

A SYNCHRONOUS DISTRIBUTED DESIGN STUDY MEETING PROCESS WITH ANNOTATION FUNCTION

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Abstract. This research investigated the impact of synchronous distributed non immersive cloud-VR (cloud computing type of Virtual Reality) meetings using the annotation function by noting an architectural design process. The experimentation of collaborative design work at the early stage of a housing renovation project was executed by three designers. The synchronously distributed meetings using cloud-VR and a freehand sketching function were completed in two days. The annotation function was used effectively when a designer wished to show the space composition and volume shape of the planned building and so on. The proposed design environment, sharing a 3D virtual space with viewpoints, plans, sketches and other information synchronously and remotely, was feasible and effective.

Keywords. Collaborative design; communication process in spatial design; distributed synchronization; virtual environment; cloud computing.

1. Introduction

In the spatial design fields such as architectural and urban design, a consensus-building process among a variety of stakeholders such as project executors, architects, residents, users, and general citizens is required through collaborative work (Judith 1996). Since it is oftentimes necessary to share three-dimensional (3D) images to study spatial design, 3D Computer Graphics (3DCG), Virtual Reality (VR) and Building Information Modeling (BIM) systems have been developed.

Spatial design meetings using these systems have been traditionally held in a single room and at a certain scheduled time. In recent years, the mobility

of people's activities and cloud computing technologies have advanced in the modern age of information and globalization. Therefore, Virtual Design Studios (VDS) have been constructed by numerous universities and institutions across the world exploiting new computing and communication technologies (Wojtowicz 1994, Maher 1999, Kvan 2000, Matsumoto 2006). Mostly, VDS system developments and design trials of an asynchronous distributed type are used allowing stakeholders to participate in the design process at various places and at different times. This enables expansion of communication opportunities, without a participant needing to be concerned about restrictions of space and time.

VDS environments can accommodate a variety of platforms. The loose integration of design intentions and collaborative platforms causes considerable complications in the transition from individual to collaborative sessions. This results from the fact that most of the management of design representations, documentation and other information is done manually. To cope with these issues, virtual design environments include highly integrated applications for design, text and image processing, communication, scheduling, and information management. An essential shortcoming of these systems is the lack of synchronization between the views that different designers have and the context of their communication.

As a result from previous approaches, which are presented in section 2, we defined the following research questions for our work. How can a design team advance their design study in a synchronously distributed type of environment by using the cloud computing type of VR (cloud-VR) and its annotation function – allowing freehand sketching in a 3D virtual environment?

This paper is structured as follows: Section 1 introduces the main focus on synchronous distributed type VR meetings. Section 2 describes previous studies and state of the art. Section 3 illustrates the design study process by architectural design team in a synchronous distributed type environment by using cloud-VR and the annotation function. A design team applied cloud-VR and the annotation function with video conference system to an initial stage of building design study examination. Section 4 is the results and discussion by an empirical project. Section 5 shows the conclusions and future works.

2. State of the Art

In a synchronous distributed environment, different research efforts on design supporting a system for sharing 3D virtual space have been carried out, however, show a number of shortcomings. First, there is a system which allows designers to be physically immersed in their sketches and physical

models, literally inside life-size, real-time representations of these, while sharing them remotely with another system of the same sort (Dorta 2011). Safin (2009) evaluates the opportunities and constraints linked to the technological transfer of a sketch-based distant collaborative environment. Françoise (2008) describes a research project which aims at studying the value of a freehand design environment for architects. This sketch-based modelling software is implemented on a Tablet PC, which provides architects with the possibility to automatically generate 3D views from the freehand drawings.

On one hand, Gu (2009) and Shen (2010) developed a visualization tool on a multi-user platform to represent design alternatives and to supplement traditional presentation materials. These studies also pointed out that audio devices and web cameras are well-suited for online deliberation. Moreover, the data volume of the content of a design study is usually large. Therefore, when drawing 3D graphics using a client PC, a computer with a high-performance Graphics Processing Unit (GPU) is always required. This means that a standard spec PC cannot be used in this kind of design meetings making the presented concept hardly applicable. Fukuda (2012) and Sun (2013), on the other hand, presented the first approach towards a synchronous distributed design meeting system with annotation and discussion functions on cloud-VR. It allows stakeholders to participate in the design process at different places and at the same time while sharing a 3D virtual space. However, there is no research reported that has investigated the impact of synchronous distributed non immersive cloud-VR meetings with a freehand sketching function in an architectural design process.

