Dynamic Architectural Visualization Based On User-Centered Semantic Interoperability

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Technically-oriented architectural spaces today are getting complicated because the building contains a number of electronic facilities and complex structures. Furthermore, the advent of the ubiquitous environment enabled the building to provide various services to users and accelerated the importance of architectural visualization as problem-solving and communicating tools. It is recommended that architectural visualization has been more intuitive and effective to support the design decision and collaboration. In this manner, this paper intends to define the role of current architectural visualization with considerations of previous research and related works in the practical field and proposes the appropriate method of architectural visualization. Also, in order to evaluate our idea, we recommend a prototype system based on dynamic and semantic representation with the avatar. It is a kind of simulator for the design of ubiquitous smart space and can deliver to users the better comprehension in how technological oriented space will be constructed and utilized.
1 Roles of Architectural Visualization

1.1 Visualization and Computational Support

Traditionally, visualization to form a mental model or mental image of something has been a crucial assistance to the understanding and controlling of complex processes (Koutamanis 2000). The process of information visualization is graphically used to view encoded data in order to form a mental model of data. The principal task of information visualization is to allow information to be derived from data. Whatever the nature of the data, the underlying philosophy of information visualization is representing a problem so as to make solution transparent (Simon 1996). Ware (2004) recommends several advantages of visualization as follows: the ability to comprehend huge amounts of data, the perception of properties that are otherwise not anticipated, the extraction of problems with data itself, i.e., detecting outliers or anomalies, the understanding of both large-scale as well as small-scale features of data, and the creation of various hypotheses related to the data.

The computational support has become one of the important research issues now in the field of information visualization. In this manner, Spence (2007) stated in his book of information visualization about three principal reasons that computer has affected massive advances in the field of information visualization. First, increasingly inexpensive and rapid access memory makes it possible to store truly vast amount of data. Second, increasingly powerful and fast computation allows the rapid interactive selection of subsets of that data for flexible exploration. Third, the availability of high-resolution graphic displays ensures that the presentation of data matches the power of the human visual and cognitive systems. Koutamanis (2000) proposed that the wide availability of affordable computing power has been a significant factor for the application of information technology to the design and management of the built environment, and the democratization of computer technologies is changing architectural visualization in two significant ways. The first is that the availability of digital media promotes wider and intensive application of computer visualization. The second concerns the extension of architectural design to visualization in information systems. Lopes (1996) mentioned that pictures are re-emerging as vehicles for the storage, manipulation and communication of information, especially in relation to the visual environment.

1.2 Visualization and Computational Support

The above listed qualities of visualization have long been recognized by architects, who have been enjoying using visual representation tools such as sketch, diagram, image, mock-up model and so on. These visual representation tools have been used not only to solve problems but also to communicate with others. In general, visualization of real and imaginary space has been a traditional strong point of architectural education practice (Evans 1989).

The gravity of visualization for architecture should also be disclosed in the situation of wider techno-cultural changes. Technically-oriented architectural spaces today are getting complicated because the building contains a number of electronic facilities and complex structures according to being trying to provide a lot of advanced services to users based on ubiquitous computing environment and realize non-Euclidean shape of building. It is recommended that architectural visualization as problem-solving and communicating tools are more intuitive and intelligent to support the design decision and collaboration more and more.

In this manner, this paper intends to illustrate the role of current architectural visualization with considerations of previous research and phenomenon of related works in the practical field and propose the appropriate method of it. At the end of this paper, we propose a prototype system applying our opinion for the evaluation.

2 Data for Architectural Visualization

2.1 Data for Information Visualization

One of the broadly accepted taxonomies for classification of data scales is the one defined by Stevens (1946). According to his taxonomy, there are four categories for measuring data scales: nominal, ordinal, interval and ratio. Shneiderman (1996) has defined tax-
taxonomy of seven data types in the context of information visualization as shown in Table 1. Conventionally, his definition seems to address almost data types discussed that we can imagine. However, in order to make the role of information visualization in the field of architecture clear, we need to further discuss the previous stated data types in the perspective of architectural data modeling.

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-dimensional or linear/univariate data</td>
<td>Text, list of strings, source codes ...</td>
</tr>
<tr>
<td>2-dimensional or planar/map/bivariate data</td>
<td>Geographic maps, plans ...</td>
</tr>
<tr>
<td>3-dimensional or trivariate data</td>
<td>Real world objects ...</td>
</tr>
<tr>
<td>Temporal data</td>
<td>Time line ...</td>
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<tr>
<td>Multi-dimensional or multivariate data</td>
<td>Relational and statistical data</td>
</tr>
<tr>
<td>Tree data hierarchies or tree structures</td>
<td>Tree data</td>
</tr>
<tr>
<td>Network or graph data</td>
<td>Graph data</td>
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</tbody>
</table>

2.2 DATA FOR ARCHITECTURAL VISUALIZATION

We suggest four types of architectural data for visualization of current architectural space; geometrical, topological, semantic, and social. Figure 1 shows the difference of each data types.

