2 Virtual Worlds

Virtual worlds are places that exist entirely in networked environments in which people co-exist, communicate and interact through their avatars. These worlds are dynamic and interactive environments that support a broad range of social, entertainment, educational, and productive activities that are loosely based on activities in the physical world. A common metaphor for the design of these worlds is the concept of place. Most designs use the concept of place as the basis for designing the ambient environment and objects in the virtual world. Virtual worlds are designed for specific purposes and can support various activities online.

The design of places in virtual worlds draws on our experience and knowledge of architectural design in the physical world. The metaphor of place and reference to concepts from architectural design provide a consistent and familiar base for the people in the virtual world and also for the designers of virtual worlds. This metaphor and reference facilitates the interaction of virtual world users with the designed environments and with each other. Effectively, the physical world provides the inspiration for the design of virtual worlds. We are beginning to see the opposite effect as well, that virtual world designs are providing the inspiration for the design of physical places. The characteristics of virtual worlds that make them dynamic, adaptive, and interactive are especially relevant to contemporary and future place design in the physical world, serving as an ideal test bed for developing and maturing design fields such as intelligent environments, ubiquitous computing, pervasive computing, and interaction design.

2.1 Evolution of Virtual Worlds

Virtual worlds emerged from the 1990s as an environment that allows multiple users access to a single application in real time on the internet. Singhal and Zyda (1999) describe virtual worlds as software systems where multiple users connect from different geographical locations and interact with each other in real time. They also characterize virtual worlds with five common features: (1) a shared sense of location; (2) a shared sense of presence; (3) a shared sense of time; (4) online communication; and (5) interaction with the virtual environments. Highlighted by these features, virtual worlds are capable of providing multiple users with the ability to interact with each other, to share information, and to interact with the virtual environment by manipulating virtual world objects in the environment through immersive computer graphics. To further articulate the definition of virtual worlds, Singhal and Zyda also draw the differences between virtual worlds and other networked environments or tools emerged at the time: the ability to support multiple users differentiates virtual worlds from early virtual reality applications and game environments[8]. The ability to share and manipulate virtual world objects differentiates virtual worlds from traditional online communication tools such as online chat rooms and video conferencing systems. The ability to support real-time interactions differentiates virtual worlds from email and traditional web browsing. However, despite these definitions and characterizations, there is not yet a universal definition or standard form of virtual worlds. Virtual worlds as a topic for design and research is relatively new and still evolving. Different designs of virtual worlds are currently perceived as integral parts of the social media that support online communication and interaction.

The brief history of virtual worlds can be traced back to about the 1980s. The term "cyberspace" was first introduced in the science fiction novel *Neuromancer* (Gibson, 1984). In this novel, Gibson (1984) describes cyberspace as "a consensual hallucination experienced daily by billions of legitimate operators, in every nation… a graphical representation of data abstracted from the banks of every computer in the human system… lines of light ranged in the nonspace of the mind, clusters and constellations of data. Like city lights…". The main contribution of Gibson's novel, as described by Whittaker (2004), was that it gave "expression to the emerging technologies" at the time, such as personal computers, the internet, computer graphics, virtual reality and other digital forms of information. Thereafter, especially in the 1990s, the term "cyberspace" attracted the attention of the general public, and became extremely popular and influential among design practitioners and researchers in different areas. To a certain extent, cyberspace seems to have become an express tunnel that links together the present and future and which provides a new horizon for opportunities, innovation and imagination. It has also had a continuing impact on a wide range of domains such as architecture and design, computer science, education, e-commerce, social science and so on. This newly emergent area does not develop alone. It has since been extended to include many sub-domains, such as communication and collaboration, design representation, human computer interaction, artificial intelligence, computer graphics, virtual and augmented reality and other networked technologies.

