A Personalized Smart Living Room

The New Inter-relationship of Smart Space

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Abstract. Culture, society, and technology heavily influence architectural form, and basic architectural elements and functions evolve to suit users' needs. In the 20th century, with the development of computational technology, architecture underwent dramatic transformation. Human-computer interaction (HCI) has changed architectural space into a smart space, which provides new ways for humans to interact with their living spaces. However, most smart space cases limit their focus to computational technology such as system efficiency and underuse architectural elements of spaces to improve interfaces. Thus this research intends to integrate both architecture and HCI to create a "new inter-relationship system framework" of smart space. An applied scenario called the "Personalized Smart Living Room" showcases the new smart space system. Compared to preexisting smart spaces, which usually focused on a single user, this new system recognizes several different users and gives appropriate personal feedback (such as a personal message or photos) and environmental atmosphere adjustment (interactive wallpaper and personalized music), by monitoring the specific user's posture and personal smartphone.

Keywords: architecture element and function, human-computer interaction, smart space, inter-relationship.

1 Introduction

Human-computer interaction (HCI) has greatly influenced the interface between people and their living spaces. For instance, a device called "Lumitouch" uses sensors and wireless technology to enhance the basic picture frame into an emotional communication channel for long distance families or couples [1]. Another system called the "Smart Floor System" has transformed a traditional, non-interactive floor into a multi-functional floor that modulates the ambient environment by sensing a user's steps [2][3][4]. "AmbientROOM" used augmented reality technology to transform the traditional office into a smart office. In an example that incorporates electronic data, Ishii et al. [5] represented digital information (e.g. the amount of email, internet speed and new information on a note board) onto the physical environment. These cases illustrate that HCI-embedded smart spaces can increase the functionality of the

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objects and physical features in a room. Architecture uses structural elements such as ceilings, walls, and doors to provide a space for functions like relaxation, work, and entertaiment. Thus, in the digital age, the relationship between structural elements and a space's functionality must be very different from that of traditional, static architecture. With the influence of HCI technology, what is the new inter-relationship between structural elements and their functions in smart spaces?

Researchers have largely approached developing smart spaces by focusing on the direct link between human and computer (such as an intuitive interface). In HCI, the computer directly monitors a user's physical gestures, voice, or brainwaves and uses this information to automate previously analog interfaces such as using a remote controller or turning on a light switch [1][6][7][8][9]. They then work to improve a system's computational efficiency and alternative interactions such as creating a more adaptive ambient environment for users [10][7][8][11][12][13]. However studying smart space through this limited view is not enough, and adding new design features to products without caring about the impact of the peripheral environment or even the related space layout does not optimize the functionality and ease of use of a smart space.

2 Problem and Objective

As computers have become more common and powerful, technology and "ubiquitous computing" [14] have incorporated into people's lives, showing up in such places as offices, homes, and restaurants. Mitchell [15] mentioned as our bodies morph into cyborgs, the buildings are also transforming. Increasingly, telecommunication systems replace physical environment, and the solvent of digital information (invisible elements) decomposes traditional building types. Architecturally, these digital elements can be transferred, grabbed or represented onto different physical features of a room. Smart space consists of physical elements (structures such as walls and ceilings and furniture) and virtual elements (digital information that can be used to create an interactive space). However, few researchers focus on how architecture contributes to smart space. Hence the challenge of this research is to clarify the new inter-relationship between physical and digital elements in smart space.

The goal of this research is to create a new inter-relationship smart space system integrating both architectural and HCI aspects, and then implement a system prototype—"Personalized Smart Living Room" based on the new system framework in a real space. This system explores a way to arrange and represent digital elements (such as smartphone messages, music, and photos) between multiple users and their living environment, especially in a living room.

3 Methodology and Steps

The methods of this research can be divided into four steps:

In the first step, two case studies establish the new inter-relationship system framework based on both architecture and HCI.

