Xiangyu Wang
Jerry Jen-Hung
Editors

Collaborative
in Virtual Env

Collaborative Design in Virtual Environments

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Xiangyu Wang • Jerry Jen-Hung Tsai (Eds.)

Collaborative Design in Virtual Environments

Springer

Xiangyu Wang
Senior Lecturer,
Faculty of Built Environment,
The University of New South Wales,
Australia

and

International Scholar,
Department of Housing and
Interior Design,
Kyung Hee University, Korea

Jerry Jen-Hung Tsai
Yuan Ze University
Yuan-Tung Road 135
32003 Chung-Li
Taiwan R.O.C.
E-mail: jerry.tsai@saturn.yzu.edu.tw

Preface

Collaborative Virtual Environments (CVEs) are multi-user virtual realities that actively support communication, collaboration, and coordination. All of the academic books in this area are more focused on the theory, user-centred design, realisation and evaluation of Collaborative Virtual Environments in general. In contrast, the emphasis on studying designers' behaviours/actions/patterns in CVEs distinguishes this book from many general books which more deal with the design and development of CVEs. As more researchers in design and related areas progressively employ CVEs as their base of enquiry, we see a need for a reference guide bringing the existing status of CVEs into awareness and expanding on recent research.

This book offers a comprehensive reference volume to the state-of-the-art in the area of design studies in CVEs. This book is an excellent mix of over 16 leading researcher/experts in multiple disciplines from academia and industry. All authors are experts and/or top researchers in their respective areas and each of the chapters has been rigorously reviewed for intellectual content by the editorial team to ensure a high quality. This book provides up-to-date insight into the current research topics in this field as well as the latest technological advancements and the best working examples. Many of these results and ideas are also applicable to other areas such as CVE for design education. Predominantly, the chapters introduce most recent research projects on theories, applications and solutions of CVEs for design purpose. More specifically, the central focus is on the manner in which they can be applied to influence practices in design and design related industries.

Overall, this book offers an excellent reference for the postgraduate students, the researchers and the practitioners who need a comprehensive approach to study the design behaviours in CVEs. This book is a useful and informative source of materials for those interested in learning more on using/developing CVEs to support design and design collaboration. The target audiences of the book are practitioners, academics, researchers, and graduate students at universities, and industrial research that work with CVEs and digital media in a wide range of design areas.

The book has 5 sections and 16 chapters totally. The sections are listed as follows and more information can be found in the Table of Contents;

Part I. Virtual Environments for Design: Fundamentals
Part II. Representation and Embodiments in Collaborative Virtual
Environments: Objects, Users, and Presence

Part I. Virtual Environments for Design: Fundamentals

To begin, Professor Mary Lou Maher overviews the technical and social issues of
CVEs and their impact on designers in her keynote chapter *Designers and Col-
laborative Virtual Environments*. This overview of CVEs sets the context and
frames the scope of the book. It discusses how CVEs has lead to new ways for
designers to collaborate and new kinds of places for designers to design.

Apparently, designing in virtual environments unavoidably involves visual-
spatial cognition. The second chapter *Visual-Spatial Learning and Training in
Collaborative Design in Virtual Environments* by Maria kozhevnikov and Andre
Garcia reviews different types of virtual environments and discusses the major
advantages that these environments can offer in the domain of visual-spatial per-
formance. The first part is then followed by the following four parts in which there
are chapters relating to more specific aspects of collaborative design in virtual
environments.

Part II. Representation and Embodiments in Collaborative Virtual
Environments: Objects, Users, and Presence

This part highlights issues with the representation of objects and embodiments of
users by avatars in CVEs. This part develops an understanding of the nature of
presence in CVEs from real-world investigation of the means by which users ex-
perience CVEs. The three chapters in the second part present current research in
this area.

Chiu-Shui Chan explored in *Design Representation and Perception in Virtual
Environments* two important cognitive activities involved in designing in virtual
environments. The first activity is design representation that is mentally created
during the design processes. The second activity relates to human perception,
which has not been changed by high-tech developments.

Form and content are two basic concepts that have a significant impact on the
sense of presence in virtual environments. The second chapter by Rivka Oxman
Design Paradigms for the Enhancement of Presence in Virtual Environments dis-
cusses current research in the design of presence in virtual environments.