The early developments in the design of virtual worlds can be categorized to have taken two major paths: (1) the conceptual development of the design and purpose of virtual worlds; and (2) the technical development of the design and implementation of virtual worlds. In the conceptual development of virtual worlds, design practitioners and researchers explore the possibilities of virtual worlds, illustrate the future of virtual worlds, and study the impact of virtual worlds on existing design theories and practices. For example, Benedikt (1991) collects a series of influential writings by designers, artists, novelists, engineers, businessmen and academics to predict and illustrate the future

8 New generations of virtual reality applications and game environments can now support multiple users.

of cyberspace from different perspectives where everything seems possible. These writings also outline the dramatic changes in the physical world and our future daily life due to the influence of cyberspace. Woolley (1993) discusses the emergence of virtual worlds, which changes public reality through virtual reality and artificial reality. Anders (1998) presents theories and examples that use space as a cognitive tool for managing our daily activities in the physical world, and how these concepts may be extended to cyberspace. Wertheim (1999) follows the history of the western conception of space from the middle ages to the information ages, and critically accesses the cyberspace and cyber culture. Now in the 21st Century, when we look back and re-examine some of the concepts and predictions, virtual worlds are indeed challenging and gradually changing the traditional forms of communication, education, entertainment and business. The physical world, however, has not been radically overtaken by the emergence of virtual worlds as some have predicted. Virtual worlds co-exist with the physical world and supplement the physical world. One current example aiming for the seamless blend of the virtual and the physical is the concept of ubiquitous computing initiated by Weiser (1991) and researched by many others nowadays (Abowd & Mynatt, 2000; Dourish, 2004). This concept has also been applied to the urban scale to consider the development of ubiquitous cities in the real context (Sang et al, 2008).

The second category of early development is the technical advances for the design and implementation, in which design practitioners and researchers work on the technical realization and building of virtual worlds. The early forms of virtual worlds emerged in the early 1990s, when the internet became more accessible. The origin of virtual worlds has served two purposes: (1) military simulation; for example, SIMNET (simulator networking) developed by the US Department of Defense that simulates battlefields for military training purposes; and (2) networked games; for example, Doom and Quake, 3D networked games first released in the 1990s by id Software[9], downloaded and shared by millions since their release. Beyond its origins of military simulation and networked games, virtual world design and implementation have been enriched and diverted to take on various forms for different purposes. The internet has accommodated many different technologies supporting the early text-based virtual worlds, graphical virtual worlds and 3D virtual worlds. The purposes that virtual worlds serve have expanded to include social communication, education, design collaboration, e-commerce, and others. The main literature on virtual world design and implementation, as suggested by Maher (1999), can address one or more of the following issues: (1) implementation – technologies for realizing virtual worlds; (2) representation – a consideration of the digital representation and management of various components of virtual worlds; (3) interface – the types of interface provided to people for accessing virtual worlds, interacting with the environments, and interacting with each other.

9 http://www.idsoftware.com

At the implementation level, 3D models have become the dominant form for visualizing virtual worlds following some early attempts at using text-based and graphical representations. The introduction of the Virtual Reality Markup Language (VRML) in 1994 led to the first 3D web browser. Virtual Reality (VR) technologies, which had been used for simulation, then became the main means for realizing virtual worlds (Morgan & Zampi, 1995). This marked the beginning of the 3D era for virtual worlds.

At the representation level, the main interest concerns the use of metaphors; for example, the study on how text-based virtual worlds, mainly MOOs, are represented and designed (Cicognani & Maher, 1998); and its extensions from the linguistic characterizations to include graphical and spatial characterizations (Maher et al, 1999; 2000; 2001). Using the place metaphor, the latter studies draw an analogy to the built environment, and a coherent hierarchy of architectural elements, such as buildings, rooms and objects are developed for representing object-oriented virtual worlds. More recently, computational models have been used for representing virtual worlds in order to integrate artificial intelligence to virtual worlds. These models include examples such as cognitive agent models (Maher & Gero, 2002; Smith et al, 2003; Maher et al, 2004) and generative design algorithms (Gu & Maher, 2003; Muller et al, 2006). At the interface level, the input and output devices of virtual worlds have been explored. Research on human computer interaction and ubiquitous computing has provided new technologies for enhancement in these areas, for example, various mobile and handheld devices for more flexible access to virtual worlds, and more affordable augmented and mixed reality solutions such as Google Glass for better immersive display. However, the most common interface for accessing virtual worlds is still a desktop or laptop computer.

