future", complete with an android maid who wreaks havoc. Other films show a science fiction vision of smart home technology that, for the most part, seems rather improbable. However, smart home technology is real and is becoming increasingly sophisticated and today coded signals are being sent through the home's wiring to switches and outlets programmed to operate appliances and electronic devices in every part of the house. And increasingly home automation is proving to be especially useful for elderly and disabled persons who wish to live independently [2].

In-House Architecture Design Approach

The main goals for the design of the in-house architecture are:

- to provide an environment for applications in the area of energy management and energy efficiency at customers' sites in smart distribution grids, to allow for access to devices and other hardware functionalities that are connected to the system via standardized data models or device service models, to allow for automated registration of new devices based on standardized data models and device services, to make the data provided from outside the BEMI that might be relevant to various applications (such as the price of electricity) accessible based on standardized data models, to define standardized services of the framework for using these data models and device services, and to also provide standardized services for functionality that will be needed for many applications: the user web interface, persistent storage of certain types of data and logging [3].

Smart home framework

Developments in the field of smart homes are not an isolated case. First of all the developments take place within the society and are influenced by trends within that society. Furthermore in order to create added value the focus should be on the smart home environment instead of only on the used technology. Thirdly creating smart environments to support elderly & disabled persons has enormous potential.
To live up fully to the expectations is however a complex process which involves various stakeholders [4].

**Smart home technology**

The use of stand-alone equipment for helping people carry out everyday activities – assistive technology – is widespread [Barlow, Bayer & Curry, 2003] [5]. By integrating stand-alone equipment into systems, the possibility to create a far more customized and integrated approach to healthcare increases but also the complexity of the system. As computer-based systems and artefacts penetrate more and more into people’s everyday lives and homes, the ‘design problem’ is not so much concerned with the creation of new technical artefacts as it is with their effective and dependable configuration and integration [4].

**SMART HOMES TODAY AND FUTURE**

**Smart Homes Today**

What then, does a smart house at the start of the 21st century have in it? What makes it smart? Let’s take the Orange at Home example. Here, a 50-year-old house has been wired up with a network, run by a server that operates all of the functions of the house. Lighting, heating, security, audio-visual systems, curtains, baths and numerous other appliances can be controlled through WAP, SMS or a dial tone on a mobile phone; and “wirefree” technology allows PDAs and webtablets within the house to do the same. There are also ordinary PCs, though what makes these a little out of the ordinary is their connection to broadband networks. Finally, there are various other technologies like a health monitoring system in the house’s “sport room” [6].

**The Future**

Many designers are now trying to provide social connectivity solutions, and hopefully the Orange at Home project will incorporate some of them as they appear. But there are some fundamentals that need to be resolved if smart homes of the future are to succeed. Perhaps most obviously there is a need for industry-wide standards that will allow the exchange of information and commands between various interactive technologies. Currently, most technologies communicate via proprietary protocols and this inhibits seamless interaction between technologies from different manufacturers. Though there are various on-going attempts to create standards both for smart homes and for hand-held devices more generally, the likelihood that agreements in this area will be reached soon is doubtful. It is not only there that large commercial interest is at play, but there are also complex technical and usability issues that have yet to be solved. The failure of Hewlett-Packard’s JetSend technology is an instance of a standard that could not get past competitive commercial interests; the current technical and usability difficulties with Bluetooth an instance of the latter. It may be that academics will find a role here, both in terms of brokering standards, and also with technology through inventing something similar to HTML—though this time it won’t be to share and read documents within physics laboratories, but for the home. [6]

Related to these issues is the emergence of homes that are wired for sight and sound in much the same way that current homes are wired for electricity. It is worth recalling that when electricity firms first provided access to power, they assumed that householders would only want one point of access, not many plugs and sockets and power points. Once this had been realised, consumers of electricity were then provided with opportunities to appropriate the power source as they saw fit. Likewise there is a view that smart homes need to provide similar networks, though whether they combine fixed wiring or air-based facilities is neither here nor there. But given what we have said, it would seem unlikely that there will appear a single network solution to this need, and much more probable that the householder will be confronted with hybrid and mixed networks in the future. Consequently, these networks and the technologies they support will not necessarily be able to communicate with all the other technologies in the home, and will probably develop in such a fashion that closely related ones are linked through proprietary controls. There will also be a mix of so-called point solutions and generic ones, all in one way or another reliant on the various networks [6].