Co-presence has been considered as a very critical factor in CVEs. Xiangyu
Wang and Rui Wang follow Rivka Oxman's discussion in the third chapter, *Co-
presence in Mixed Reality-Mediated Collaborative Design Space,* and reflect on
the concept and characteristics of co-presence, by considering how Mixed Reality-
mediated collaborative virtual environments could be specified, and therefore to
provide distributed designers with a more effective design environment that im-
proves the sense of "being together".

Part III. Design Cooperation: Sharing Context in Collaborative Virtual Environments

The third part contains chapters addressing collaboration, communication, and coordination methods and issues in using CVEs for collaborative design activities.

The first chapter by Walid Tizani, *Collaborative Design in Virtual Environments at Conceptual Stage,* outlines the requirements of collaborative virtual systems and proposes methodologies for the issues of concurrency and the management of processes.

The second chapter by Jeff WT Kan, Jerry J-H Tsai and Xiangyu Wang, *"Scales" Affecting Design Communication in Collaborative Virtual Environments,* explores the impacts of large and small scales of designed objects towards the communication in three-dimensional collaborative virtual environments.

As a means for design coordination and progress monitoring during the construction phase, the chapter by Feniosky Peña-Mora, Mani Golparvar-Fard, Zeeshan Aziz and Seungjun Roh, *Design Coordination and Progress Monitoring During the Construction Phase*, presents a complementary 3D walkthrough environment which provides users with an intuitive understanding of the construction progress using advanced computer visualization and colour and pattern coding techniques to compare the as-planned with the as-built construction progress. The innovation of this method is to superimpose 3D Building Information Models (BIM) over construction photographs.

Part IV. How Designers Design in Collaborative Virtual Environments

The fourth section looks at how designers design in CVEs. Nobuyoshi Yabuki sets out in his chapter, *Impact of Collaborative Virtual Environments on Design Process,* to review the current design and engineering processes and identifies issues and problems in design and construction of civil and built environments. Based on these findings, he then investigates and summarizes the significant impacts of CVEs on design and construction of civil and built environments.

As an effort to study how designers learn design in CVEs, in their chapter *A Pedagogical Approach to Exploring Place and Interaction Design in Collaborative Virtual Environments*, Ning Gu and Kathryn Merrick report on their experience of teaching the design of virtual worlds as a design subject, and discusses the principles for designing interactive virtual worlds.

Ellen Yi-Luen Do, wrote the third chapter, *Sketch that Scene for Me and Meet Me in Cyberspace.* It discusses several interesting projects using sketching as an interface to create or interact in the 3D virtual environments.

In the final chapter in this part, *A Hybrid Direct Visual Editing Method for Architectural Massing Study in Virtual Environments*, Jian Chen presents a hybrid environment to investigate the use of a table-prop and physics-based manipulation, for quick and rough object creation and manipulation in three-dimensional (3D) virtual environments.

Part V. Case Studies

This part collects 4 chapters on emerging technology implementation and applications of virtual environments in collaborative design.

Firstly, Bharat Dave, in his chapter, *Spaces of Design Collaboration*, emphasizes the socially and spatially situated nature of collaborative design activities and settings, and identifies issues that remain critical for future collaborative virtual environments.

In the following chapter, *Modeling of Buildings for Collaborative Design in a Virtual Environment*, Aizhu Ren and Fangqin Tang, present an application independent modeling system, which enables quick modeling of irregular and complicated building structures adapted to Virtual Reality applications based on Web.

Phillip S Dunston, Laura L Arns, James D Mcglothlin, Gregory C Lasker and Adam G Kushner present in their chapter, *An Immersive Virtual Reality Mock-up for Design Review of Hospital Patient Rooms,* the utilization of Virtual Reality mock-ups to offer healthcare facility stakeholders the opportunity to comprehend proposed designs clearly during the planning and design phases, thus enabling the greatest influence on design decision making.

In the final chapter, Marc Aurel Schnabel discusses in *the Immersive Virtual Environment Design Studio,* the implications of designing, perception, comprehension, communication and collaboration within the framework of an 'Immersive Virtual Environment Design Studio'.