2.2 Design Metaphors

Through the use of metaphor, concepts in one domain can be understood, expressed and experienced in terms of another (Lakoff & Johnson, 1980). The early use of metaphors can be seen in ancient literatures, and have been widely applied and recognized in poetry and novels. Metaphors are not simply about language; in fact, the human conceptual system is largely metaphorical (Lakoff & Johnson, 1980; MacCormac, 1985; Erickson, 1990). In other words, the use of metaphors shapes our human understanding, thus greatly affects how we think and what we do. The essential aspects of metaphor are very well highlighted by MacCormac (1995): “Without metaphors, to describe and explain the unknown would become impossible”. This is especially evident in contemporary societies with the rapid development of new technologies, which appear to have been unfamiliar to us initially. Therefore, we extend the familiar concepts to understand, apply and further develop these new technologies. There are many examples of such in our daily life; for example, telegraph, television, digital television, email, e-commerce, and e-learning. Lakoff and Johnson (1980) highlight the power of metaphors. Metaphors pervade the human conceptual system. The use of metaphors enables us to grasp many concepts that are either abstract or not clearly delineated in our experiences. It is by means of other concepts that we better understand in terms of familiar structure, spatial orientation, objects, and so on. Metaphors define reality, especially social realities, by providing a coherent network of entailments that highlight certain aspects of our experiences but hide others. The acceptance of the metaphor forces us to focus only on those highlighted aspects of our experiences, and leads us to believe that the entailments of the metaphor are true. The created reality can then be used as guidance for future actions, and these actions, in turn, reinforce the power of metaphors to make experiences more coherent. Some new metaphors can also provide new meanings. Unlike conventional metaphors that structure the general conceptual system of our culture, these new metaphors are imaginative and creative and exist outside the conventional conceptual system. Such metaphors are capable of giving us a new understanding of our experience.

In the design domain, the use of metaphors allows practitioners and researchers to adopt familiar design concepts to make references to other design knowledge, or to simply be inspired. Different metaphors have been applied to compose music, create artworks, design artefacts and generate systems in areas such as music and creative art, architectural design, engineering design and design computing. For example, in photography, Radice (1998) documented a series of pictures by the Italian designer and photographer Ettore Sottsass taken between 1972 and 1973. These pictures are largely composed of artificial objects with the natural desert surroundings of Spain. Each artificial object was carefully selected and placed in the scene. These objects went beyond their original meaning in industrial civilization, and were used as metaphors by the artist which he illustrated through the interplay with the natural landscape. For example, a door does not simply define a gateway to exit one place and to enter another place; instead, through the door we “enter into darkness” or “are meeting our love”.

In computer science, the use of metaphors is also very common. Since the nature of our conceptual system is metaphorical, it is not difficult to understand that the use of appropriate metaphors plays an important part in assisting our interactions with the environments we inhabit. This is also the case when we interact with computer environments (Erickson, 1990; Marcus, 1998; Hsu & Schwen, 2003). Stefik (1996) provides a historical review of the metaphors we use to describe and design computers and computer networks. They are “giant brains”, “information superhighway” and “multiple metaphors”. The main metaphor applied to computers in the 1950s was the giant brain, however, this metaphor did not predict the broader future of computers. Computers did not become bigger in order to become more powerful. In the 1980s, the information superhighway metaphor was applied to describe the high-speed connectivity of the computer networks. This metaphor is useful for thinking about the flow of digital information, but does not provide adequate insight for illustrating how our future lives would be affected by computers. Stefik presents multiple metaphors to extend and enrich the concept of the information superhighway by thinking about emerging information infrastructure and exploring new possibilities. Stefik explores four of these multiple metaphors: digital library (for thinking about information storage and shared knowledge), electronic mail (for thinking about digital communication), electronic marketplace (for thinking about digital properties and e-commerce), and digital worlds (for thinking about virtual community and its supporting infrastructure such as virtual reality, telepresence and so on). Each metaphor addresses one particular aspect, which together provide a richer range of meanings and possibilities for the information superhighway.

From these multiple metaphors, it is evident that new technologies and experiences make reference to various familiar concepts in the physical world. Similarly, to extend these ideas further, we can consider designing virtual worlds in terms of designing built environments in the physical world (which is relatively more familiar to us). This leads to the use of the place metaphor for designing virtual worlds.