2.2.1 GEOMETRICAL AND TOPOLOGICAL DATA

In the research of data modeling for the development of CAAD (Computer aided architectural design) system, building data is generally classified into two categories: geometrical and topological data. Choi (1997) proposed the concept of “structured floor plan” which of structure is hierarchical and object-oriented, and plays an important role in containing design information for each design project during the design process. The data structure of Structured Floor Plan is a composition of objects that represent the important architectural elements as a conventional metaphor such as wall, window, column, slab, and so on, which linked each other spatially. Also each space composed with architectural objects is linked with other spaces syntactically. In other words, each architectural object is composed of much geometry linked with other geometries (Choi et al. 2007). As we surmised in the previous states, the architectural data is composed of the geometrical data and their topological network representing the architectural metaphor.

2.2.2 SEMANTIC DATA

We can find an example of semantic characteristics of current architectural data in BIM (Building Information Model). BIM has become one of important research issues currently. It is a set of information generated and maintained throughout the life cycle of a building and also the process of generating and managing a building information model (Lee et al. 2006). BIM covers geometry, spatial relationships, geographic information, quantities and properties of building components. BIM can be used to demonstrate the entire building life cycle including the processes of construction and facility operation. Quantities and shared properties of materials can easily be extracted. Scopes of work can be isolated and defined. Systems, assemblies, and sequences are able to be shown in a relative scale with the entire facility or group of facilities. According to Eastman et al (2008), modern BIM design tools are smart and capable of defining objects parametrically. That is, the objects are defined as parameters and relations to other objects, so that if an object changes, the related ones will also. Parametric objects automatically re-build themselves according to the rules embedded. The rules may be simple, requiring a window to be wholly within a wall, or complex defining size ranges, and detailing. Yang and Zhang (2006) defined these characteristics of BIM as semantic characteristics. To him, this semantic interoperability is a crucial element to make building information models understandable and model data sharable across multiple design disciplines and heterogeneous computer systems. For the sake of
proposing the importance of semantic interoperability in building design, he suggests that the data model in building design and management system should contain data of selected CAD behaviors, relationships, constraints, and reference links as a termed object behavior semantically. In the idea of his suggestion, semantic data is divided as different one from topological data that semantic one sounds like a sort of topological data.

Dourish and Chalmers (1994) enlighten the meaning of semantic in his research related with information navigation. He gives an example of a bookstore to illustrate semantic navigation easily. If we picked up a book because it is sitting on the shelf next to one we have just been examining, then we are navigating spatially. On the other hands, if we pick up another book because it was referred to in a citation in the first book, then we are navigating semantically. Semantic characteristic of current architectural space could be inferred from the hypertext system of website. A hypertext system, for example, provides ‘link’ between semantically-related items and offers a means to move from an item to another according to these semantic relationships.

2.2.3 SOCIAL DATA

The previous stated Dourish’s study related to information navigation let us know the existence of 4th data for architectural visualization because navigation must be one of important aspects of information visualization; that is to say, social data (Dourish and Chalmers 1994). He presented the term ‘social navigation’ that was created to illustrate a unique phenomenon, in which a user’s navigation through an information space was primarily guided and structured by the activities of others within that space. ‘Social’ navigation was in opposite to ‘spatial’ and ‘semantic’ navigation. Spatial navigation depends on the structure of the space itself and ‘semantic’ navigation, in contrast, relies on the semantic structure of the space. We can refer to the example of bookstore again. If we picked up another book because it was recommended to us by someone whose opinion we trust, we are navigating socially (Dourish 2003). He proposed two characteristics of social navigation. First, Social navigation will be considered as an aspect of collaborative work, in which information can be shared within a group to help each group member work effectively, exploiting overlap in concerns and activities for mutual coordination. Second, it will be presented as a way of
moving through an information space and exploring activities and orientations of others in that space as a way of managing one’s own spatial activity.

In general, architectural space does not mean just physically-defined solid and void. Formerly, Kalay and Marx (2001) proclaimed the difference of between ‘Space’ and ‘Place’. According to him, “place is a space activated by social interactions, and invested with culturally-based understandings of behavioral appropriateness”. Consequently, ‘Place-making’ is the conscious process of arranging or appropriating objects and spaces to create an environment that supports desired activities, while conveying the social and cultural conceptions of the actors and their wider communities. Furthermore, the current technology-oriented architectural space based on the interaction between ‘space and user’ or ‘user and user’ is trying to provide various services that guide user’s activities more than before, and finally the activities of users can intensify the social characteristics of place.