In contrast to previous research efforts, this research presents how a design team can advance their design study in a synchronously distributed type of environment by using the annotation function of cloud-VR – allowing freehand sketching in a 3D virtual environment.

3. Cloud computing type VR and experimental plan

3.1. ANNOTATION FUNCTION OF CLOUD-VR

In the presented cloud-VR concept, 3D-VR contents are transmitted by the video compression method of the H.264 standard from the cloud-VR server. Therefore, real-time 3D images can be quickly transmitted in high quality and do not require a well-equipped client PC. Figure 1 shows the general system architecture that contains two main components of the cloud-VR, the server and the client. Commands about viewpoint changes, plan changes, etc. of the 3D virtual space on the client are calculated from the VR contents on a

cloud-VR server. Then the calculated contents are displayed in real time on the client as a video, using the H.264 standard. A user who interacts with the cloud-VR system can operate the virtual space or change plans of the displayed contents. Therefore, this concept has the following merits: 1) A highly efficient graphics environment is not required in a client allowing for use on mobile devices in addition to high-performance PCs; 2) Several participants can share a viewpoint, design alternatives, or the VR setup in synchronization; 3) The VR system or 3D contents are edited and unified by the management on the server side. To allow multi-user access, the cloud-VR controls the operation authority and shows clearly who is currently operating the GUI. The operation authority is the right to be able to operate the VR system. In other words, only the user who has the operation authority can operate the VR in synchronous distributed meeting mode to share the same viewpoint among users.

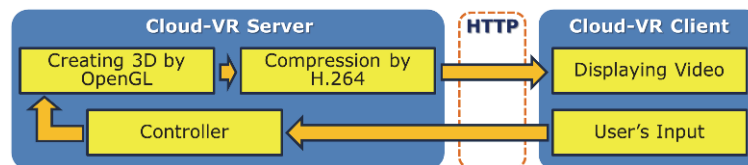


Figure 1. Configuration of data transmission in cloud-VR.

When using 3D virtual space to explore design approaches, people expect to be able to draw sketches and add figures and memos to the 3D virtual space. For instance, people need to draw arrows or sketches to indicate their notes and changes to a plan or VR content in a collaborative design work. Thus, annotation can be defined as freehand sketching and annotated text in a 3D virtual space in the context of this paper. For annotation, an intuitive and seamless interface is necessary so that a designer's thoughts or a meeting may not be interrupted.

The annotation function has been developed to be able to draw a freehand sketch, and add vector graphics such as arrows and text to the 3D virtual space, when sharing 3D virtual space to explore a design (Sun 2013).

3.2. EXPERIMENTAL PLAN

As an experimentation to investigate the impact of synchronous distributed non immersive cloud-VR meetings using a freehand sketching function by noting an architectural design process, we defined a collaborative design work at the early stage of a housing renovation project in Shimonoseki City, Yamaguchi Prefecture, Japan. To consider the case of an architectural design meeting, we assumed a project to reconstruct a low layer residence which

had become obsolete due to collective housing developments. As conditions for the target site, the dimensions of the plot were 17.6m in building width, 6.8m in building depth, and 12m in road width (see Figure 2). Additionally, the building coverage ratio (the size of the constructed buildings floor plate, i.e., the first floor total area as compared to the total size of the plot of land) was 80% and the floor area ratio (the total floor area of the building constructed – first floor, second floor, third floor, etc. – as compared to the size of the plot of land) was 600%. The case assumed a business district, including a fire protection zone.

In the actual virtual meeting, three designers, who were in different locations, in Chiba in Japan (hereinafter "Designer 1"), Osaka in Japan (hereinafter "Designer 2"), and Heidelberg in Germany (hereinafter "Designer 3"), used the annotation function. Designer 1 is an architect with practical experience and created an architectural plan in this experiment. Designer 2 has good skills in VR operation and understood the current situation of the target site well. Designer 3 documented the experimentation.

All the designers used Windows PCs on which were installed cloud-VR and Google Hangouts as a video conference system, and they could access the Internet. Audio for the video conference system was supplied via a headset in order to avoid noise between users. In the video conference system, in order to share the current status of the entire PC display and the position of the mouse pointer with other users, the PC display itself of the user was shown using a web camera. This confirmed that the problem of latency that may occur in the cloud-VR did not occur. Finally, during the experiment, through video recording, the audio and video of the experimentation were recorded for analysis of the design process.

