Developing a Virtual Test-Bed to Design Human-Centered Ubiquitous Space

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Keywords: Design Support Systems, Human-centered design, Simulation, Test-bed, Ubiquitous space, Virtual reality,

Abstract: Future space is currently getting a great deal of attention to apply ubiquitous computing technology. To design these spaces, the need to make a physical test-bed, a real building model, is essential for human-centered design. However building a physical test-bed generally is economically expensive and even if the test-bed could be settled, it must be carefully designed before it is built. In this paper, we suggest a virtual smart test-bed, called “V-PlaceLab”. This system allows not only to research a human behavior with the aid of computer simulation on a virtual environment, but also to design a human-centered ubiquitous space mentioned above.

1. INTRODUCTION

Currently, future space especially targeted on applying ubiquitous computing technology is getting much attention in the field of architecture. At the same time, various ubiquitous technology-based products are being developed mainly based on service scenarios for diverse user groups predicted (Vikram, Barton, 2002). Since these service models and scenarios for the ubiquitous space should be analyzed and evaluated, it's indispensable to build a physical test-bed, a real building model such as PlaceLab at MIT (Lamarca, Chawthe, et al., 2005). These physical test-beds are developed generally to construct human-centered and user-oriented ubiquitous space rather than that of technology-oriented while observing user's activities and reactions in these actual sites. However building a physical test-bed
generally costs a lot and is time-consuming. And even if the test-bed could be settled, it should be carefully designed before it is built.

In this paper, therefore, we suggest a virtual smart test-bed, called “V-PlaceLab”, using CAD (Computer-Aided Design) and virtual reality techniques. This system allows not only to research a human behavior with the aid of computer simulation in virtual environment, but also to design a human-centered ubiquitous space mentioned above.

2. THEORETICAL FOUNDATIONS

2.1 Visual simulation for architectural environment

As computer technology progresses and revolutionizes, it allows to represent architectural environment effectively not simply in two-dimensional mode, but also in three-dimensional and real time modes. However, considering that most architecture is designed for human use, representing spaces without the human presence for which they were intended may be something of a deception. In order to properly represent an architectural space meant for humans, designers must accept the fact that humans are design entities that impact space as powerfully as walls and columns (Hoon, Jabi, 2003).

Therefore, it has been gradually changed from ‘building simulation’ in which from where the physical shape of the building is simply simulated to ‘space simulation’ where relationship between space and human using avatar is more emphasized. (see Figure 1)

![Figure 1: The Conceptual Change of Architectural Simulation.](image)

So far avatar has been developed to express human’s appearance and behaviors through many research. In reality, however, lots of cases show that avatars tend to wander in space superficially without critical and thoughtful understanding of how these avatars could be related with space as these
spatial elements in space cannot be separated (Lee, Choi 2002). That is because, when this space is simply regarded as groups of polygons, interaction between avatar and the spatial information becomes apparently difficult or impossible.

Accordingly, to simulate desirable space that includes spatial information, we need to systematically structuralize spatial information and effectively transfer avatar so that specific situation between space and residents can be represented realistically.

2.2 Consideration of human-centered ubiquitous space design

- Place: A basic unit for ubiquitous space

Places differ from mere spaces in that they embody social and cultural values in addition to spatial configurations. It is the concept of place, not space that connects architecture to its context and makes it responsive to given needs (Kalay 2004).

![Example of ‘Space’](image1.png)  ![Example of ‘Place’](image2.png)

*Figure 2. The Conceptual Change of Architectural Simulation.*

According to Kalay(2004), ‘Place’ is composed of ‘space’ and other physical objects in this space as well as users’ social activities described in figure 3. Just as architects can merely construct a nice house, it is the residents who create important relationships in this house and finally make it a ‘home’. That is why ubiquitous space should be simulated as a “place” regarding mentioned factors.
- Interactivity

Since the goal of the ubiquitous computing relies on developing certain environment where computing technology becomes a crucial part of human life and the environment, the exploration of interaction among human, space and object becomes even more apparent and important than ever. According to Richard Buchanan (Richard 2001), interaction can be categorized into four types as shown in figure 4.