Acknowledgements

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Xiangyu Wang
Jerry Jen-Hung Tsai
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Contents

Part I
Virtual Environments for Design: Fundamentals

Designers and Collaborative Virtual Environments
Mary Lou Maher (University of Sydney)

Visual-Spatial Learning and Training in Collaborative Design in Virtual Environments
Maria Kozhevnikov and Andre Garcia
(Harvard Medical School and George Mason University)

Designers and Collaborative Virtual Environments

Mary Lou Maher

University of Sydney, Australia

Abstract. This chapter provides an overview of the technical and social issues of CVEs and their impact on designers. The development of CVEs has lead to new ways for designers to collaborate and new kinds of places for designers to design. As a new technology for collaborative design, CVEs impact the collaborative process by facilitating movement between working together and working individually. As new technologies for interacting with CVEs include tangible interfaces, we can expect to see changes in the perception of the design that lead to changes in spatial focus.

Keywords: 3D Virtual Worlds. Collaborative design, tangible interaction, protocol studies, adaptive agents.

1   Introduction

Collaborative Virtual Environments (CVEs) are virtual worlds shared by participants across a computer network. There are many descriptions of CVEs, and Benford et al (2001) provides one that is assumed in this chapter: The virtual world is typically presented as a 3D place-like environment in which participants are provided with graphical embodiments called avatars that convey their identity, presence, location, and activities to others. CVEs vary in their representational richness from 3D virtual reality to 2D images to text-based environments. The participants are able to use their avatars to interact with and sometimes create the contents of the world, and to communicate with one another using different media including audio, video, gestures, and text. This kind of virtual environment provides opportunities for collaborative design that gives remote participants a sense of a shared place and presence while they collaborate.

   CVEs provide new ways to meet communication needs when negotiation is important and frequent, and complex topics are being discussed. They provide more effective alternatives to video conferencing and teleconferencing because they provide spaces that explicitly include both data representations and users (Churchill et. al. 2001), an important consideration in collaborative design where the focus of a meeting may be on the design ideas and models more than on the faces of the collaborating designers. During the early days of CVEs (in the early 1990s), researchers put an emphasis on simulating face-to-face co-presence as realistically as possible (Redfern and Naughton, 2002). More recently, it has been realised that

this is not enough for collaborative design, and may not necessarily even be required to develop a shared understanding of the design problem and potential solutions (Saad and Maher, 1996).

Redfern and Naughton (2002) nicely summarize a range of technical and social issues provided in the development and use of CVEs in distance education that can be adapted for understanding the development and use of CVEs in collaborative design.

Managing collaborative design processes. In a design project, collaborative work involves the interleaving of individual and group activities. Managing this process over the several months of a design project requires considerable explicit and implicit communication between collaborators. Individuals need to negotiate shared understandings of design goals, of design decomposition and resource allocation, and of progress on specific tasks. It is important that collaborators know what is currently being done and what has been done in context of the goals. In a collaborative design task this information can be communicated in the objects within the CVE where the collection of objects forms an information model, such as the Building Information Model in building design processes. DesignWorld is an example of a research project that explores ways of integrating CVEs with an external database of objects and project information (Maher et al 2006).

"What You See Is What I See" (WYSIWIS). Conversational and action analysis studies of traditional collaborative work have shown the importance of being able to understand the viewpoints, focuses of attention, and actions of collaborators. CVEs assume a co-presence in a virtual world that is shared, even though the viewpoint of the world may be different when the avatars are located in different places and facing different directions. Communication among the participants in a CVE is often about location and viewpoints, allowing individuals to pursue their own tasks as well as have their attention focussed on a shared task. Clark and Maher (2006) studied communication in a design studio course that was held in a CVE and showed that a significant percentage of the communication was about location and presence.

Chance meetings. Informal meetings with colleagues are rarely provided for in collaborative tools, yet they are an important characteristic of the effectiveness of many workers, particularly knowledge-workers. Recent research has investigated mechanisms for supporting chance meetings without the requirement for explicit action by the user (McGrath & Prinz, 2001). In collaborative design, studies have shown that designers move fluidly from working individually to working together. Kvan (2000) presents a model in which different stages of collaborative design are characterized as closely coupled or loosely coupled. CVEs provide the opportunity for individual work in a shared place that supports chance meetings.

