Toward a machine for living: A literature survey of smart homes

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Abstract. Are we finally achieving Le Corbusier's vision of the house as a machine for living? This paper examines houses of future with ubiquitous computing. We review recent research on smart homes and experimental prototype studies of the domestic environment. We survey several new concepts of architectural and device design, and study technologies for creating smart homes. We envisage a new generation of CAAD designers, who may integrate information technologies together with traditional building materials achieve a new machine for living as Le Corbusier once did.

Keywords. Smart homes; ubiquitous computing; CAAD.

Introduction

Le Corbusier (1923/1986) believed that a home should be a machine for living. He admired machines, such as airplanes, automobiles and ocean liners, because they responded properly to requirements. Le Corbusier saw engineers achieving these new machines with new tools that include stating a problem concisely and employing new technologies. He tried to achieve the same in architecture.

In the information age, designers enjoy fruitful possibilities of technology advancements to create new kind of living environments, smart homes. Their enthusiasm toward new technologies is similarly to that of Le Corbusier's in his time. Therefore, with the spirit of achieving a machine for living, this paper examines houses of future with information technologies, in particular, ubiquitous computing (Weiser, 1993). We review recent research on smart homes and experimental prototype studies of the domestic environment. We survey several new concepts of architectural and device design, and study technologies for creating smart homes.

What is a smart home?

A smart home is a house with embedded intelligence technologies to provide a safe and comfort environment and help its occupants to perform household tasks effectively. The development of intelligence technology to date applies primarily in the workplace that is it focuses on office automation. Although the Computer Supported Cooperative Work (CSCW) research considers a wide range of work environment, which includes home office, it is not a straightforward transfer of office automation technologies to our home environment. While office automation is geared toward productivity and efficiency, these are not the main issues for our home environment. This means that new concepts and methods are required to support realities of life at home.

Atkin (1988) identified three attributes that an intelligent building should possess:

1. Buildings should "know" what is happening inside and immediately outside.
2. Buildings should "decide" the most efficient way of providing a convenient, comfortable and productive environment for the occupants.
3. Buildings should "respond" quickly to the occupants' requests.

Barlow and Gann (1998) expressed that, in smart homes, the material environment of the home and domestic tasks should be automated and smart homes should provide external information services to improve the management of family and professional life. Van Berlo (1999) also stated that smart home is the integration of services and

technologies, applied to homes with the purpose of automating them and obtaining an increased safety/security, comfort, communication and technical management.

In summary, smart homes should:

1. be a safe and secure living environment;
2. utilize automation and intelligence technologies;
3. provide comfort living and conserve energy;
4. support family life with improved communications; and
5. allow occupants chances for personal development.

The visions

To achieve smart homes, researchers embark on issues of people, living and technology. In a smart home, the technology has the ability to change the way of family living, and simultaneously, the household itself can shape the character of the technology by acting upon it.

Venkatesh and Nicosia (1997) propose a model of household to address how domestic technologies interact with the sub-environments of household. The model defines two key concepts. One is the "social space" in which household activities occur. The other is the "technology space" in which household technologies are embedded and used. Dewsbury et al. (2002) discuss how smart technology can be incorporated suitably within the entire design process. The MIT house_n project designs a place that respond to the complexities of life, and it uses new technologies, materials and design strategies (Larson, 2000). Edwards and Grinter (2001) examine a number of challenges from the technical, social and pragmatic domains. Crabtree et al. (2001) use ethnographically oriented methods to explore and reflect on aspects of technology usage and design in homes. Intille (2002) states that the most valuable house in the future is not the one that uses technology to control the environment but the ones that help occupants learn how to control the environment on their own.

The prototypes

There are currently several academic research prototypes that complement the visions. These prototypes focus on two themes: human behaviors and communication. For example, Aware Home and Adaptive House emphasize on behavior observation to obtain information that allows the house to make proper reactions. The Georgia Tech Aware Home project has a room that can identify different occupants. The research theme is focus on computing needs in our everyday life (Kidd et al., 1999). The University of Colorado Adaptive House can infer patterns to predict actions of occupants (Mozer, 1998). Other smart home prototypes focus on assisting human communications as well as human-computer interaction. The MIT Intelligent Room project supports natural interaction between occupants and the room (Brooks, 1997; Coen, 1998). The comHOME project employs the video mediated communication in a future home environment (Junestrand et al., 2001). The Casablanca project designs the devices of social communication for the house (Hindus et al., 2001).

The issues

Majority of the ubiquitous computing research focuses on developing gizmos. As architects, we need technologies that integrate architectural concepts, which in turn support activities at home. Architectural concepts must go hand in hand with technological advances in every phase. Junestrand et al. (2001) suggested that the development of future technologies should be closely allied to the architectural design

of the domestic space. Crabtree et al. (2001) use Alexander's pattern language solutions to support the sociality of domestic activities through the spatial configuration of technologies. Intille (2002) hopes to have a new structural form in the future such that technologies may be embedded in building elements, which are easy to control and upgrade.

In the future, designers need to provide ubiquitous computing research in the setting, demonstrate a new household-construction model and the evolution of theories for designing. Once ubiquitous computing is integrated in domestic environment, it may affect social activities of occupants in the environment. Researchers need to evaluate how the technology may impact the occupants' life. Researchers also need to understand how to design smart technologies in order to provide utility to different occupants.

The education

Achieving smart homes demands a new generation of architects, who understands smart technologies well and can collaborate with experts from divers knowledge domains. This calls for a renovation of traditional architectural education. Traditional courses in architectural department focus on the engineering aspects, e.g. environmental control and equipment management, in addition to design studios. We need to broaden the training from engineering to include information technology and humanity.

On the architectural design field, “open building” (Habraken, 1999) obviously is an innovative approach to design and construction that may enhance the quality and efficiency of the design process. In this perspective, the building is designed as a well-organized combination of system and module, each of which can be carefully coordinated to ensure a better process and systems include the building site, the structural envelope, the facilities, the furniture and other stuff. By reconfiguring the systems and sub-systems from each other, opportunities are increased for better organization, increased consistency, quality and more control and flexibility for the smart house. The new feature of design methodology will fulfill the reality of ubiquitous computing.

On the building technology field, there are so many subjects on-going in this fields that consider integrated building design strategies for all aspects of architectural design. The subjects of research include improving energy efficiency, planning a sustainable site, safeguarding water, creating healthy indoor environments, and using environmentally preferable materials. Major technology issues should be considered by all members of the design team. The team has consistency goals to set in the building program and develop the new technology to support the new feature of building. Therefore, the next generation of architectural course will be around the humanity and environment that should be the focal point we desire to care.

Conclusion and discussion

There are many research issues in smart homes, from studying occupants behavior, device interface to market issues (Pragnell et al. 2000; Petersen et al. 2001). This area of research requires collaborations of experts from various disciplines including architects, sociologists, computer scientists, engineers, and industrial designers. We survey these underlying research issues. This paper hopes to raise these issues and to create a conversation among researchers. In particular, by reviewing the existing literature about smart homes and technologies, we hope to provide a base to broaden its research focus.

We envisage this as the next generation of CAAD. The role of computers should go beyond the “tools of design” and become the “medium of architecture”. While our current CAAD training focuses on exploiting the computational tools, the future CAAD training will emphasize on integrating information technologies together with traditional building materials into buildings. It is with this new generation of CAAD designers we will achieve a new machine for living. This is the same spirit Le Corbusier hold.

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