**ANALYSIS OF SMART HOME AS A NEW DWELLING CONCEPT**

**Developing a research framework**

The concept of Smart Home plays an important role in the planning of future housing models. An increasing number of research groups are working in this domain. Each of these research centers is focusing on the concept of Smart Home from a distinctive perspective; Different names are used, such as Automatic home, Adaptive home, Com home and Smart Home. But what unifies all types of Smart Homes in a joint domain is their final goal. the Smart Home Association in the Netherlands defined Smart Home technology as the “integration of technology and services through home environments for higher comfort and quality of living at home” (Bierhoff et al) [7].

Improving the quality of life and comfort in the home environment is one of the oldest dreams of mankind and one of the most important reasons for developing technology. Although technology makes life more comfortable, it does not necessarily guarantee an improvement of the quality of life. According to the diagram of the quality of life introduced by Jacqueline Vischer, there are three ranges of environmental comfort. Viewing comfort as a tripartite continuum can help to assess the overall quality of the living environment [8].

- Physical comfort encompasses aspects such as temperature, air, sound and lighting, or – from a technological perspective – HVAC and safety systems that have been researched extensively over the years in the domain of Home automation.
- Functional comfort responds to the user’s needs and their preferences. Rather than a neutral state of unawareness, functional comfort is an active interaction with the environment. In such a way, that the environment supports peoples tasks and activities. This
consciousness requires thoughtful awareness and good design of both space and technology [8].

- Psychological comfort relates to human needs and lifestyles. This comfort is more related to the conditions of integration of technology with space for better compatibility with user’s everyday life (Aldrich) [9]; here, technology push is replaced by a user center approach [8].

Accordingly, a framework for developing the spatial conditions of the Smart Homes that incorporates new technology and lifestyle is presented in this paper. It has three basic elements: ambient technologies, lifestyle and house environment. New technologies can be applied in any space of a house; a lifestyle consists of activities and a house consists of spaces. Technological changes influence lifestyle and result in some activity changes. As a consequence, activity changes influence spatial conditions and result in changes of the space. The final result is a new kind of space which supports both psychological and functional comfort in addition to physical comfort [8].

Technological changes
All the devices and spaces inside the Smart Home support people carrying out their everyday activities, tasks and rituals in an easy, natural and intelligent way. As these devices become smaller, more connected and more integrated into the home environment, the technology disappears into surroundings until only the user interface remains perceivable by users. These technological changes will affect the way of living at home and will influence the spatial needs and preferences of those living there [8].

Activity changes
As already mentioned, the introduction of Smart Home technology into future dwellings may result in changes in activities. In lifestyle studies of the future, the domains of work and life, education and home activities, daily routines and entertainment, public and private, are no longer strictly separated. At home, too, many activities are performed simultaneously; cooking while watching TV, monitoring the children sleeping in the bedroom while entertaining friends in the living room; working while doing other daily routines etc. So there is an interaction between a more complex set of activities in time and space. As reported by the „Living Tomorrow„, lab on a research initiative on future lifestyles, houses which are completely networked, both inside and outside, enable permanent communication. Thus people can, for example, dictate the shopping list via the kitchen computer and in return they can be informed directly about the expected waste volume and the best disposal option.

It is also possible to have a virtual team working while each employee is in his/her house. Intelligent ovens read the product information via barcodes on the food wrapping and program themselves. There are flat-screens everywhere, which show TV and Internet programs; each family member can have access to personal information and can work while doing other activities such as cooking [8].