First of all, we have ‘person to thing interaction’. In ubiquitous space, a person interacts with ubiquitous technology-based objects that function as an interface linking physical environment to virtual environment.

Secondly, ‘person to person interaction’ refers to the interaction which Buchanan defined as ‘transaction’. Human behaviors, conversations as well as all the signs and meaning, beneath those behaviors play a key role in this interaction.

Thirdly, we have ‘human to environment interaction’ that questions and emphasizes the identity of humans in the environment. In particular,
ubiquitous computing environment offers adaptable and optimized services by detecting human behaviors and emotions. In this regard, human to environment interaction in ubiquitous space can be considered to be more meaningful than in typical space.

The final interaction is ‘human to cosmos interaction’. In this context, cosmos can be interpreted in a broad sense including human culture, phenomenon, and religion where various social activities are accepted as elements for interaction through participation.

Since interaction is consisted not only of physical elements but of social activities, human behaviors for social activities are critical value to build a place.

- Digital storytelling

The lexical meaning of storytelling is ‘the activity of telling or writing stories’ (Oxford, 1989) and digital storytelling can be interpreted as storytelling with the aid of digital media. The digital storytelling enables people to express themselves and to make their own valuable experience.

In this paper, we suggest a digital storytelling method especially targeted to design human-centered ubiquitous space. The most important thing for human-centered and user-oriented design is to meet user’s needs. In this regard, various stories for each user should be customized to satisfy one’s need. Particularly, stories and experience in human interaction is valuable for the ubiquitous space. In this environment, user creates spatial experience as an active participant and the ubiquitous space offers a place for storytelling.

3. V-PLACELAB: A VIRTUAL TEST-BED AS A SIMULATION TOOL FOR SPACE, OBJECT AND HUMAN BEHAVIOR

In order to design human-centered ubiquitous computing environment, we suggest a virtual test-bed, called ‘V-PlaceLab’, using CAD (Computer-Aided Design) and virtual reality technique. It is a simulation tool which enables designers to create scenario demonstrating how users can utilize the space. Scenario is created by setting the interaction among space, objects and human behaviors. This brings about the shift in architectural simulation from ‘space simulation’ to ‘place simulation’ as shown in Figure 5.
Building Simulation
Simulating the physical shape of the building

Space Simulation
Simulating the space with superficial avatar

Place Simulation
Simulating the space, objects, intelligent avatar

Figure 5. The Conceptual Change of ‘Architectural Simulation.’

3.1 Conceptual framework of V-PlaceLab

The kernel of V-PlaceLab is the result from integration among different spatial modules; u-space, u-furniture, u-products, scenarios and intelligent avatars. As illustrated in Figure 6, our framework embodies the essence of place enabling the interaction among spatial entities. This section describes functions and characteristics for each spatial module in details.

The characteristics of each component are described as follows;
- u-Space: basically, u-space in V-PlaceLab is created by ‘PlaceMaker’ (Choi 2005); a spatial context-aware CAAD tool in which created components contain their spatial context information. u-Space is a smart environment module in which space contains not only spatial configurations but also activity, and user information. Other spatial context information includes spatial network, adjacency and connectivity among spaces. Like the role of contemporary architecture, this module functions as a hub providing
interactive channels for the other modules. It acts as a smart scene providing interactivity to u-object and avatar. Above all, it carries the essence of place. By means of spatial context-aware data model, location-based functions are provided such as three-dimensional way finding, and activity searching.

- u-Object: it consists of ubiquitous technology-based furniture and product. According to the study of the new level of interactivity with objects (Hoon, 2001), there are three levels; movable objects (e.g., furnishings), breakable object (e.g., glass panes), and operable objects (e.g., video monitors, soda machines). In addition to this, we propose a new level, ubiquitous technology based-object that has its own attribute such as location, direction, property, and behavior. A user can interact with u-Object through its behavior. For example, a smart chair can measure the user’s weigh while he or she is sitting on it. At the moment, the reaction of u-object is displayed as balloon

- Intelligent avatar: in our system, a user can create scenario through the manipulation with intelligent avatar. As an avatar is placed in any space, spatial information can be retrieve from current space. It gives an apparent distinction from traditional avatars that stroll the space without those spatial knowledge. Furthermore, we performed motion capture to create various kinds of human gesture such as walking, thinking, sleeping and chatting. This increases quality and accuracy in simulation. (see Figure 7 right) Above all, our intelligent avatars imbue space with some scenarios, transforming a mere space into a place.