2.3 Place Making in Virtual Worlds

The image of architecture has always been defined and perceived as the art of places. In the physical world, places differ from spaces by including social and cultural values, in addition to spatial configurations (Kalay, 2004). This distinction of place nicely highlights the key elements in the formation of places. They are the spatial environment, the people who inhabit the environment, and the interactions between these two. This understanding is echoed by many other scholars. Norberg-Schulz (2000) uses the word “totality” to describe the art of places, which by principle deals with “the experience of living”. Steele (1981) illustrates a diagram to define the concept of a sense of place: “Setting + Persons = Sense of Place”. The term “setting” in the diagram refers to the “surrounding” (spatial setting) and “context” (social setting). The persons are psychological factors. Relph (1976) claims that places at all scales are “whole entities” that synthesize natural and artificial objects, functions and activities, and meanings given by intentions.

By using the metaphor of place we can design virtual worlds by place making rather than by page, document or database making. The underlying rationale of using the place metaphor is based on an assumption that, because to a large extent our social and cultural behaviors are organized around spatial elements of the physical world, we can carry over these patterns of behaviors to virtual worlds by designing them to have the same potentials for conception and interaction that the physical world exhibits (Kalay & Marx, 2001; Champion & Dave, 2002; Kalay, 2004). The patterns of behavior we learn in the physical world therefore become useful in virtual worlds. By structuring virtual worlds in a way that allows us to apply these learned traits from the physical world, we can reduce the cognitive effort needed to inhabit the worlds. By adopting the metaphor of place, designing virtual worlds as a relatively new area is able to make analogical references to place design that has been developed for centuries, rich with its own theories and practice. The analogy provides a base to understand and further extend the use of these networked environments. On the other hand, the emergence of virtual worlds also has had a reverse impact and created new dimensions for exploring place design. Such examples include liquid architecture (Novak, 1991), hyper architecture (Puglisi, 1999), information architecture (Schmitt, 1999) and interactive architecture (Fox & Kemp, 2009). Virtual worlds made up of computing entities that can be directly scripted and programmed can also inform the latest digital design development such as the scripting cultures (Burry, 2011).

However, place making in virtual worlds is, after all, different from place making in the physical world. Firstly, virtual worlds are networked digital environments. Virtual worlds can be experienced only via computers. Secondly, designing virtual worlds can go beyond the principles of physical place design to further explore the potentials specific to virtual worlds, as these worlds do not need to obey the law of physics and other than input and display devices, comprise pure computing entities. With these considerations in mind, designing virtual worlds, therefore, is not authentic place making; rather, it is a loose sense of place making that adopts certain relevant design concepts and knowledge from the built environments for the virtual context. Based on Kalay's (2004) criteria for virtual place making, we summarize the following characteristics of place making in virtual worlds.

– Functional virtual places – places provide ambient environments for certain intended activities online, which offers the reason or purpose for being there;
– A sense of location – places provide relative locations, and locations create a context for the intended activities to occur. A sense of location helps to recall our traces in the virtual worlds, and these traces help us to differentiate one place from another;
– A sense of presence – places involve some kind of engagement with objects and people. Through these interactions, a sense of presence is provided; and
– Uniqueness of virtual places – virtual worlds afford a variety of experiences different from our physical experiences; for example, in virtual worlds we have unique ways of navigation from place to place using hyperlinks, and the ambient environment and objects can be interactive and even proactive.

2.4 Design Platforms and Examples

There are far fewer examples of designed virtual worlds compared to designed places in the physical world. This is reasonable considering the relatively short history of virtual worlds. During the past two decades, technologies and tools for designing virtual worlds have undergone a series of evolutionary changes from the early text-based virtual worlds such as MUDs (Multi-User Domains) and MOOs (MUD, Object-Oriented) to the current 3D virtual worlds.

In the text-based virtual worlds, words are the only matter because the creation of the worlds depends almost exclusively on the use of words. The virtual worlds and their components are described using only text. People connect to a shared networked environment to interact with the environment and each other by using textual commands. MUDs are widely recognized as the first generation of shared networked environments. This technology was originally developed as a networked place for the role-playing game Dungeons and Dragons, which was then extended into MOOs to support other online games, and to further service the virtual communities in general activities, such as social communication and online learning.