Peripheral awareness is increasingly seen as an important concept in collaborative work, as evidenced in ethnographic studies. Team members involved in parallel but independent ongoing activities need to be able to co-ordinate and inform their activities through background or peripheral awareness of one another's activities. The affordance of peripheral awareness for collaborative design in a CVE is demonstrated in a study done by Gul and Maher (2009). In this study, designers were given similar design tasks in a 3D CVE and in a remote sketching

environment, and asked to collaborate for a fixed period of time. An analysis of the protocol data shows that in a 3D CVE designers were inclined to spend part of the time working together and part coordinating their individual work, while in a remote sketching environment the designers did not work individually.

Non-verbal communications are known to have a strong effect on how utterances are interpreted. Research into alternative input mechanisms for capturing this type of information from the user has been underway for some time: recently, attempts are being made to make these mechanisms intuitive and non-intrusive. Clark and Maher (2006) show how participants communicated using specified gestures for their avatars in the design studio. Augmented reality approaches to CVEs promise a more spontaneous integration of movement in the physical world being communicated in a virtual world.

The *"designing for two worlds"* principle: People are never fully immersed in a virtual world, but are always partially in the real world too. Certain activities when carried out in the real world have a very strong impact on the participant's activities that should be recognised in the virtual world – for example, answering the phone. DesignWorld (Maher et al 2006) accommodated this by maintaining a video of each designer in his physical office in a window adjacent to the 3D CVE with the designers' avatars. This allows communication to be directed in the virtual world or in the physical world, and the physical presence and activities of the physical world to be communicated to the designers in the virtual world.

This chapter provides an overview of two comparative studies of collaborating designers using CVE technologies. These studies provide a starting point for understanding the impact of these technologies on design cognition and design collaboration. The chapter ends with an overview of a project that considers the opportunities that CVEs provide for designers to explore a new kind of design discipline: the design of places in virtual worlds. These three projects consider designers more comprehensively in the context of CVEs: from designers as users of CVEs to designers of CVEs.

2 Supporting Collaborative Design: From Sketching to CVEs

Sharing design ideas ranges from working together at a table while sketching with paper and pencil, to working in a CVE. CVEs do not replace sketching on paper while co-located; they provide a different kind of environment for collaborating. Since the tools for expressing and sharing ideas are so different, we would expect that the collaboration is different. Gul and Maher (2009) describe a study comparing design collaboration while designers sit together sketching to remote sketching and designing in a 3D CVE. The aim of the study is to identify the changes in collaborating designers' behaviour and processes when they move from co-located sketching to remote designing.

The study considered three collaborative design settings: sketching around a table, remote sketching, and designing in a CVE. The sketching setting is shown in Table 1. The image in the left part of the table shows a camera image of two designers sharing a physical table with sketching tools such as paper and pencil.

Table 1. Sketching experimental setting (Gul and Maher, 2009)
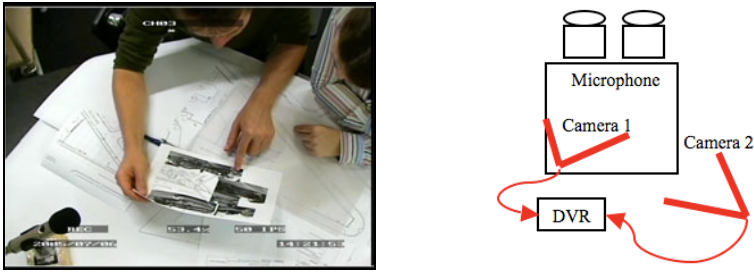
Table 2. Remote sketching setting (Gul and Maher, 2009)