The second step applies a scenario to the system prototype: Based on the previous system framework, we apply a scenario—"Personalized Smart Living Room" to test the system in a real living room. The concept of the scenario can be separated into three parts: user 'a' mode (Saori), user 'b' mode (Scottie) and user 'a&b' mode (multiple users).

The third step implements the system: The "Personalized Smart Living Room" is composed of two main components. First, physical elements include walls, a sofa, a table and, smartphones; Second, virtual elements include interactive wallpaper, personalized digital messages, photos and music.

Table 1. System components

Components	Sub-components (elements)
Physical Elements	Wall
	Sofa
	Table
	Smartphone
Virtual Elements	Interactive wallpaper
	Personalized message
	Personalized photos
	Personalized music

4 Results

4.1 New Inter-relationship System Framework Establishment

In order to provide a new inter-relationship system framework, two smart spaces were used as case studies based on their architecture and HCI:

Case 1: BCI studio [16]

To enable people to interact with a space more naturally, the space senses the mood of the occupant and responds appropriately by adjusting the environment. BCI studio proposes a brain-computer interface (BCI) system. This smart space enables the user to work in a more energized way via the BCI system. When the space "perceives" (by monitoring the user's brainwaves) that someone is getting sleepy, it will take appropriate action, such as providing specific background music or adjusting the lighting and temperature in the room as subliminal reminders to the user in order to make him/her stay alert and productive.

Case 2: Time Home Pub [17]

To facilitate more intuitive use of space, "Time Home Pub" senses changing events and activities by adjusting the background lighting pattern to provide a suitable ambience. The "Time Home Pub" not only adjusts the environment according to human activities, but also solidifies the connection between human feelings and memories.

This case used the whiskey glass as an atmospheric control switch in a real living room. This system consists of three main devices: an interactive table, the whiskey glass, and Liveframe.

Architecture View of Smart Space. Over time, classical architectural elements such as walls, columns, and floors have exceeded their original use by combining structural and ornamental functions into one element. This is exemplified in the modernist architecture of the early of 20th century [18]. At the end of the 20th century, with the development of human-computer interaction (HCI), a new "floating" element appeared in the interior space of buildings — the "digital element". This kind of element enhances the connection between physical elements in a space (Figure 1). The HCI-embedded physical elements are communication interfaces that can display/output or record/input digital elements (Figure 1). Therefore from an architectural view of smart space, two different elements exist, "digital elements" and "transformed physical elements". Digital elements can freely navigate between physical elements, buildings, or even the cities, but physical elements are restricted to edifices.

Traditional structural elements + new digital elements

Compared to the traditional studio, BCI embedded physical space not only provides a working space for users but also automatically perceives their needs and gives appropriate feedback by monitoring brainwaves. In Time Home Pub, a HCI embedded wall not only preserves its original functions of 'support', but it can also adjust the environment according to a user's activities.

Transformed physical elements + new digital elements

In smart space, some HCI embedded physical elements (such as furniture or appliances) transform their original functions into a dual channel interface. These transformed physical elements are able to input/output to digital elements, creating a bridge between two previously disconnected features of a room. For example, in Time Home Pub, by applying HCI, the tea table not only preserves its original appearance and function but also communicates with a whiskey glass and Liveframe. This augmented table can record friends' time-marks, track whiskey glasses with tracking marks, adjust music patterns responding to bar mode, and make a perfect connection with old photos from Liveframe.