In 1990, Stephen White developed the first MOO server. MOOs enable an easier creation of virtual worlds through object-oriented programming[10]. The use of object-oriented languages for designing virtual worlds is influential, as many of the current virtual worlds are object-oriented. Subsequent development of MOOs adds a graphical dimension by using a web browser window for visualizing the virtual world using digital images – each MOO object is often visualized with a graphical icon and some MOOs also provide a 2D layout plan to organize these icons and a 2D map to direct users.

In text-based virtual worlds, users rely largely on spatial reasoning and mental models to perceive and process spatial information of the virtual worlds. In 2D graphical virtual worlds, the textual descriptions are enhanced by the use of digital images which provide virtual worlds with a new graphical dimension. However, 2D images do not allow us to fully exploit the spatial organization potential of the virtual worlds. After these early attempts and the development of personal computers that could process and display 3D models, the next step in the implementation of virtual worlds was to search for 3D alternatives that could mimic the built environments and support 3D spatial experiences.

Nowadays, most virtual worlds are visualized using 3D models. Platforms for designing 3D virtual worlds include Active Worlds[11], Second Life, OpenSim[12], Open Cobalt[13], 3DVIA Studio[14], and others that have been developed from or inspired by gaming engines such as Quake[15] and World of Warcraft. The development of 3D models as virtual worlds is a major focus for most of these design platforms. This focus leads to a strong emphasis on the visual aspect of the designs. In these virtual worlds, virtual world objects often appear as place-element-like models. Selected

10 http://www.moo.mud.org/moo-faq
11 http://www.activeworlds.com
12 http://opensimulator.org
13 http://www.opencobalt.org/
14 http://www.3dvia.com/studio/
15 http://www.idsoftware.com/games/quake

objects can have scripted behaviors to support predefined actions for interactions in the virtual world. Virtual world users are represented as avatars, the animated characters. Avatars communicate with each other via in-world communication and interact with the environments by activating behaviors of various objects.

We briefly review several platforms for designing 3D virtual worlds that support these typical features and show a typical place design for each platform.

Active Worlds (AW) is one of the earliest platforms for designing and operating 3D virtual worlds. Using AW, virtual worlds are designed and implemented based on the AW object library. The object library provides a list of 3D models that simulate place elements. Users are able to build virtual places using these models. The object library can be expanded by using external 3D modeling and translation tools. Virtual world objects can have behaviors by using AW triggers and commands, a simplified scripting language. The interactions in AW can also be further extended using the AW Software Development Kit (SDK). Figure 2.1 shows a virtual cinema designed and implemented using AW.

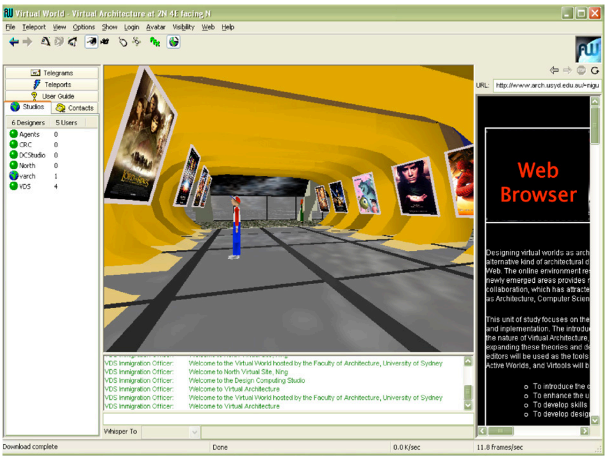

Figure 2.1: A virtual cinema designed in the Active Worlds University of Sydney universe, by the students.

Second Life (SL), as one of the most popular 3D virtual world platforms, is developed with a strong focus on virtual communities in supporting a diverse range of online activities. Besides gaming, social communication and e-learning activities, SL is particularly known for its e-commerce activities including trading for virtual estates and properties. SL provides basic in-world modelling tools for designing and implementing virtual worlds by direct manipulation of geometric primitives. Behaviors of virtual world objects and avatars can be controlled and customized using Linden Scripting Language (LSL). Figure 2.2 shows a public place in SL.

Figure 2.2: A public place in Second Life.