We can find an example of social characteristics of current architectural data in the project of ubiquitous smart space. The College of Computing at Georgia Tech introduced ubiquitous smart space for the next revolutionary advance in smart spaces research (Abowd et al 1998). According to their research, users of ubiquitous smart spaces won’t have to delay, interrupt, or restructure their activities to take advantage of a central smart room facility if every space is smart. The visionary application that motivates and drives a coordinated effort by the research community is to create ubiquitous smart spaces: demonstrations of smart spaces that encompass entire working communities, and cover all aspects of each participant’s life. They propose that their ubiquitous smart space provides several specific types of assistance for users: capturing everyday experiences, access to information, communication and collaboration support, natural interfaces, environmental awareness, automatic receptionist and tour guide, and training.

3 The Method to Visualize the Current Architectural Data

3.1 SPATIAL INTEGRATION

The main idea of visualization is helping people to think by a frame of reference and a temporary area to store cognition externally in the process of discovery decision making, and explanation (Carsten et al. 2006). In architectural visualization, the frame of cognition can be inspired by physical space because most of architectural data for visualization is associated to a physical three dimensional space. Some of commercial software company is trying to create spatially-integrated BIM system like ArchiCAD, Revit and so on. In these software, when a user draws a building simply using traditional 2D metaphors, the system automatically generate not only 3D building model but also the relationship among objects. The user can input other related data into his drawing and the spatially mapped data is managed in specific rules. 3D building model as a kind of graphic user interface enables user to search, browse, and analyze information linked with building and building components intuitively.

3.2 MULTIPLE VIEWS

In order to visualize different sorts of data simultaneously, the multiple view technique is often used in visualization environments (Carsten et al. 2006). In a research related to digital architectural visualization, Koutmanns (2000) proposed three visualization methods: projecting appearances, scientific visualization, and dynamic visualization. His idea of visualization based on advanced computational power means that architectural data should be visualized not only building appearances but also their information behind such as building behavior and performance. Compared with other subfields of computer graphics, information visualization has a serious restriction: the available screen space (Carsten et al. 2006). Especially, semantically-rich building information is not easy to visualize at once in limited screen space. Multiple views means both the visualization of different types of data simultaneously and the visualization of complex systems containing several information sources. Further, it means visualizations where several views provide a different abstract perspective on the same information. Multiple view systems provide dynamically visualizations where each view can be used separately without any loss of information. This is use-
ful because the architect today should consider many different sort of information semantically to create an appropriate result.

3.3 REPRESENTATION OF SOCIAL DATA

According to Dourish’s study, semantic and social navigation do not name types of systems; rather, they name phenomena of interaction. The conceptual segregation among “spatial” that is composed of geometry and topology, “semantic” and “social” styles of information navigation was intended to provide terms in which these different forms of data could be visualized. Social data should be based not simply on the data of others, but data about the activity of others (Dourish and Chalmers 1994). In the current architectural space like the ubiquitous smart space, we cannot visualize the social data just using traditional visualization technique such as: diagram, graph, 3D model, and so on. Even 3D animation cannot visualize the social data because it display according to what the director order and expect. Architectural design is not for the sake of building itself but dweller. Therefore, architect should consider the dweller’s activities corresponding with the physical environment in order to make a proper alternative. In special, the ubiquitous smart space provides a lot of services to dweller according to dweller’s behavior and intension. It is not one-to-one correspondence but social phenomenon between user and environment or among users. In this manner, architectural visualization owes to represent the unpredictable social phenomenon and we suggest a game-based visualization technique to visualize the new smart architectural space. Game-based visualization means a kind of simulation using avatars based on the 3D space model linked to diverse semantic data. After architect make 3D space model that represent his idea, he put avatars that represent the dwellers into his virtual space. He can control avatars to move from space to space. When the avatar enter a space or meet other avatars, virtual environment provide specific service based on the several intelligent rules and then let architects figure out the social phenomenon.

4 Implementation

4.1 INTRODUCTION OF V-PLACELAB

We suggest a prototype system namely ’V-PlaceLab’ to evaluate our idea of visualizing the new architectural data. It is developed as a simulator for the ubiquitous smart space that means that human centered and technologically-integrated space based on situ-
tion-aware, autonomic, and self-growing (http://www.cuslab.com). V-PlaceLab represents planned ubiquitous services in the early stage of building design using virtual buildings, objects, and avatars. Semantic information defined in XML (Extended Markup Language) file format contains sequences of services mapping virtual buildings and objects and virtual avatars. This system visualizes dynamically not only spatial but also semantic and social information according to avatar’s behavior and environmental situation (as shown in Figure 2).