(a)   (b)
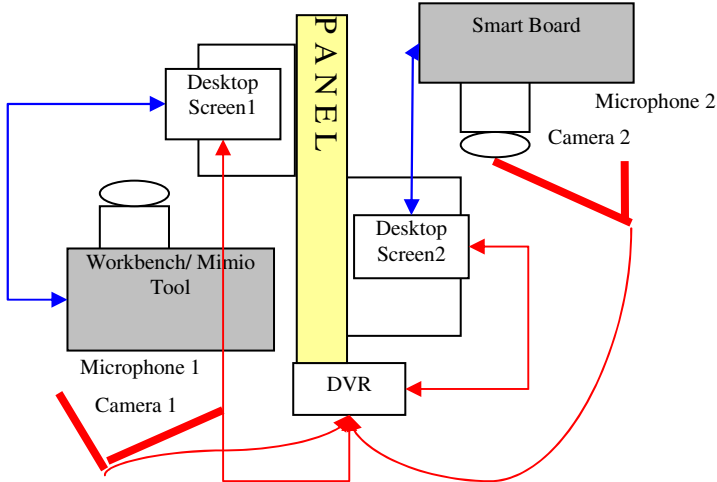
(c)

The schematic in the right part of the table shows how the designers were observed by placing 2 cameras connected to a digital video recorder.

The remote sketching setting used GroupBoard (www.groupboard.com), a collaborative sketching application, and display surfaces with pen interfaces. One

Table 3. Remote sketching and CVE interfaces (Gul and Maher, 2009)

(a) GroupBoard Interface

(b) ActiveWorlds Interface
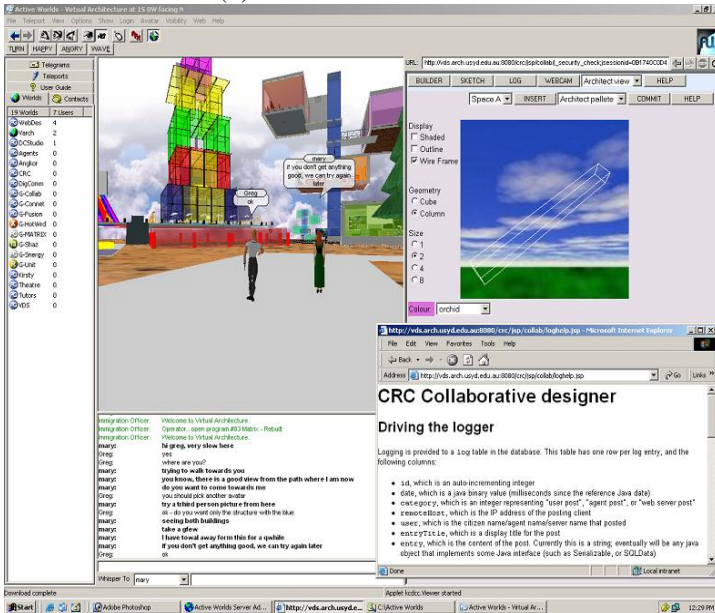
designer was sketching on a tabletop system and the other designer was sketching on a whiteboard mounted on the wall. The setting is shown in Table 2. The top row of the table shows the tabletop sketching environment (left) and the mounted whiteboard sketching environment (right). The bottom row of the table shows a schematic of the layout: the location of cameras for recording the design session, and the use of a panel to simulate remotely located designers.

Table 3 shows the applications for the two remote design sessions: the Group-Board application supported a shared sketching window, as shown in Table 3(a) and the Active Worlds (www.activeworlds.com) application is a CVE, as shown in Table 3(b). The third setting was set up similarly to the second setting with cameras on each of the remotely located designers, as well as capturing the interactions on the display screen.

A protocol analysis method was used to compare face to face sketching to remote sketching and a CVE. The protocol data included video of the shared representation and gestures of the designers, and the verbal utterances of the designers. The continuous stream of protocol data was first segmented using the utterance-based segmentation method as used in (Gabriel 2000; Maher, Bilda and Marchant, 2005) where a new segment was marked when there was a shift from one designer acting/talking to another. When a segment contained complex actions, each segment was segmented again using the actions-and-intentions segmentation method used in (Gero and McNeill, 1998). The segments were coded using a hierarchical coding scheme according to perception, action, and realization categories, as well as codes for collaboration mode (meeting, individual) and representation mode (2D, 3D).