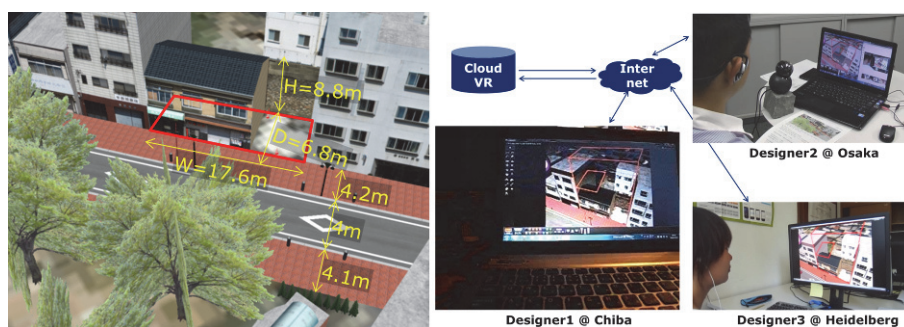


Figure 2. Experimentation: Building site (left) and meeting scene (right).

4 Results and Discussion

4.1. RESULTS

The experimentation was conducted over two days during July, 2013. On the first day, called "DAY 1", the three designers made themselves familiar with the conditions and the present situation of the site using fly-through and walk-through operations in the 3D virtual space of the cloud-VR. Next, Designer 1 examined the building volume to determine the design conditions for building coverage and floor area ratio. As a result, it was decided that a seven-storey building could be built. The first floor was intended for shops and the second to seventh floors for dwellings. A separate entrance to the apartments had to be established on the first floor. Between DAY 1 and DAY 2, Designer 1 created the drawing in the schematic design phase based on the initial sketches made on DAY 1. Then, Designer 2 created a 3D virtual model of the building by using 3DCAD software and imported this to the cloud-VR server. On DAY 2, a more detailed design examination was carried out. Figure 3 shows the experimental scene and the main annotation menu on the cloud-VR. Figures 4 and 6 show screenshots of some scenes from the two days which used annotation functions. Figure 5 shows the drawings. Tables 1 and 2 show the design process of the experiment.

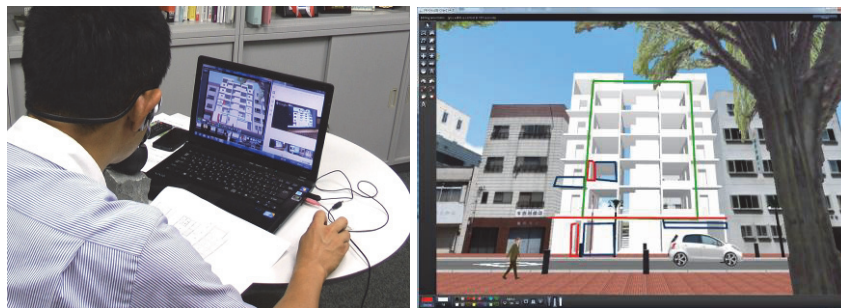


Figure 3. Experimental Scene (left), the main annotation menu on the cloud-VR (right).

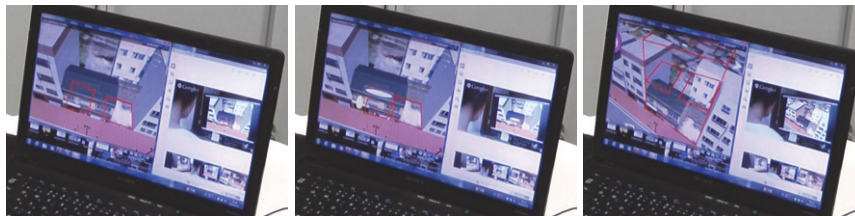


Figure 4. DAY 1: Scene 10 (left), Scene 12 (middle), Scene 13 (right).

Table 1. Collaborative design process using annotation function of the cloud-VR: DAY 1.

