

Assessment of the Use of 3D-Viewing and Mark-up Tool for Rich Network Design Communication

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Though there have been many successful examples of Virtual Design Studio, there still exist unsuccessful cases in which participants felt dissatisfied or even frustrated, especially at synchronous stages of design_communication. A discussion that required designers to refer to 3D models was one of the situations where technical support was insufficient to satisfy the expectation of designers. Assuming that an interactive viewing of 3D models and use of a mark-up utility on a shared PC window could enhance such design communications (though this also requires network bandwidth and computational power) the author conducted experiments in design discussion between two designers to test the capability and effects of these tools for network collaborations. This paper discusses the framework and results of the experiments, and proposes the next step for system developments.

I. Background and objective

With the development of network communication technology, the methods and procedures of architectural design are rapidly changing. Since the early challenges of network design collaboration were first reported [1], there have been many successful examples of Virtual Design Studio, showing that interaction among participants enhances the performance of the design team [2, 3, 4, 5, 6, etc.], but there still remain unsuccessful cases in which participants feel dissatisfied or even frustrated, especially at synchronous stages of collaboration [7]. This is not only because the insufficient bandwidth of the present-day Internet inhibits necessary communication [8, 9, 10], but also because software solutions to collaboration are relatively immature and insufficient to satisfy the expectations of designers [5].

Reviewing the past experiences of VDS, discussions that require designers to refer to 3D models represent one of the most difficult but important situations requiring technical development for support¹. In these situations a common approach has been that a designer explains his or her design, pointing with a cursor on shared web browser that displays a series of 2D images such as plans, sections or rendering images uploaded onto the web. However, this procedure of presentation not only interrupts smooth discussions and design thinking while browsing different windows, but also requires the designer to provide extra verbal representations to supplement information the web images cannot represent.

In order to advance synchronous network design collaboration from a possible level to an effective level, it is essential, after testing various combinations of tools and design applications, to propose an effective set up and necessary features to be developed further. Gabriel [11] conducted experiments to observe the role of AV media as tools for network design communication. Chen [12] observed the capability of network media to represent design ideas in comparison to traditional media and computer media. However, studies focusing on the techniques of synchronous design communication still remain underdeveloped.

As experimental use of the mark-up utility and interactive 3D viewing utility at a design studio seemed to have enhanced design discussions (though they still require network bandwidth and computational power) the author conducted experiments in design discussion to test systematically the capability and effectiveness of these tool usages in network collaboration. This paper discusses the framework and results of the experiments, and suggests a future direction for support system development.

2. Subjects of the experiment

2.1. Assumptions and aspects of observations

Assumptions for the experiments can be summarized as the following:

- 1) Use of a series of 2D images uploaded onto the web to explain formal features of 3D models tend to interrupt discussion and entail more time to complete necessary work because designers have to switch from one window to another in order to give a total image, and they also have to give extra verbal representations.
- 2) Use of an interactive 3D viewing and shading utility will allow smoother communication because designers can freely select suitable viewing conditions to observe different features of a model in one window
- 3) A mark-up utility will also be able to reduce extra operations such as switching windows or changing viewing conditions, because a freehand sketch can supplement information not represented by a reference model.
- 4) A mark-up utility will be able to reduce the time required for essential communication. In other words, it will upgrade the rhythm of conversation because it will reduce complicated verbal expressions to indicate some specific element of models or a point of reference in the referring windowⁱ, and because it will also reduce the need to switch windows.

2.2. Theme of the experiment and context of discussion

To test these assumptions, the author conducted experiments in design discussion between two designers (A & B) through the Internet, in which four different combinations of tools and design applications were tested. There were two scenes for the discussions; firstly designer A attempted to communicate to designer B the shape and size of a set of 3D models through an online discussion. To verify that designer B understood the original model correctly, B was asked to duplicate the model with a CAD application on B's own PC. Designer A and B were allowed to continue questions and answers until A agreed that the duplicate represented the original. Secondly, Designer B added simple design elements to the duplicate, cut an opening in the model through which one could see from one side to the other, and explained the proposal to A.