An immediately notable result from the segmentation process was that the designers had more attention shifts when sketching face to face, that is, the average duration of the segments was shorter and there were more segments in a design session. In a CVE, the designers stayed focused on one activity longer and had fewer segments to complete the same design goals. When comparing the protocols for sketching vs working in 3D, the study found that when sketching the designers did more "create" and "write" actions and when 3D modelling the designers did more "continue" actions which provided more detail in the co-created representation. The effect of facilitating more detailed digital representations is that the result of the remote 3D design sessions was a more developed design solution.

The second most notable result of this study was that the designers worked together continuously when sketching. They stayed focused on a common task. The designers in the CVE worked in two modes: together on the same task, and separately on individual tasks. The CVE provided awareness of the collaborator but also allowed the collaborating designers to have their own view of the design model and work independently, while checking in with each other occasionally.

3   Adding Tangible Interaction to 3D Design

The interaction with most CVEs is still enabled by the keyboard and mouse. Interaction technology is moving towards alternatives to the keyboard and mouse, such as pen interfaces, the Wii, direct brain-computer interaction, and tangible interaction. A study by Kim and Maher (2008) looks at the difference in the design process when designers use a mouse and keyboard vs 3D blocks as tangible input devices.

Tangible user interfaces (TUIs) offer physical objects as an alternative to typical computer input and output devices, and are often combined with augmented reality (AR) blending reality with virtuality (Azuma et al. 2001; Azuma 1997;

Dias et al. 2002). Using a tabletop system, designers can interact with 3D digital models more directly and naturally using TUIs while still utilizing verbal and non-verbal communication (Bekker 1995; Scott et al. 2003; Tang 1991). Many researchers have proposed that tangible interaction combined with AR display techniques might affect the way in which designers perceive and interact with digital models (Billinghurst and Kato 2002; Streitz et al. 1999; Ullmer and Ishii 1997). However, the central preoccupation of research on TUIs has been in developing new prototypes for design applications focusing on the functionality, where the Kim and Maher (2008) study provides empirical evidence for the effect of TUIs on designers' spatial cognition.

This empirical study considers the effects of TUIs on designers' spatial cognition using a protocol analysis. In order to focus on the impact of tangible interfaces on designers' spatial cognition, two settings are compared: a graphical user interface (GUI) as a desktop computer with a mouse and keyboard in ArchiCAD, and a TUI as tabletop system with 3D blocks in ARToolkit.

The tabletop system was developed at the University of Sydney and is described in (Daruwala, 2004). The tabletop system is shown in Figure 1 The horizontal display provides the means on which tangible interaction can take place and the binary patterns of the 3D blocks were made in ARToolKit[1] for the display of the 3D virtual models. A web camera captures the patterns and outputs them on a vertical LCD display in real time. In order to provide a same visual modality as the GUI environment, an LCD screen is used for the TUI session instead of a head mounted display (HMD).

Table 4 shows the set-up for the TUI session. The LCD screen was fixed to the left of the designers, and a 2D studio plan and 3D blocks were placed on the horizontal table. The web camera was set at a suitable height and angle to detect all the markers of the 3D blocks. A DVR (digital video recording) system was set to record two different views on one monitor, where one camera was used to monitor designers' behaviour and the other to capture the images on the LCD screen. This enabled the experimenter to observe designers' physical actions and the corresponding changes in the representation. A microphone was fed into the DVR system through a sound mixer and the camera filmed to record a clear view of designers' behaviours. A pair of designers sat at the same side of the table.

Table 5 shows the set-up for the GUI sessions. The overall experiment set-ups were similar to those of the TUI sessions. However, the camera was set to the left of the designers to avoid the LCD screen set to the front of the table from blocking its view of the designers. A pair of designers sat together in front of the computer, and the designer on the right usually operated the mouse.

Designers in the TUI sessions communicated design ideas by moving the objects visually, whereas designers in the GUI sessions discussed ideas verbally. Further, designers in the TUI sessions collaborated on handling the 3D blocks more interactively whereas designers in the GUI sessions shared a single mouse,

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[1] ARToolKit is free AR software using a computer vision method and includes tracking libraries and source codes for the libraries, which is easy to use and allowed us to customise existing codes for our own applications (Billinghurst et al. 2003).