ID	Time (m:s)	Cloud-VR operation	Main speaker	Typical conversational content
01	0:00		Designer 2	Purpose of the design meeting was explained.
02	2:00	Designer 2	Designer 2	Designer 2 acquired the operation authority and explained the current situation of the target city (national road, railway station, harbor, symbol tower, and orientation).
03	3:45	Designer 2	Designer 2	Designer 2 explained the target building site.
04	4:05	Designer 2	Designer 2	On Designer 1's request, Designer 2 marked the target building site using the annotation function. The dimensions of the site (W=17.6m, D=6.8m, front road=12.3m) and the status of the surrounding terrain were confirmed.
05	5:45	Designer 2	Designer 1	The construction condition (zoning=commercial area, building coverage=80%, floor-area ratio=600%) were confirmed.
06	6:45	Designer 2	Designer 1	On Designer 1's request, Designer 2 operated VR to check access from the railway station and views of the building site (view from the ground and from the sky).
07	9:50	Designer 2	Designer 1	The buildable construction volume was confirmed. (Floor number, building use of roadside)
08	12:20	Designer 2	Designer 1	The buildable area per floor was confirmed. An entrance to the rental housing, and a store were planned on the first floor. Rental housing was planned from the second to the 7th floor.
09	14:00	Designer 1	Designer 1	The operation authority was changed to Designer 1.
10	14:25	Designer 1	Designer 1	Using the annotation function, from a bird's-eye view of the site, Designer 1 sketched the planar shape of the first floor of the building.
11	15:05	Designer 1	Designer 1	Using the annotation function, from a bird's-eye view of the site, Designer 1 sketched the common areas of the first floor level (plan 1). A concept of plan 1 was presented.
12	16:05	Designer 1	Designer 1	Designer 1 sketched the common areas of the first floor level (plan 2). A concept of plan 2 was presented.
13	18:30	Designer 1	Designer 1	From a bird's-eye view that was closer to the building site, using the annotation function, Designer 1 sketched the volume of the planning building.
14	21:55	Designer 2	Designer 2	The operation authority was changed to Designer 2. The scenery seen from the window of the planned building was reviewed.
15	27:20	Designer 2	Designer 1	The content of the next meeting was confirmed.
16	27:50	Designer 2		Meeting ended.

*: Annotation function use

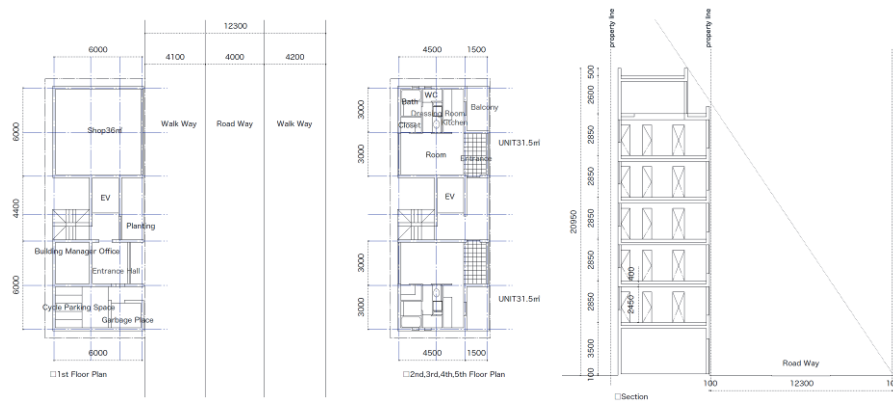


Figure 5. Technical drawings made on between DAY 1 and DAY 2.

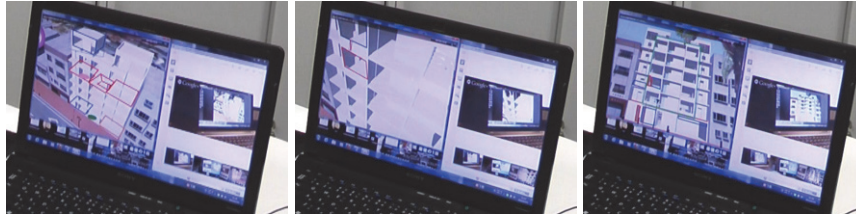


Figure 6. DAY 2: Scene 04 (left), Scene 06 (middle), Scene 12 (right).

Table 2. Collaborative design process using annotation function of the cloud-VR: DAY 2.

