Abstract. The research and development of smart houses are emergent because of the information and communication technological development and the search for better living quality from occupants. This paper therefore explores how smart technologies are applied into smart houses within the living context. Through a pilot study of cases and technological innovations to address the new living context by technology-interface-design strategies, a development framework of smart house is formed by three major elements, i.e. smart materials, technologies, and design. In order to actualize house senses, the prototype for smart houses is evolved. When space and wireless smart components are integrated, the living environment becomes more flexible and adaptable to accommodate or support activities digitally, and users can interact with space via context aware computing for acquiring and assimilating information in order to enhance their living experience.

1. Introduction

The emergence of Information Technologies clearly influences the current building design as well as the relationship between information and spaces. Houses have been considered as a living machine, container of materials and occupants, or activators of information and activities. The recent development
of smart house is driven by technological advancement such as ubiquitous computing and sensor technologies. However, to date, the limited amount of research into smart house that has been carried out has been primarily focused on the technical possibilities (Aldrich, 2003). Previous researches are focusing on the adoption of technologies and its applications in daily activities, while the implementations are less addressing user needs. It is critical to reconsider the house design from the user and environmental point of views. Therefore, this paper is aimed to propose smart interfaces in house design, i.e., the “House Sense” concept by examining the assumptions and cases. The smart living interfaces are introduced, and demonstration and preliminary evaluation are reported.

2. World-wide Survey

“Smart houses” was named by media as automated houses, electronic houses, networked houses, or digital homes, etc. (Chiu, 2005). The vision of the building industry is to create a center for home appliance digitally, including home appliance, entertainment center, web services, environmental controls (temperature and light control units), etc., that will be smartly operated in spaces. On the contrary, a “dumb” house can only provide pre-configured devices and control interfaces such as thermostats for particular functions and applications. In order to get a better picture of smart house development, a world-wide survey is conducted to compare different approaches in adopting smart materials and technology in smart houses, and it particularly focused on how the concept is integrated by design and smart interface design, including informative, interactive, and intelligent spaces. The regions of smart house development include US, UK, Germany, The Netherlands, Sweden, Japan, Korea, Hong Kong and Taiwan, Figure 1.
A “smart house” can be defined as a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond (Aldrich, 2003).

Smart houses should be environmental awareness, interactivity, efficiency, time-based, and system-based. The above depictions are appeared in some house projects such as the TRON House and Toyota’s dream house PAPI in Japan, Georgia Tech’s Aware Home, the Adaptive House by Colorado University, and MavHome (Managing An Intelligent Versatile Home) by University of Taxes in Arlington, USA. The research findings indicate that various smart technologies are applied into smart houses within the living context (Chiu, 2005). “Architecture as a living interface” becomes the potential direction for design.

Future houses should address the needs for smartness, such as (1) improving the basic living conditions and spatial functions such as user-centric physical conditions; (2) reducing work loads such as provision for users with necessary context information in networked digital life; and (3) providing special services and supports for elder people in the aging society. Smart interfaces are proposed to ease uses and detect various conditions to optimize interaction.
3. Research Framework

The above survey provides the impetus for developing an ideal framework for a smart house consisting of three main components, i.e., smart skins, smart life, and smart care. Smart skin is a space-centric module that can be adaptive for environmental changes. Smart life is an activity-centric module that can be informative for context awareness. Smart care is a user-centric module that can be sensitive for individual needs. The house design can be integrated with smart materials, smart technologies, and smart design, Figure 2. The new context of “user-activity-space” can be addressed for defining “technology-interface-design” strategies. Therefore, the prototypes for smart house is evolved, when space and wireless smart components are integrated, living or working environment become more flexible and adaptable to accommodate or support activities digitally, and users can interact with space via context aware computing for acquiring and assimilating information in order to enhance their living experience.

![Smart house research framework](image)

4. House Senses

House Senses are referred as a general conscious awareness about the living activities surrounded by occupants in a house. Smart houses are analogical to the human body in terms of functionality. Obtaining “sense” (such as touch, vision, smell, taste, hearing, and balance) is the basis to maintain human body or buildings. Each part of the human body, organism, systems has its own function, and these need to be worked together to maintain life, including respiration, metabolism, nerve, etc. It requires a central control and system to make the human body work, and brain is in charge of communication.
Similarly, smart houses rely on sensors to acquire external inputs or codes. Smart houses also require a central processing unit like human brain in charge of decision-making and activating consequent actions. The Oxygen project undertaken in MIT provides a good example of this analogy (Dertouzos, 1999). Ubiquitous computing technology initiated by Weiss (1991) enables the information infrastructure to serve the house functions. It is also possibly to apply advanced algorithms such as artificial neural networks (ANN) to communicate among various software agents, and finally deliver the messages to home appliances or users.

Smart house can be integrated with technologies by innovative design, and viewed as a design concept, product or a living technological interface. Therefore, this study examines various design concepts and alternatives, and proposes the prototypes of interfaces, namely, (1) body zone, (2) space tag, and (3) privacy / un-privacy. Partial results are carried out in the real projects to examine the effectiveness of strategies and scenarios. A system requires the initiator and actuator, i.e. the input and output. The system requires both hardware and software by applying sensors or locators to detect conditions and using intelligent agents to initiate environmental awareness. For instance, the front-end (input-output) and back-end (information and knowledge mechanism) relationship is illustrated in Figure 3.