4.2 DATA MODELING

4.2.1 VIRTUAL BUILDING DATA MODEL
Humans do not perceive architectural space as an image, but as a hierarchical composition of various elements (Lee et al. 2004). Therefore, our virtual building data model contains spatial information to explain the configuration and hierarchy of spatial components based on the idea of Structured Floor Plan (Arbanowski et al. 2001). Spatial information is not only a foundation of spatially-integrated visualization but also spatial reasoning that semantically enables virtual user to perceive and to recognize the space using hierarchical relationship and spatial connectivity among building component classes.

4.2.2 VIRTUAL OBJECT DATA MODEL
Objects in the space are one of important guidance of human behavior as well as the trigger of ubiquitous service. Thus, smart objects also contain their own functions and status to interact with users and other objects. Each object that has a specific event performed by a virtual user in the same manner as occurred in real world by means of sensors installed in smart objects which must belong to at least one space enabling them to communicate with other entities.

4.2.3 SPATIAL CONTEXT DATA MODEL
The modeling of spatial context handles additional non-geometric information attached to a space. It describes typical characteristics and spatial configuration for the built environment. ‘Domain’ stores spatial information of building type in the same manner as ‘space type’ does for space. Generally, domain and space type for each space are unique. They require disparate spaces, activities, area used by different types of user. Our spatial data model performs as a typical spatial knowledge base of any agent based system.

4.2.4 VIRTUAL USER DATA MODEL
In order to provide proper services to each user in ubiquitous smart space, the system
must be capable of storing and retrieving user’s personal information accurately. The personal preferences and needs, persons to interact with, and sets of devices to control by each individual, define one’s personal communication space. (Arbanowski et al. 2001) Such personal information is stored in virtual user data model at user and activity classes.

4.2.5 INTERACTION DATA MODEL
Interaction in the virtual environment could take place by means of interaction data model. It performs as an interface between virtual user model and the others. In other words, it enhances the concept of human-centered service by applying context-aware ability. It serves as the key transaction and the initial status for any possible interactions by connecting all the components such as space, user, object, activity and event. Once a specific event motivated by a user is detected, all related activities will be retrieved as the user’s potential goals. Each activity contains a set of commands for operating all related objects and services.

4.3 SEMANTIC INTEROPERABILITY
Figure 4 shows an example of semantic data used in V-PlaceLab. This information that our co-worker provided is linked to data model semantically. These semantic data is visualized like Figure 7. We also developed a parser to read and represent these data in V-PlaceLab. Figure 5 is a class diagram of UCCS Package that is a group of classes that parse Community data and make an instance of it defined in a XML file (as shown in Figure 4). Each class corresponds with the element of community and each manager class integrated to cmWorkspace manages the each instance of class. Originally, Community data is created by u-Service Manager that manage sensors and actuators in the ubiquitous computing environment in order to provide an appropriate service to users according to the change of situation. However, V-PlaceLab contains u-Service Manager inside to unify design and simulation. u-Service Manager observe avatar’s behaviors and intensions and generate a instance of Community data that is delivered to UCCS Package to visualize.

4.4 VISUALIZATION IN V-PLACELAB
Previously, we proposed the method of visualizing the architectural data: spatial Integra-
tion, multiple Views, and game-based Visualization. According to our idea, V-PlaceLab is not only a spatially-integrated platform but also multiple viewers. Semantic data that contain services, events, building performance, records and so on is bonded to 3D building model composed by conventional architectural metaphors as well as is represented simultaneously. V-PlaceLab can visualize the semantic data as various shapes in 1st person and 3rd person perspectives in the real-time manner (See Figure 7). Especially, simulation using virtual avatar can evaluate both the social phenomenon of this space and the performance of ubiquitous services.

5 Discussion & Conclusion
This paper intends to illustrate the role of current architectural visualization and propose the appropriate method of it. First, the type of data to visualize is studied based on the previous research and practical field. We emphasized semantic and social data in the current architectural data visualization because they became important in the era of ubiquitous computing environment. In the method of visualization, we proposed three concepts of visualization for the semantic and social data: spatial integration, multiple views, and game-based visualization. In the end of paper, we described a prototype system developed to evaluate our idea. This system based on dynamic and semantic representation with avatars is a kind of simulator for the design of ubiquitous smart space and can deliver users the better comprehension in how technological oriented space will be constructed and utilized. Furthermore, this system as a framework for spatial information monitoring can be used to facilities management service.

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