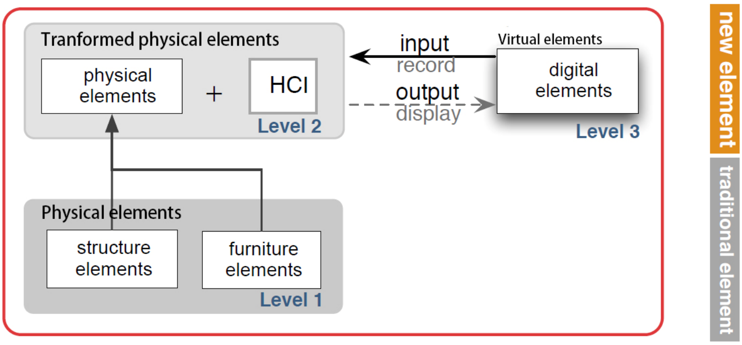

Fig. 1. Architecture view of smart space

HCI View of Smart Space. The HCI view of smart space focuses on the relationship between a user and objects in a physical space. In traditional architecture (Figure 2), a user can directly interact with objects such as the stove, TV, or a pen . However the object cannot respond to the user with feedback of any kind. On the contrary, in the smart space (e.g. Case 2), the user can connect with other elements such as animated wallpaper, a whiskey glass and Liveframe through the new interface – an interactive table. Also, the smart space system can appropriately give multiple types of feedbacks to its users. In Figure 2, we can clearly understand the interaction loop between the user and space based on the HCI view.

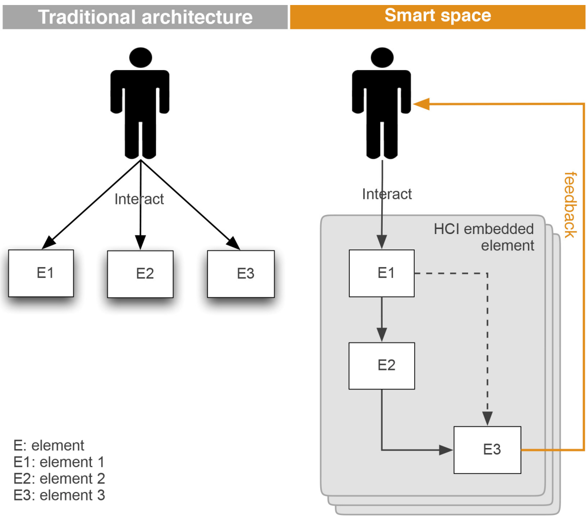

Fig. 2. HCI view of smart space

New System Framework Establishment. The new inter-relationship system framework integrating both architecture and HCI is shown in Figure 3 (from the bottom to top): Different types of physical space (e.g. living room, kitchen or bedroom) are constructed of different elements. The HCI-affected "physical elements" become "transformed elements" which are able to output/display and input/record "virtual elements". In other words, the virtual elements can be transferred, or navigate, between physical elements. Also the space provides new functionality to satisfy users' needs. This new relationship between user and space is achieved by monitoring the user's brainwaves or behavior. The space can observe the user's intention and physical status and adjust itself to adapt to the user's needs. Figure 3 clearly demonstrates the new inter-relationship based on both architecture and HCI view of smart space, and the detail relationship between 'human', 'space' and 'elements (physical elements and digital elements)' (figure 3).