ID	Time (m:s)	Cloud-VR operation	Main speaker	Typical conversational content
01	0:00		Designer 2	The purpose of the design meeting was explained.
02	0:30	Designer 2	Designer 2	Designer 2 acquired the operation authority and displayed the 3D building model created based on the meeting of DAY 1 in the 3D virtual space.
03	1:03	Designer 1	Designer 1	The operation authority was changed to Designer 1.
04 *	1:33	Designer 1	Designer 1	While overlaying the sketch on the 3D models, Designer 1 presented the zoning of the space using the annotation function (elevator space, store space, entrance of the apartment, space for each rental dwelling unit (36m ²)).
05	4:20	Designer 1	Designer 1	Designer 1 presented the concept of space design. Both the 6th and 7th floors are designed as one dwelling unit. The forms were considered from a sky exposure plan of the front road.
06 *	7:00	Designer 1	Designer 1	From bird's-eye view that was closer to the building site, using the annotation function, Designer 1 explained the elongation of the windows necessary in order for the structure to be used for residential housing with a fire protection system.
07	10:55	Designer 2	Designer 2	The operation authority was changed to Designer 2. After entering the building interior, Designer 2 moved the building interior space via a walk-through. Designers 2 and 3 reviewed the view from inside the building and the window.
08	16:00	Designer 2	Designer 2	Designers 2 and 3 reviewed the view from the 5-7th floors and common areas.
09	23:00	Designer 2	Designer 2	Designers 2 and 3 reviewed the building façade from outside the building.
10 *	29:15	Designer 1	Designer 1	The operation authority was changed to Designer 1. While sketching using the annotation function, Designer 1 studied the sash and balcony of the building.
11 *	33:45	Designer 2	Designer 2	The operation authority was changed to Designer 2. Designer 2 proposed the façade design (color, material).
12 *	35:15	Designer 1	Designer 1	The operation authority was changed to Designer 1. While sketching using the annotation function, Designer 1 studied the building façade.
13	36:50	Designer 2		Meeting ended.

*: Annotation function use

4.2. DISCUSSION

Through the collaborative design work over two days, the synchronously distributed cloud-VR meetings with freehand sketching function were finished shown in section 4.1. The proposed richer system for sharing a 3D virtual space in regard to viewpoint, plan, sketch and other information synchronously and remotely was examined. The annotation function was used effectively when Designer 1 drew the zone shapes of space composition, the

volume shape of the planned building and so on in the schematic design phase. On the other hand, problems when using the proposed design environment occurred, as mentioned below.

- When the video conference system and cloud-VR were displayed, the screen of the notebook PC (14 inch) was filled with their windows. In the meeting, documents describing design conditions and drawings were required, but no space for these documents remained on the screen. Therefore, hard copies of these documents were used.
- Using the annotation function, a designer can draw directly by overlapping the sketch and the 3D model in 3D virtual space. Design activity such as the above has traditionally been carried out only in the imagination of the designer. Owing to the annotation function, design participants could share a concrete design image and could study the design through interactive operation. On the other hand, in an actual design work, it is hard for a designer to study a design only by using the screen of a perspective drawing such as VR. For an accurate understanding of the scale, orthographic drawings such as technical drawings are also required. Therefore, what a designer presents using technical drawings may be expressed in VR synchronously.

In addition, problems with the annotation occurred, as mentioned below.

- When a designer will draw sketches, the operation authority must be passed from the designer who previously had the operation authority. Furthermore, in order to pass the operation authority, it is necessary to terminate the annotation function once after saving. During the meeting, this operation interrupted the designers' conversation and thinking.
- When a designer was drawing a sketch using the annotation function, the designer could not move the viewpoint of the 3D virtual space. In the experiment, the designer who was sketching requested a function to zoom in on the design object more.
- If the 2D sketch drawn was converted into a 3D model immediately, a quick study from various viewpoints can be possible.
- As for the annotation function, as well as drawing of vector graphics such as lines, polygons and circles, the feature of painting a region by dragging is necessary.

5. Conclusion

This research investigated the possibilities for synchronously distributed cloud-VR meetings using an annotation function in an architectural design process. Therefore, the experimentation of collaborative design work at the early stage of a housing renovation project was executed. The synchronously

distributed cloud-VR meetings with freehand sketching function were finished by three designers in two days. The proposed richer system to share a 3D virtual space in regard to viewpoint, plan, sketch and other information synchronously and remotely was examined. The annotation function was used effectively when designers drew the zone shapes of space composition, volume shape of the planning building and so on.

Through the experiment, some problems of the proposed design environment and the annotation function were clarified. Future work should attempt to solve the problems.

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