Open Cobalt emphasizes the use of virtual worlds as workplaces for research and other professional collaboration. Open Cobalt enables users to access and share not only objects within the virtual world but also other remote software applications, through the virtual world. As shown in Figure 2.3, although Open Cobalt supports the creation of virtual places, the focus of Open Cobalt is more on its capabilities for supporting real-time online collaboration via shared objects and applications.

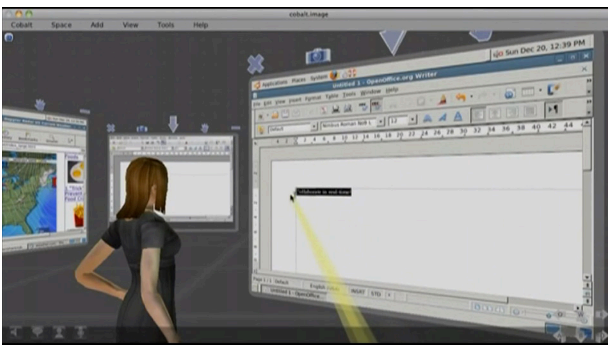

Figure 2.3: Collaborative document sharing and editing in a virtual world created using Open Cobalt (image taken from Open Cobalt web site: http://www.opencobalt.org).

3DVIA Studio (3S) develops 3D virtual worlds as different virtual and augmented reality applications for different purposes, ranging from online gaming to real-time product and building visualization. 3S provides 3D model editing features and can support the import of large industry data sets. It also serves as a graphical programming system for designing interactions in 3D virtual worlds. Figure 2.4 shows a popular social game played on Facebook and developed using the platform. 3S is robust for designing highly interactive and customized 3D virtual worlds, but can be technically demanding for general designers as many virtual world features need to be developed from scratch.

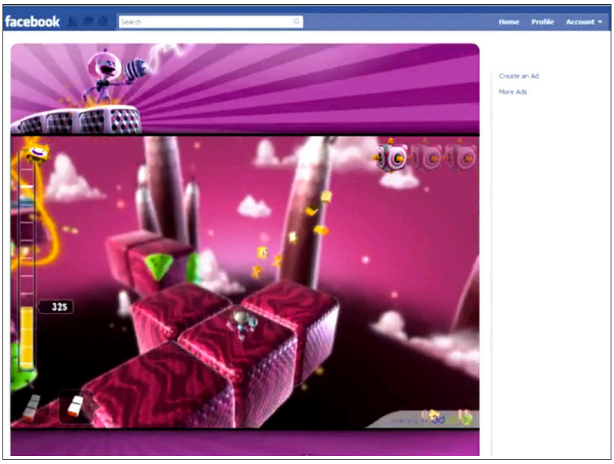

Figure 2.4: Billions Save Them All, a 3D social game played on Facebook and developed using 3DVIA Studio (http:// www.3dvia.com/studio/gallery/billions).

While we are seeing a rise in the number of virtual world platforms and opportunities to build and experience places in virtual worlds, most 3D virtual worlds share the following two common characteristics: (1) there is a general lack of formal approaches to understanding and designing 3D virtual worlds as places; and (2) the current process of virtual world design and implementation can be cumbersome, and relies heavily on the designers' ability to not only conceive of the place as a set of 3D geometric models, but also program and script the behaviors of each object. There are numerous books that explain how to build and program in virtual worlds (eg. Weber et al, 2007), but few describe the design of places as an intentional design activity.

This book contributes to the theoretical foundation of designing virtual worlds by introducing a formal computational approach to designing places in virtual worlds based on design grammars and computational design agents. Virtual world designers, researchers and online communities will be guided to understand the design principles of virtual worlds as places, examples of rules for designing places for specific purposes in virtual worlds, and principles for making virtual worlds adaptive through the use of computational agents. The book also explores the impact and future of these dynamic, adaptive, and interactive virtual worlds for networked games, social media places, collective design intelligence and interactive architecture.

References

Abowd, G.D. and Mynatt, E.D. (2000), Charting Past, Present, and Future Research in Ubiquitous Computing, *ACM Transactions on Computer Human Interaction*, 7(1), pp. 29-58.