**Figure 3.** Context-aware of activities in smart houses

a. Body zone – There are various activity zones in a house, such as living, dinning, resting and entertaining space. Each space has its functional requirements and information supports. While the range of accessing information is subject to the wireless device and its frequency, body zone is subject to the spatial design for accessing
devices or controls. To extend the physical range of body zone, user id can be detected by applying RFID technologies to activate interactive devices within an accessible range of occupant’s use zone.

b. Space tags – Space tags are physical or virtual objects that can be used to retrieve spatial information for reminding events or triggering displays and controls. RFID can also be used to detect the individual status. Consequently, spatial information can be augmented by human computer interface to associate memories or behavioral patterns.

c. Privacy/Un-privacy – Social or psychological dimension is an important aspect of smart space design. Privacy is referred to the quality of being secluded from the presence or view of others. On one hand, information can be displayed or shared for reminding events and emergence, and information can also be concealed or hidden for individual use on the other hand. Various material and technologies can be applied to HCI design and used for visualizing personal information on home appliance.

To demonstrate the relationship and implementation, we have carried into three scenarios as the follows.

4.1. SMART HOUSE AS A DESIGN CONCEPT

The idea of smart house can be interpreted as the simplest nature of living experience that can be enhanced with creativity and accessibility. The idea will be as easy as the smart car or smart objects to communicate, operate, and reflect the living scenarios. As the aim of daily life for occupants, the living style is designed to reduce the work loads. A simply approach to apply home appliance such as “Coffee cups and tables” as a metaphor of living conditions to access controls or information. Therefore, occupants can participate activities with coffee cups and access devices without switches or keys. Body zone is defined in according with the working range of activities and accessibility, Figure 4. We test it in different modes such as family chat or briefing presentation, and in a single, two persons or a group conditions. Information is displayed or hidden at various modes to facilitate events.
4.2. SMART HOUSE AS A PRODUCT

Smart house can be designed as typical prototype to support current and future activities. Sensors and intelligent agents are integrated into the design, Figure 5. Therefore, designers should better understand the content, including the user needs and feasibility. The quality can be improved by its information and digital content for enhancing communication and effectiveness, and to interaction and functionality.
4.3. SMART HOUSE AS A LIVING TECHNOLOGICAL INTERFACE

Nowadays, remote controllers or mobile devices are over-designed and too complicated for general users to operate or change settings. Living interfaces at houses should be integrated with spatial design smartly. A simply approach to apply home appliance such as “doors and walls” as a metaphor of living conditions to access controls or information. For example, a polymer dispersed liquid crystal (PDLC) glass screen that adjust the transparency by polarizing the light direction and transparency. It is implemented as an input device on a glass door, Figure 6.

Designers should explore the living interface of interaction and communication among people and people (user), space, and objects, including the physical one (such as partition) and the virtual (such as displays and projections). It also includes the proactive mode and reactive mode, and involving various user behaviors.

5. Discussion

The experience from implementation raises some questions for further discussion and exploration. Smart house design requires better understanding the user needs to define program, apply appropriate technologies, and finally integrated together into a total solution. Like previous experiments as indicated in literatures such as TRON House, Aware House, PAPI, etc., there are some user concerns for level of interaction and context awareness. The discussions about architectural program, accessibility, mobility, and privacy issues are depicted below.
5.1. HIGH TOUCH ARCHITECTURAL PROGRAM

Architecture program traditionally is a detailed list of required spaces, specifying floor areas, technical requirements, and adjacency needs. But the future architecture can be far less about responding to such rigid program and much more about creating flexible, diverse, humane habitats for electronically supported nomadic occupancy (Mitchell, 2003). The smart house can be an architecture of continually reconfiguring, clusters of spatial events characterized by their duration, intensity, volatility, and location. We might find a better match between technologies and spaces with various design strategies. Smart environments may well be complex but it is no more complex than necessary. Sometimes a simple and hence ostensibly 'dumb' building is smarter than a technology-dominated living-and-working machine over which the user has lost control. It is also found in studied projects that human activities do not necessarily rely on high-tech devices, but more importantly, human reply high touch of usable smart devices, i.e. only use appropriate devices associated with the context.

5.2. USER NEEDS - ACCESSIBILITY AND MOBILITY

Accessibility is important for some conditions in daily life, and more important is for elder people. A wireless network connected space can be enhanced with sensorial technologies for smart cares of children or elderly people, and therefore, human touches are increased. Via PDA or other handheld devices, users can have not only accessibility but also mobility.

To reach the accessibility, smart houses cooperate instead of neglecting new ideas or technologies. There is not necessary that a smart environment consists of all high-tech devices but on the contrary it is natural or low-tech oriented with high touch of the smart concepts.

5.3. SOCIAL DIMENSIONS OF SMART SPACE

How information can be visualized, shared, transmitted or hidden is more than a technical issue, but a social and design issue. In the study, we have evaluated the privacy concerns. For example, signal such as color, sound, frequency, as well as metaphor, cues are important for context awareness. To remind occupants about general and specific events, commonsense and individual sense such as living-room sense, bathroom sense, and kitchen sense are tested to highlight the association and proximity that can be further used to activate smart devices.
6. Conclusion

In summary, this paper is aimed to create a better and efficient living interface via the introduction of smart house concept and smart technologies. Smart house design is explored by considering “architecture as a living interface”, in which information can be used to visualize, support, enhance or augment the activities requested by user needs in a smart manner. Therefore, the framework is depicted and the potential for creating smart house is explored. Three prototypes of interfaces (Body zone, Space tags, Privacy /Unprivate) were demonstrated that smart houses are capable of enhancing sense of places with smart design concepts. The study findings indicate that designers’ role is no longer just to apply state-of-the-art technologies into design, but rethink the space and user requirement smartly in the future house design. Smart house will be human-centric, not building system or electronic devices oriented. In respond to various user needs, human computer interface can be integrated with sensor technologies and smart devices for easy accessibility and privacy. However, smart house design requires interdisciplinary expertise for creative inspiration and system integration. This research implies the potential of smart space as a concept, product, or living interface for creative designers in future directions.

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