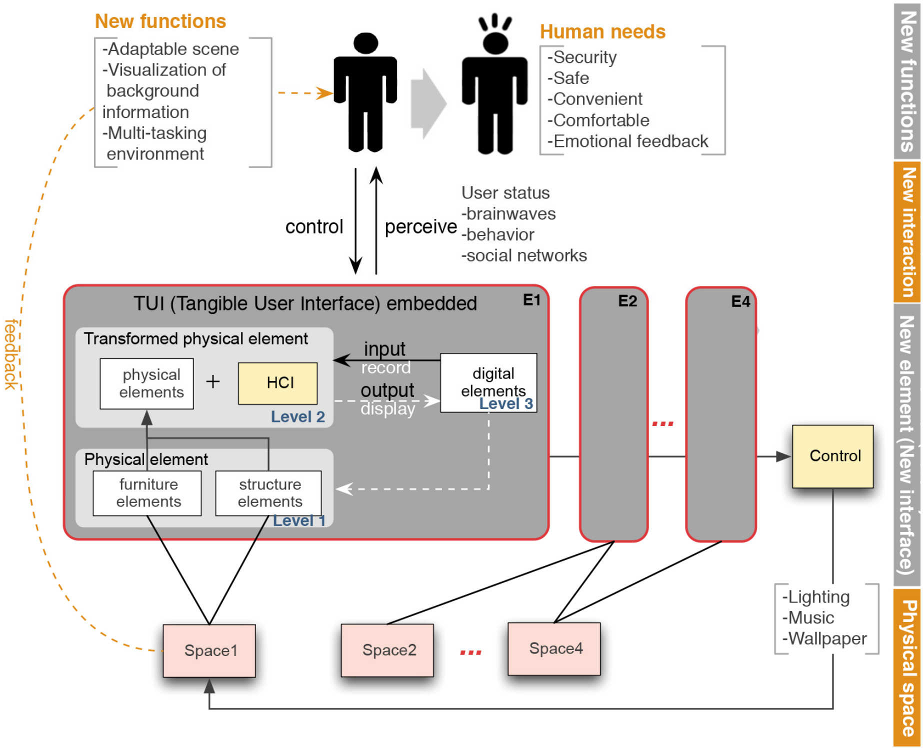

Fig. 3. New inter-relationship system framework based on architecture and HCI viewpoint

4.2 System Prototype

Based on our new framework, we tested the new system in a physical living room. With so much electronic information everywhere, "digital elements" (such as digital messages, photos or music) will become as important as physical elements in smart space. Therefore the smart space has to take into account how digital elements are presented and arranged onto physical elements, and the environment must recognize whether users are in a personal or public space by using smartphones to identify surrounding people as friends/family or strangers. The system can then appropriately and comfortably transfer personal information such as notifications or messages via different interfaces such as computers, cellphones, walls, or tables in a location dependent manner. Thus, the system can rearrange digital elements and find a comfortable way to present information in different physical elements.

Scenario Demonstration. Our new system framework, the"*Personalized Smart Living Room*" executed three scenarios: Scenario 1) user Saori; Scenario 2) user Scottie; Scenario 3) multiple users.

Scenario 1: User Saori
After work, Saori comes home and lies down on the sofa. The system immediately detects that Saori is in the space. Since the sensors of the sofa recognize that Saori is now tired, the room's interactive wallpaper displays Pop Art, and the room plays Saori's favorite music from her smartphone to help her relax. Since Saori is browsing through photos she has taken with her cell phone, the table transforms into a large photo frame and displays a slide show of photos to provide more comfortable feedback.

Scenario 2: User Scottie
Scottie comes home and usually sits down on the left side of the sofa. The system immediately perceives that Scottie is home. The wallpaper responds to his posture by presenting an animated pattern on the wall. Meanwhile, the room plays Scottie's favorite music from his smartphone. Suddenly, he notices that there is an important unread message on the table—"Meeting is changed to 9 am". After 10 minutes, he feels tired. He stands up from the sofa, and the environment changes back to normal living room.

Scenario 3: Multiple users
When Saori and Scottie come back home together, the system immediately recognizes that there are two people in the living room. In order to reflect the joyful and harmonic atmosphere, the environment changes to its bar mode. Spots on the wallpaper change color according to the users' movements, and the space plays Jazz music.

Fig. 4. Scenario demonstration: scenario 1) The space presented user Saori's the pictures she took today; scenario 2) The space presented Scottie's important message through the tea table; scenario 3) In order to reflect multiple users, the space changed into bar mode

Scenario Applied System Framework. In order to evaluate the new system framework, the "Personalized Smart Living Room" was applied to the existing system framework (Figure 6). Through this prototype, we can clearly understand how different users interact with the elements in the space and the relationship between physical elements, transformed physical elements, and digital elements. For instance, the space can wirelessly grab users' personal information (personal photos, messages, and music) from their smartphones, and the table will then display personalized information according to different users' habits. Furthermore, this kind of system framework (Figure 6) can illustrate the new functions the smart space provides and how it gives appropriate feedback by changing the atmosphere (e.g. ambient music and interactive wallpaper). The users can easily and comfortably read their personal information anywhere around the physical surface depending on their locations (private or public space) instead of being limited to reading messages from their smartphones.