The process of the conducted experiment consisted of the following nine steps:

- Step-1) The organizer of the experimenter gave designer A a 3D CAD model of abstract shape and asked him/her to explain to B the shape and dimensions of each part of the model using the assigned tools.
- Step-2) A made preparations necessary for the explanation.
- Step-3) A explained to B using the assigned tools.
- Step-4) A and B repeated questions and answers until B had the necessary information to duplicate the models with his/her own CAD.
- Step-5) B built a 3D model.

Step-6) The organizer, who observed B's modeling process, instructed designers to repeat Step-4 and Step-5 until B's model became an exact duplicate of the original.ⁱⁱⁱ

Step-7) B cut a window-like hole in the model

Step-8) B made preparations necessary to explain the shape, size and location of the cut out window in the model.

Step-9) B explained to Designer-A how he or she opened the window and received A's comments on the proposal.

2.3. Communication tools tested

All cases used video conferencing tools to exchange dialogue, as well as an application-sharing tool to share design applications, however, each case, from Case-I to Case-IV, used a different combination of tools and design applications to share information on the shape and the size of the 3D model (Table I).

► Table I. Comparison of conditions for network collaboration by case

| Case No. | Case-I | Case-II | Case-III | Case-IV |
|--------------------------------------|--|--|--|--|
| Shared materials used for discussion | A series of 2D images of 3D models uploaded onto the GW-Notebook | A series of 2D images of 3D models uploaded onto the GW-Notebook | CAD file of 3D models uploaded onto the GW-Notebook | 3D models running on a CAD application |
| 3D viewing while in discussion | Not possible | Not possible | Possible, with the plug-in software of a web browser | Possible, with the viewing utility of CAD application |
| Mark-up while in discussion | Not used | Directly mark-up the referring window with the help of Mimio utility | Mark-up screen captured image of the window, after pasting it to the White Board utility | Directly mark-up the referring window with the help of Mimio utility |

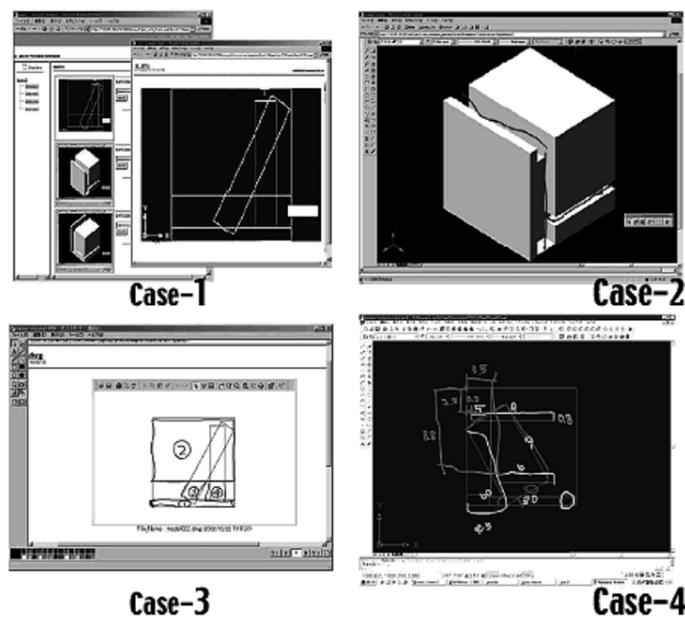
Case-I and Case-II shared a common web browser that could display a series of 2D images of the model that each designer thought necessary for explanation and discussion, such as the plan, elevations, and axonometric drawings or their shaded images. Those images were all prepared and uploaded onto the Web-based groupware, GW-Notebook^{iv}, at the Step-2 or Step-8. To explain the model from different views, the designers switched active windows of the groupware displayed in the form of a thumbnail list.