INTERNAL SPATIAL ORGANIZATION CHANGES

With respect to the domain of spatial organization changes, the focus of this paper is limited to three main categories of the Smart Home which are summarized as kitchen space, living spaces and work space also the relation among them. These areas correspond with the three main areas that are mostly influenced by new technologies in a Smart Home [8].

Smart kitchen
While contemporary kitchen still is a distinct area in most homes, in the house of future the kitchen is recognized as an important place for family gathering as well as for cooking. According to Ahluwalia [10], a current trend is to have a kitchen as the hub of the home more than ever before. Families want the kitchen island to be large enough to serve as a multi-purpose location: As a place to do homework, crafts, and to pay bills, as well as to enjoy a cup of coffee. It is predictable that more and more people will tend to have a kitchen integrated with the living space to support their multitasking because of the increased time spent at home in the future.

Understanding the trend, conceptual kitchens will be integrated with living spaces especially when smart technologies such as wireless power and smart devices make them feasible. In terms of design, there are some ideas that try to interpret the kitchen as the hub of the home. The “Hettich Kitchen Concept 2015” with a smart island and a smart wall presents a kitchen integrated with other parts of the home environment rather than claiming to be the centre of attention (Stackelbeck) [11]. The smart kitchen of Philips also presents an “Interactive Kitchen Table” as the focal point of any domicile. Friends and family would gather around this table and relax, chat and perhaps even help out with the cooking. Here, no preset cooking zone exists. Cooking takes place in different parts of the „Dynamic Table Top Interface„. Kettle or pans can be passed to others at the table so they can finish preparation; the wine cooler can be shifted to make room in order to chop food. These devices continue to cook or cool and energy flows follow them as they move around the surface, and so does the display interface on the table top surface. This table is both a dinner table and a stove.

It not only helps to save space, but it also makes the kitchen environment more social and convenient (Philips designers) [12]. In general, these concepts try to introduce a kitchen free from a room with no physical boundaries that can support multitasking activities such as entertainment, social communication, virtual activities, job related activities and family gatherings etc [8].

Using smart devices, information networks, wireless power, flexible work spaces and other technologies presented in the Table 1 are very helpful to achieve this goal but new architectural options are also essential to be investigated for a tighter integration of the Smart Kitchen in to people’s lifestyles [8].
**Smart living spaces**

Smart living rooms which are most affected by Smart Walls will support different activities in future dwellings. The space should allow many activities at the same time or at different times. Both interactive and passive activities are supported by the Smart Walls, including watching TV, children gaming, Tele educating, Tele working, Tele communicating and surfing on internet. These new interactive aspects influence the location of the Smart Walls, the arrangement of the furniture around it and the entire space. Such new layouts will be fundamentally different from the current living room layouts predominantly designed for passive TV consumption. Personal zones and wellness zones and their relation with public parts of a house are another important issue in studies of the spatial organization of future Smart Homes. In this regard, (Susanka) [13] argued that instead of conceiving a house as a series of rooms dedicated to single functions, it is more useful to think of it as a collection of multifunctional places in which the various daily activities of household can occur. The results of the “Home of the Future” survey suggested that people also need a bedroom as a private zone beyond the purpose of sleeping (Ahluwalia) [10]. Thus, when activities shift from the bedroom and take place in other spaces, bedrooms seem not to be required anymore in their current style and sleeping zones as private zones will likely emerge instead. In his research “The Future Evolution House” (Hoxr, 2009) [14] claimed that certain rooms will likely disappear in future houses and will be replaced by multifunctional spaces. He also stated that spaces dedicated to wellness will be among the most important parts of future houses. Similarly, a study published by the “Living Tomorrow” lab claims that bedrooms will be replaced by cozy islands with integrated multimedia. On the other hand, the relationship change between private and public zones is one of the crucial issues to be addressed due to transformations in social patterns in a Smart Home (Junestränd) [15]. All these statements reveal that the spatial organization of the Smart Home needs some redefinitionsto suit future lifestyles resulting from new technological developments [15].