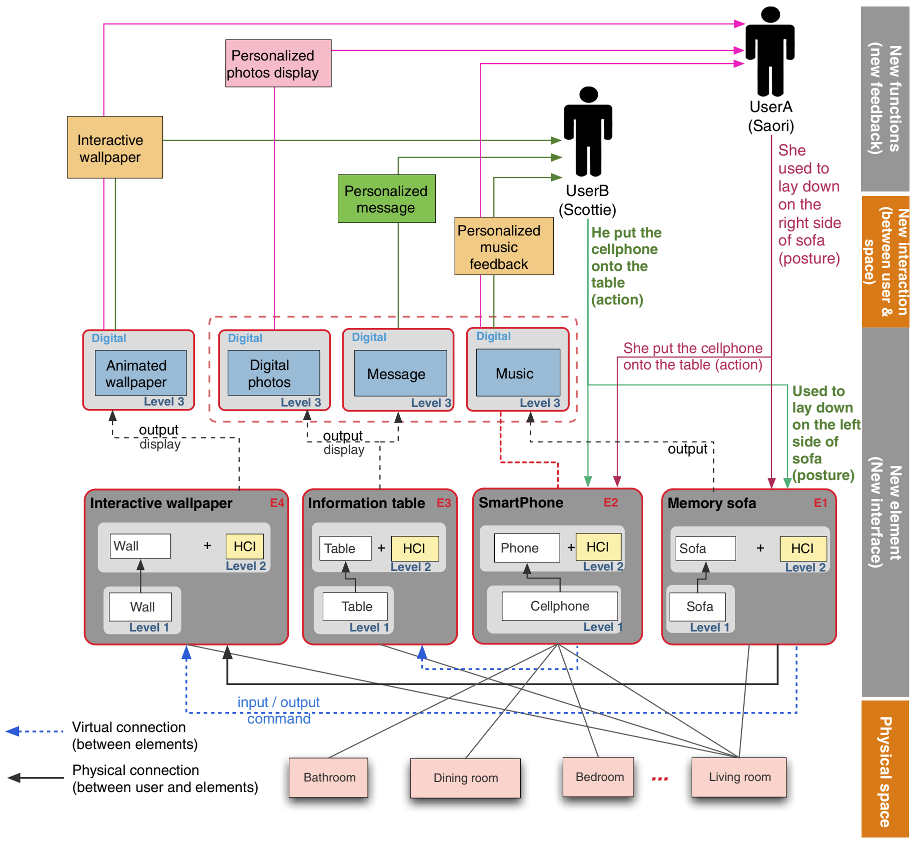

Fig. 5. "Personalized Smart Living Space" system framework

4.3 System Implementation

The system hardware was controlled by two computers (PC1 and PC2) and can be separated into three parts: personalized ambient music, interactive wallpaper and personalized information table display. Personalized ambient music is controlled by a force sensor resister (FSR) embedded in the living room's sofa. This sensor recognizes a user's pose and weight and sends this data to PC1 through an Arduino controller board to evaluate the user's status. PC1 will then process this information and send commands to play the user's favorite music (choosing from their personal smart phone) around the space. The interactive wallpaper (pop style) was generated by processing information from real-time video (by webcam) and previous weight values (from FSR). For personalized information display, lighting sensors (photocell) embedded in the system's tea table can recognize if there is a smartphone on the table and then send a signal to PC2 to evaluate results through the Arduino board. The processing from PC2 projects personal information (smartphone: Line, message or photos) onto the table in a user-specific manner.