Case-III used a CAD file of a set of 3D models uploaded onto GW-Notebook. To explain the model from different views, designers used the viewing and shading utility of the plug-in software of a common web-browser, AutoDesk Volo-View Express. This allows designers, during the discussion, to use such operations as zoom, pan, 3D-rotate, or even shade models displayed in the web browser. In Step 5, designer B built a duplicate

model on B's CAD application, and after cutting a window-like hole in Step 7, B uploaded it to the GW-Notebook for explanation in Step-9.

Case-IV used a CAD application, AutoCAD. In Step 5, designer B built a duplicate model on B's CAD application. After cutting a window-like hole in Step 7, designers A and B switched application sharing roles so that designer A could observe B's application. To explain the model from different views, the designers used a viewing and shading utility of the application.

Case-II and Case-IV used the Mimio mouse mark-up utility that allows designers to draw a freehand sketch with a mouse over the shared window of a design application on each display. However, Case-III used the Whiteboard feature attached to Microsoft NetMeeting as a mark-up tool. In this case designers drew sketches after pasting the screen-captured image of the browser window to the White Board. Case-I did not use any mark-up tools but used only a cursor on a display to point to models or the desired part of the window.



◀ Figure 1. Examples of the image of the shared window

3. Setup for the experiment

3.1. Space and system used

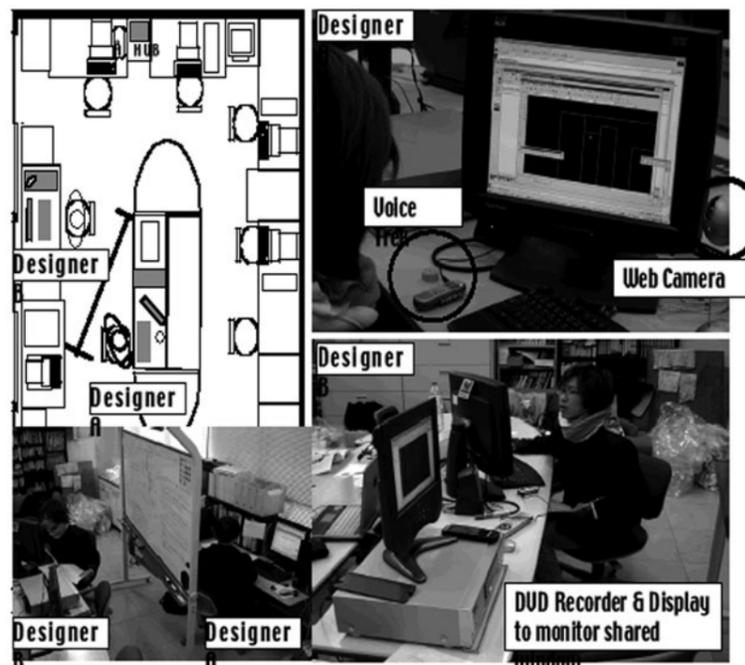
In order to easily observe the process of experiment, the authors asked designers to work in one room, just separating each workspace with a light partition. Each workspace had a network PC with SXGA display monitor⁵,

web camera, and an audio speaker and microphone set (Table 2 and Figure 2). The participants also used sheets of paper and pencils to take notes. In order to observe how designers handled the design application and mark-up utility in the shared window while in discussion, the authors provided a digital voice recorder to record dialogues, and a DVD recorder (player) to record a scan-converted image of one of the display monitors. Special software, Winshot, which captures a still image of a display monitor at original resolution with a mouse click, and a digital camera were also used to record clear images at every key scene in the experiment.