- Scenario: it describes how an intelligent avatar interacts with space, object, and other avatars as time goes by. Currently, scenario can be created by manually input command lines or perform action series as a user clicks the right mouse button. Once a scenario has been recorded completely, user can play back and investigate the continuous simulation. The way a user defines scenario can reflect the user’s needs to our system, avatars can be used to simulate in such a way he or she wants. Figure 7 shows a screen shot of scenario recording process. Thus, we can create several scenarios in the same scene according to the users’ needs result in a digital story telling design tool.
3.2 The operations in V-PlaceLab

The main functions of V-PlaceLab are enumerated as follows: simulating for a physical test-bed as an architectural design tool, positioning virtual appliances such as u-furniture and u-product in V-PlaceLab, simulating human behaviors with intelligent avatars and, presenting the simulation of ubiquitous technology scenarios based on ubiquitous computing technology. The graphical user interface of V-PlaceLab consists of menu bar, stage, library panel, cast panel, property panel, and script panel as shown in figure 8. The operation processes of V-PlaceLab are also described here. First, a user can import the virtual space model from PlaceMaker, a semantically-rich CAAD tool in which created components contain their spatial context information. Second, we can locate the components such as u-furniture and u-product from the library panel. They can be shown and modified in the cast panel. The next step is to insert chosen avatars, and those avatars’ behavior will be shown and edited in the property panel. Finally, user can record and run scenarios to see the simulation result. Through these processes, a digital storytelling for ubiquitous computing space design and simulation is constructed revealing the innovative change by means of digital technology upon space design.
4. APPLICATIONS

The system developed to design human-centered ubiquitous space can be applied to various systems. For further development, we plan to distribute this system and expand its applications to cover diverse domains as well as collaborate with other researchers. Here we outline three possible applications.

4.1 Developing scenario for ubiquitous product

Many ubiquitous technology-based products have been developed based on scenarios as guidance for these products so far. For this scenario, it is crucial to analyze human behaviors that will affect in the usage of those products. In this sense, our virtual smart test-bed, V-PlaceLab, allows us not only to implement more effective scenarios after virtually but also to actually use various uT-Products while studying human behaviors simultaneously.

4.2 VR simulation for TV production

Currently, 3D StudioMAX has been using for VR simulation of TV production. It is, however, time-consuming and impossible to modify it in real-time. As a result, we suggest a possibility that V-PlaceLab can be extended as a VR simulation tool of TV production. Not only it's easy to
create and modify a stage set through space library of V-PlaceLab, but also cameras, lighting systems, studios, and avatars can be created by so that it can be used as to pre-test and modify the scene and settings before the actual film production.

4.3 Human spatial behavior research for evacuation simulation

In terms of evacuation simulation, there can be many different urgent situations needed to anticipate human spatial behaviors according to context. By means of spatial reasoning, our V-PlaceLab can introduce a new evacuation simulation system that identifies user’s location and even defines relations in between users and other people for more effective evacuation simulation. After all it can simulate all social behavior interactions which can occur in real world especially in densely populated district such as downtown, subway, etc.

5. CONCLUSION

Our system is not designed just only to simulate simple physical environment, but also to test how users will interact with uT-objects and to anticipate what kinds of human behaviors will occur in ubiquitous space. Furthermore, we can develop better human-centered design in this environment while testing possible scenarios and editing the components in real time manner. As visual simulation system like V-PlaceLab presents human behaviors and users’ demands visually, it is obvious that this system can also be highly applied to the research and study for human behavior analysis. Since it costs considerable amounts of both time and money to practically construct the ubiquitous space, it also needs to be carefully and efficiently designed in advance. Therefore, we hope that our research contributes to designing ubiquitous space as an effective place that tolerates and reflects all of user behavior patterns.

6. ACKNOWLEDGEMENTS

This research is supported by the UCN Project, the MIC 21st Century Frontier R&D Program in Korea.
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