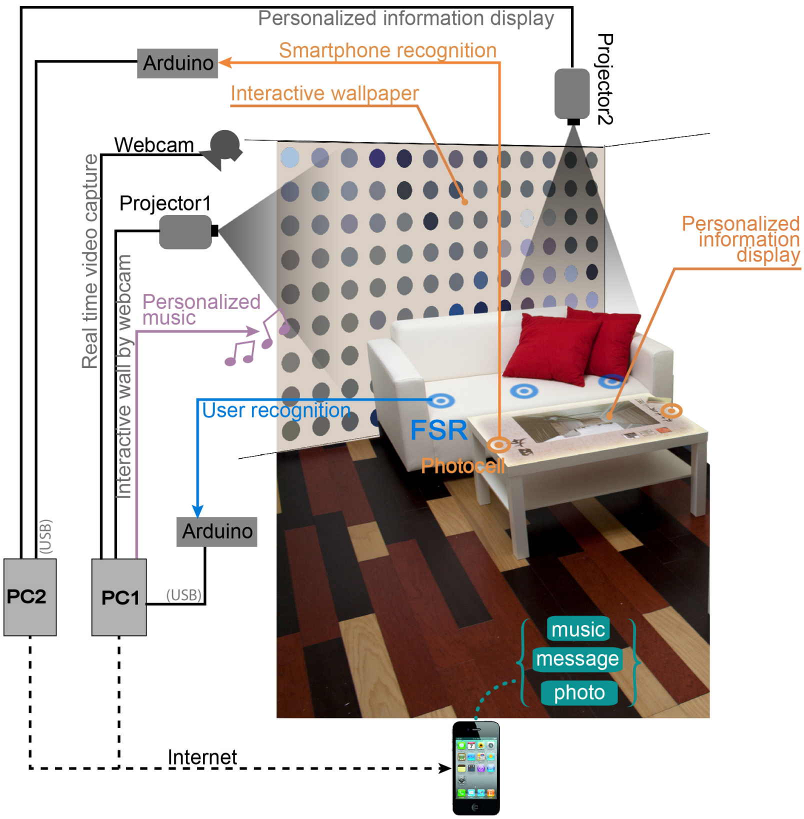

Fig. 6. Environment setup

5 Concluding Remarks

The profound difference between a traditional space and a smart space is in HCI, which enhances the functional and structural elements of architecture. However, most smart space cases have overly focused on computational technology such as system efficiency. In order to create a "new inter-relationship system framework" of smart space, this research used two case studies to address smart space from both architecture and HCI perspectives. From the architecture perspective, adding scenarios to the new system framework allow us to observe of the composition of elements in a space (Figure 3) and the connections between different layers of elements. From the HCI aspect, we can understand how users interact with the environment and how the space provides feedback (e.g. music, images, and notifications).

This new inter-relationship system framework also dually contributes to both the architect and HCI researcher. It can help elucidate the evolution of building technology and the building morphing from the exterior and the layout changing from the interior if I only stand from architecture view to smart space. It is difficult to know the impact of architecture on computational technology. Thus, evaluating both architecture and HCI together to study smart spaces can explore the connection between smart space, technology, and humans. Future research will explore a new vision of smart space design. In the 21st century, architectural design must take into account "ubiquitous computing". Architects have to not only consider the exterior forms, but also a building's interior functions. They must also keep in mind how to adequately merge technology into our lives. Therefore, HCI in a smart space should primarily be implemented based on its architectural context and human needs.

Although the system created in this study was only a prototype, it demonstrates a new inter-relationship system framework. This system's efficiency, implementation and sensor devices can be improved. In order to solidify the new inter-relationship of smart space system, future studies will verify the system's broader applicability and feasibility by exploring smart space in other household rooms such as the dining room, bedroom and bathroom.