► Table 2. Hardware and software used for the experiment

| Hardware for Design Communication | Software for Design Communication | Hardware and Software for Recording the process of the |
|--|---|--|
| Network PC (IBM Intellistation Mpro CPU Pentium IV, RAM 768MB, Windows 2000) | Videoconferencing and Application sharing (Microsoft NetMeeting 3.01) | Digital Camera (SONY Cybershot DSC-P9) |
| (IBM NetVista A22 CPU Pentium 2.0GHz, RAM 512KB, Windows 2000) | Web-browser and Plug-in (Internet Explorer 6.0, AutoDesk Volo-View Express 2.0) | Scan Converter (Canopus Power Presenter 1280) |
| Web Camera | Web-based groupware (GW-Notebook) | DVD recorder player (Toshiba RDX) |
| Microphone and Speaker Set | CAD (AutoCAD 2000) | Digital Voice Recorder (Olympus Voice Trek DS150) |
| | Mark-up tool (Microsoft White Board) | Display image-capturing software (Winshot) |
| | (Mimio 1.02, mimimouse) | |

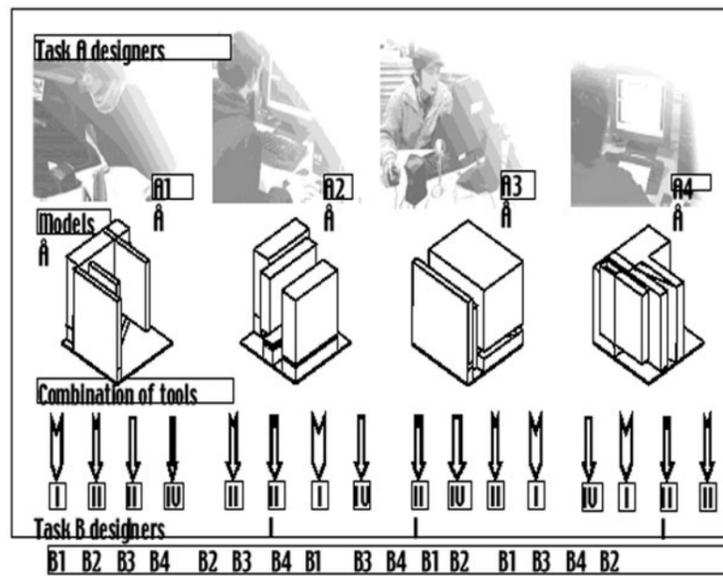
► Figure 2. Laboratory set-up for the experiment



3.2. Design of experiments

The experiment participants were eight graduate students of architecture from Kumamoto University, who were assumed to have almost equal ability in design communication and who had previously used various tools and design applications in experimental situations. Splitting these eight students into two groups of four designers, A and B, the author asked them to work on the four different models, which were of similar complexity^{vi}, forming pairs from group A and group B. As it needed time and energy to test all the combinations, the author designed 16 experiments with different combinations that minimized the influence of personality and combination effects, as well as the learning effect of a specific model and tools. In other words, each student participated in four experiments in which the combination of tools and design applications (Case), the model, and the pair of designers were systematically changed each time. In addition, the case order was changed for each designer (Figure 3).

After the experiments, a short questionnaire was given out, which asked participants to indicate which situations caused them unease in explaining the model, and to give their reasons.



◀ Figure 3. Combination of designer pairs, models, and tools

4. Analysis

4.1. Aspects of analysis

Among the 9 steps of work established in each experiment, the authors mainly observed how the participants worked and exchanged dialogues at

Steps -3, -4 and -9 in which the combination of tool and design application would have direct influence.

To test the assumptions, the authors analyzed the texts transcribed from the digital audio records in terms of the followings aspects, in parallel with observing the DVD records.

- 1) The number of times that application windows were switched (SWCH), as an indicator of hindrance against smoother communication caused by tools.
- 2) The number of times that demonstrative pronouns (DPRO) and adjective phrases (APHR) the designers used to indicate specific 3D objects or points of reference represented in the display. These were used as indicators of other hindrances caused by requiring designers to provide extra verbal representation in order to supplement the inadequate ability of the tools to represent models^{vii}. "This" or "that" were common examples of the DPRO used, and "left (element)," "upper (objects)" were those for APHR.
- 3) The time required completing the three steps of work (TIME). This was used to compare the speed of communication possible for each case.