**Smart workspace**

The Briefcase Ware House by Jimenez Lai. It is a warehouse with no partition. This project is a house within a house. Furthermore, it blurs the boundary between the definition of working space and living space. Throughout the past century, work space and home became increasingly distinct both mentally and physically. Work and private life were considered as separate spheres. But according to Leonard[16], this trend will be reversed again by an increasing integration of the two domains. Increasingly more people are beginning to work from home either part-time or full-time. Changes to the nature of work including technological advancement, the introduction of flexible working hours and teleworking increasingly interweave work activities with home life. On the other hand, as (Kennedy) [17] remarked “the more time spent working at home, the greater integration and blurring of home and work boundaries will happen”. That is to say, that work-related activities on the one hand and private activities on the other will be integrated in future rather than be balanced as presently done.

In the paper presented here, it is shown how work-life integration in the Smart Home is affecting the boundaries between work space and other living space. The most important advantage is that people do not need a specific space to make it work. Any corner in house may be suitable as a home office thanks to ICT and AmI technologies. In such a scenario, some granted boundaries between spaces may dissolve and more negotiation around tasks may take place. A number of shifting boundaries including those between work and private spaces in the house will be introduced. Due to these changes, an architecturally distinct area is no longer required and the separation of work space and living space is increasingly broken down and rearranged by “blurring boundaries” (Leonard) [16]. The former physical separation of work in public spaces and non-work in the private spaces of the home does no longer apply in the same way. Hence, smart technology has brought profound changes to the ways people work at home, with boundary less physical spaces, more virtual workspaces, and the potential for constant wireless connection to ones work. The workplace is no longer necessarily a discrete physical location. While this level of integration is achievable by technological developments, the complexity of managing both work and home activities needs more researches to manage all “crossover” work activities at home (Sellen et al.) [18]. Hence, any successful model of work-home integration needs research on the spatial aspects of workspaces in the Smart Homes.

To address these challenges, some architectural ideas are reported in the following table based on studies of available smart domestic environments [8].

**FLEXIBILITY IN-BETWEEN**

A Smart Home improves the possibility of spaces by technology and multitasking in each space while the physical elements of the space itself can be completely or partially fixed. The final result can be an open space with multifunctional zones equipped with some flexible smart furniture and devices which are networked. The available example of flexible a prototypical Smart Home is the Proto Home which has an open space with a main core and other applicant around it [4].

**CONCLUSION**

As shown in this paper, residential dwellings will likely become the most important hub of human life due to technological developments. Current homes however seem to be poorly prepared for this future. “The housing industry, for the most part, is resistant to change, wary of new technology, inefficient, and unresponsive to the future needs. Most people live in places that are low-tech, inflexible, disruptive to upgrade, and ill-designed” (MIT whitepaper) [19]. Smart Home is a potentially interesting and valuable concept to consider physical space,
technological interfaces, and human activities simultaneously in dwellings.

At present, most of the Smart Home research is focused on improving the potential of devices, regardless of their use to real-world family lifestyles. As an example, a Smart Wall is designed to support different activities in a future living room. However, from a lifestyle perspective, some day-to-day scenarios will likely cause sociological problems in its use and will contribute to a decrease of acceptance of such technologies:

- Father wants to have a telecommunication session, while the children want to enjoy entertainment and mother would like to watch a movie at the same time.
- Both parents want to work with the smart wall at the same time.
- The children need the smart wall for tele-learning at home, while the mother requests its tele-working capabilities.

REFERENCES

[1] Smart Home Intelligence - The eHome that Learns, David Bregman, International Journal of Smart Home, Vol.4, No 4, October, 2010