Table 4. Experimental set-up for the TUI session (Kim and Maher, 2008)
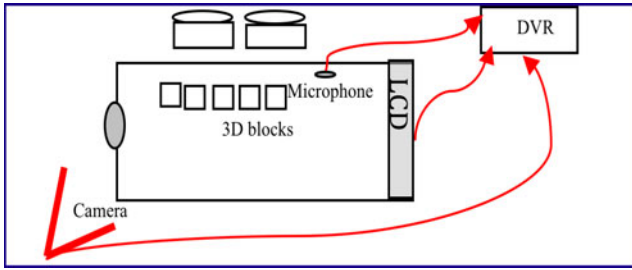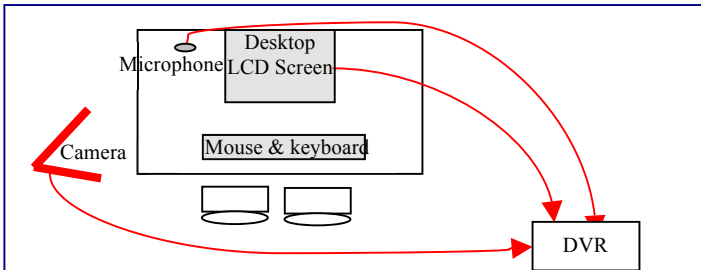

Table 5. Experiment setting for GUI session (Kim and Maher, 2008)

thus one designer mainly manipulated the mouse while the other explained what s/he was focusing on. These findings suggest that designers' collective interactions differed in the two design sessions.

It is notable that designers of the TUI sessions often kept touching the 3D blocks, and designers of the GUI sessions showed similar touching actions using

the mouse. 'Touch' actions did not accompany any change in the placement of objects, but seemed to involve a cognitive process. Kim and Maher (2008) conjectured that 'Touch' gestures supported designers' perception of visuo-spatial features based on the argument by Kirsh and Maglio (1994): Some actions that appear unmotivated actually play valuable roles in improving performance, for instance, simplifying mental computation, from a perspective of epistemic goals.

Designers in the TUI sessions randomly placed pieces of furniture on the horizontal display of the plan, and then decided on their locations by moving them around. They were acting spontaneously, responding to their perceptual information straight away. On the other hand, designers in the GUI sessions seemed to decide their actions based on the information initially given rather than perceptual information. For example, regarding the placement of a new desk, designers in the GUI sessions emphasized the function of a desk for a computer programmer by saying "the programmer might need a desk for holding little computer things" and placing it in the corner. However, designers in a TUI session considered two locations for the desk, in the corner or near the window, then deciding to put it near the window so that the designer could look out, thus creating a spatial relationship between the desk and window. These findings suggest that designers developed design ideas in different ways according to the different interaction modes.

Through the results of the experiments, Kim and Maher (2008) found that the physical interaction with objects in TUIs produce epistemic actions as an 'exploratory' activity to assist in designers' spatial cognition. Further, the epistemic 3D modeling actions afforded by the interface off-load designers' cognition, and the naturalness of the direct hands-on style of interaction promote designers' immersion in designing, thus allowing them to perform spatial reasoning more effectively. In addition, designers' perception of visuo-spatial information, especially 'spatial relations', was improved while using the 3D blocks. The simultaneous generation of new conceptual thoughts and perceptual discoveries when attending to the external representation may also be explained by a reduction in the cognitive load of holding alternative design configurations in a mental representation.

In terms of the design process, designers' problem finding behaviours were increased in parallel with the change in designers' spatial cognition. The 'problem-finding' behaviours and the process of re-representation provided the designers with deeper 'insight' leading to key concepts for creative design. In summary, the study provides empirical evidence for the following views on TUIs: firstly, TUIs change designers' spatial cognition, and secondly, the changes of the spatial cognition are associated with problem finding behaviours typically associated with creative design processes.

4   Adaptive Virtual Worlds

While most developments and studies of CVEs focus on how to support collaboration, little research attention is given to the design of the virtual world as a place. Since a CVE is a virtual world, we can ascribe behaviours to the objects in the world in addition to designing their geometry and location in the world. This provides an opportunity to rethink how places are designed in CVEs. Gu and Maher