In comparing the counts for DPRO and APHR used for each case, the author also calculated their frequency in every minute of work (TIME) and in every 100 phrases^{viii} uttered by the two designers. As there were utterances in the dialogue that did not directly relate to the subject of work, such as those made for control communication, for manipulating tools, or for maintaining interpersonal relationships^{ix}, the authors counted only those made to explain or question the formal features of the 3D models (DPHR).

4.2. Observations

In the cases that used the mark-up utilities, the designer frequently marked-up to indicate a point of reference as well as to draw freehand sketches in explaining subjects that were not represented in the subject window. Several pairs of designers marked-up character coders to refer to objects before starting explanations or questions, and this made a particular contribution to the discussion in Case-II and Case-III.

4.2.1. Average frequency of switching windows

The average frequency of SWCH by TIME and DPHR became lower by descending order of case number (TABLE 3). In Case-IV, the designers completed all discussions in a single window with the help of the viewing utility, while designers had to switch windows frequently in Case-I. The average frequency of Case-II was lower than Case-I because sketches drawn with the mark-up utility helped with necessary explanations without switching, but it was still higher than Case-III.

| Case | Case-I | Case-II | Case-III | Case-IV |
|---------------------------------------|-----------|-----------|-----------|---------|
| / | 2D images | 2D images | 3D on web | 3D CAD |
| Aspects of observation | Mark-up | Mark-up | Mark-up | Mark-up |
| TIME: Average Time at Steps-3, -4, -9 | 730sec | 824sec | 983sec | 760sec |
| Average Time spent at Step-8 | 276sec | 164sec | 5sec | |
| TIME: Total time described above rows | 1006sec | 988sec | 995sec | 765sec |
| Average counts | | | | |
| DPHR: phrases relating to the subject | 361.5 | 314.8 | 394.7 | 311.8 |
| SWCH: window switching | 20.5 | 13.3 | 12.3 | 0.0 |
| DPRO: demonstrative pronouns | 57.8 | 43.3 | 49.3 | 40.4 |
| APRO: adjective phrases | 18.8 | 10.3 | 13.5 | 12.0 |
| Average frequency in 60 seconds | | | | |
| SWCH / TIME | 1.7 | 1.0 | 0.8 | 0.0 |
| DPRO / TIME | 4.8 | 3.2 | 3.0 | 3.2 |
| APRO / TIME | 1.5 | 0.8 | 0.8 | 0.9 |
| Average frequency in 100 phrases | | | | |
| SWCH / DPHR | 5.7 | 4.2 | 3.1 | 0.0 |
| DPRO / DPHR | 16.0 | 13.8 | 12.5 | 13.0 |
| APRO / DPHR | 5.2 | 3.3 | 3.4 | 3.8 |

Notes: This table indicates average data for each case.

◀ Table 3. Summary of observed data

Case-III indicated a higher frequency than originally expected because the simultaneous use of two applications, White Board and GW-Notebook, required the designer to take extra steps in switching windows. This could have become as low as Case-IV, if only the same mark-up tool as Case-IV had been used.

4.2.2. Average Frequency of Complicated Expressions

The use of the mark-up utility reduced the frequency of complicated expressions. Both the average frequency of DPRO and APHR by TIME and DPHR in Case-II, Case-III and Case-IV was lower than those in Case-I. There were no significant improvements by the use of a 3-D viewing utility. Case-IV, and Case-III indicated almost the same, or a little higher than the average frequency for Case-II.