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References

1. Chang, A., Resner, B., Koerner, B., Wang, X., Ishii, H.: LumiTouch: An Emotional Communication Device. In: CHI 2001 Conference on Human Factors in Computing Systems (2001)
2. Kidd, C.D., Orr, R.J., Abowd, G.D., Atkeson, C.G., Essa, I.A., MacIntyre, B., Mynatt, E., Starner, T.E., Newstetter, W.: The aware home: A living laboratory for ubiquitous computing research. Cooperative Buildings, 1991–1998 (1999)
3. Orr, R.J., Abowd, G.D.: The Smart Floor: A Mechanism for Natural User Identification and Tracking. In: Proceedings of the 2000 Conference on Human Factors in Computing Systems (CHI 2000), April 1-6. The Hague, Netherlands (2000)
4. Kientz, J.A., Patel, S.N., Jones, B., Price, E., Mynatt, E.D., Abowd, G.D.: The Georgia Tech aware home. In: The Proceeding of CHI 2008 (2008)
5. Ishii, H., Wisneski, C., Brave, S., Dahley, A., Gorbet, M., Ullmer, B., Yarin, P.: AmbientROOM: Integrating ambient media with architectural space. In: CHI 1998 Conference Summary on Human Factors in Computing Systems, Los Angeles, California, United States, April 18-23, pp. 173–174. ACM, New York (1998)
6. Crabtree, A., Hemmings, T., Rodden, T.: The social construction of displays. In: O'Hara, K., et al. (eds.) Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies, pp. 170–190. Kluwer, The Netherlands (2003)
7. Ruyter, B.D. (ed.): 365 Days Ambient Intelligent in Home. Philips Research. Royal Philips Electronics (2003)

8. Ruyter, B.D., Aarts, E.: Ambient intelligence: visualizing the future. In: AVI 2004: Proceedings of the Working Conference on Advanced Visual Interfaces, pp. 203–208 (2004)
9. Kim, S.H., Chung, A., OK, J.H., Myung, I.S., Kang, H.J., Woo, J.K., Kim, M.J.: Communication enhancer—appliances for better communication in a family. The Journal of Personal Ubiquitous Computing 2004(8), 221–226 (2004)
10. Raskar, R., Welch, G., Cutts, M., Lake, A., Stesin, L., Fuchs, H.: The office of the future: A unified approach to image-based modeling and spatiallyimmersive displays. In: Proceedings of SIGGRAPH 1998. ACM Press (1998)
11. Lee, C.H.J., Bonanni, L., Espinosa, J.H., Lieberman, H., Selker, T.: Augmenting kitchen appliances with a shared context using knowledge about daily events. In: The Proceedings of the 11th International Conference on Intelligent User Interfaces, pp. 348–350 (2006)
12. Jeng, T.S.: Sentient Buildings that Sense, Think, and Adapt. NCKU BANYAN Research Express 2(10) (2008)
13. Takeuchi, Y.: Weightless walls and the future office. In: CHI 2010: Writing in the Real World, Proceedings of the 28th International Conference on Human Factors in Computing Systems, pp. 619–628 (2010)
14. Weiser, M., Brown, J.S.: The Coming Age of Calm Technology (1996), http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm; Revised version of: Weiser, M., Brown, J.S.: Designing Calm Technology. PowerGrid Journal 1(01) (July 1996), http://powergrid.electriciti.com/1.01
15. Mitchell, W.J.: City of Bits: Space, Place, and the Infobahn. The MIT Press (August 1, 1996)
16. Huang, Y.C.: A Space Make You Lively: A Brain-Computer Interface Approach to Smart Space. In: The Proceedings of the 11th International Conference on Computer Aided Architectural Design Research in Asia (CAADRIA 2006), Kumamoto, Japan, pp. 303–312 (2006)
17. Huang, Y.C., Wu, K.Y., Liu, Y.T.: Future home design: An emotional communication channel approach to Smart Space. Personal and Ubiquitous Computing 17(6), 1281–1293 (2013)
18. Summerson, J.: The Classic Language of Architecture. MIT Press, Cambridge (1996)