4.2.3. Average Length of Time for Discussion

In the beginning, the author assumed that TIME would become shorter in a higher number of cases because of the advantages provided by the utilities. However, Case-III took the longest and Case-I the shortest because of the influence of various factors. Case-III, in particular, took more time than expected because the simultaneous use of two applications, GW-Notebook and White Board, required the designer to take extra steps in PC operation, such as capturing the display image, and pasting that image to the White Board for marking-up.

A human factor was also involved in this unexpected result. Case-I and Case-II were relatively short because designers had the opportunity to

consider beforehand the most effective process of explanation while preparing presentation material. Considering the time at Step 8 that was spent exploring necessary views and uploading captured images to GW-Notebook, the working time for Case-I and Case-II would have been longer than those recorded, though the author failed to record that time designer A spent at Step 2 preparing the presentation. Only adding the time spent at Step-8 to TIME, the total communication time for Case-I became longer than those for Case-3 and Case-4. When those for Case-2 were included, the result would become much clearer.

It also became clear after analyzing the transcribed texts that the expressions in Case-II, Case-III and Case-IV were more concrete and detailed than those in Case-I, which resulted in longer discussion times. The mark-up utility and 3D-viewing utility seemed to have enhanced the quality of discussion by allowing easy and rhythmical explanation and timely presentation of models.

5. Conclusion

Though the number of observations was limited to eliminate human factors sufficiently, it is possible to conclude that the use of interactive 3-D viewing and a mark-up utility, especially the latter, provided a convenient environment for smooth design discussion through the Internet.

In the discussion after the experiment, all designers reported the Case-I to be inconvenient for network design discussion, while seven of the eight designers reported Case-IV as the most convenient and effective, and Case-II as the second best, though the PCs used still seemed to have lacked computational power and interrupted viewing operation of 3-D models on a shared CAD window several times. The last designer reported Case-II and Case-IV to be almost the same because the evaluation depended on the situation used. Though the White Board had the convenient utility of referring back to sketches drawn in the earlier stages of discussion, the extra steps of copying the screen image and pasting it to the White Board disturbed smooth communication.

It is quite common to introduce various tools to support network collaboration as in these experiments, which simultaneously used such tools as GW-Notebook or a CAD application for presenting design, Net-Meeting for videoconferencing and application sharing, and Mimio or White Board for marking up. But the simultaneous use of different tools designed for a respective utility not only requires extra works for setting-up and tuning operational parameters of those tools, but also tend to cause system trouble during network collaboration. Considering to these tendencies, it is inevitable to develop a user friendly integrated system for network collaboration that can support comprehensive design communication.

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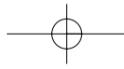
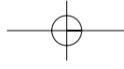
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- i Most distributed design work can be done asynchronously, but there are still stages during the process of design development in which synchronous design discussions play quite critical roles.
- ii In asking the length of object, one commonly asks “the length from here to here”, which could be reduced to “this length” with the use of mark up. This reduction could improve the rhythm of conversation.
- iii To speed-up the process of design experiment, the authors asked the organizer to verify the duplicated model.
- iv GW-Notebook is a web-base groupware developed by the author to support network collaboration. It has a simple utility for uploading any type of design document file as well as to display both thumbnail list style and multi-window style at original resolution. This was used to speed up designers’ preparatory work for presentation. For details, see [13].
- v A high-resolution display monitor was used to give a broad workspace, but it seemed to require extra PC power.
- vi Each model can be built from the same size cube using the same steps of Boolean operation.
- vii The authors had the idea of using these indices while observing a student presentation in a studio that used different media. The students tended to use complicated expressions when they could not directly refer to specific elements of their models or to a point in their design documents.
- viii Due to the nature of the Japanese language, the phrase was counted as a quantitative index of the volume of verbal expression.
- ix Gabriel [11] proposed to classify verbal communication in collaborative design into four major categories consisting of 16 sub-categories. Communication Control, Communication Technology, Social Communication, and Design Communication are the four major categories he used.

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3D Crossover: exploring *objets digitalisé*

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