Anders, P. (1998), *Envisioning Cyberspace: Designing 3D Electronic Spaces*, McGraw-Hill, New York.

Benedikt, M. (ed) (1991), *Cyberspace: First Steps*, MIT Press, Cambridge, MA.

Burry, M. (2011), *Scripting Cultures: Architectural Design and Programming*, Wiley, London.

Champion, E. and Dave, B. (2002), Where Is This Place?, *Proceedings of ACADIA 2002*, California State Polytechnic University, pp. 87-97.

Cicognani, A. and Maher, M.L. (1998), Two Approaches to Designing Virtual Worlds, *Proceedings of Design Computing on the Net 98*, *International Journal of Design Computing*, 1 (online).

Dourish, P. (2004), *Where the Action Is: The Foundations of Embodied Interaction*, MIT Press, Cambridge, MA.

Erickson, T.D. (1990), Working with Interface Metaphors, in B. Laurel (ed), *The Art of Human-Computer Interface Design*, Addison-Wesley, Reading, MA, pp. 65-73.

Fox, M. and Kemp, M. (2009), *Interactive Architecture*, Princeton Architectural Press, New York.

Gibson, W. (1984), *Neuromancer*, Ace Books, New York.

Gu, N. and Maher, M.L. (2003), A Grammar for the Dynamic Design of Virtual Architecture Using Rational Agents, *International Journal of Architectural Computing*, 4(1), pp. 489-501.

Hsu Y-C, and Schwen, T.M. (2003), The Effects of Structural Cues from Multiple Metaphors on Computer Users' Information Search Performance, *International Journal of Human-Computer Studies*, 58, pp. 39-55.

Kalay, Y.E. (2004), *Architecture's New Media: Principles, Theories, and Methods of Computer-Aided Design*, MIT Press, MA.

Kalay, Y.E. and Marx, J. (2001), Architecture and the Internet: Designing Places in Cyberspace, *Proceedings of ACADIA 2001*, Buffalo, New York, pp. 230-240.

Lakoff, G. and Johnson, M. (1980), *Metaphors We Live By*, University of Chicago Press, Chicago.

MacCormac, E.R. (1985), *A Cognitive Theory of Metaphor*, MIT Press, Cambridge, MA.

Maher, M.L. (1999), Designing the Virtual Campus as a Virtual World, *Proceedings of Computer Supported Collaborative Learning 99*, Stanford University, pp. 376-382.

Maher, M.L. and Gero J.S. (2002), Agent Models of Virtual Worlds, *Proceedings of ACADIA 2002*, California State Polytechnic University, pp. 127-138.

Maher, M.L., Gu, N. and Li, F. (2001), Visualisation and Object Design in Virtual Architecture, in J.S. Gero, S. Chase and M. Rosenman (eds), *Proceedings of CAADRIA 2001*, University of Sydney, Australia, pp. 39-50.

Maher, M.L., Liew, P-S, Gu, N. and Ding, L. (2004), An Agent Approach to Supporting Collaborative Design in 3D Virtual Worlds, *Automation in Construction*, 14(2), pp. 189-195.

Maher, M.L., Simoff, S., Gu, N. and Lau, K.H. (2000), Designing Virtual Architecture, *Proceedings of CAADRIA 2000*, Singapore, pp. 481-490.

Maher, M.L., Simoff, S., Gu, N., Lau, K.H. (1999), Two Approaches to a Virtual Design Office, *Proceedings of Design Computing on the Net 99*, *International Journal of Design Computing*, 2 (online).

Marcus, A. (1998), Metaphor Designs in User Interfaces, *Journal of Computer Documentation*, 22(2), pp. 43-57.

Morgan, C.L. and Zampi, G. (1995), *Virtual Architecture*, B.T. Batsford, London.

Muller, P., Wonka, P., Haegler, S., Ulmer, A. and Van Gool, L. (2006), Procedural Modeling of Buildings, *ACM Transactions on Graphics*, 25(3), pp. 614-623.

Norberg-Schulz, C. (2000), *Architecture: Presence, Language, Place*, Skira Editore, Milan.

Novak, M. (1991), Liquid Architecture in Cyberspace, in M. Benedikt (ed), *Cyberspace: First Steps*, MIT Press, Cambridge, MA, pp. 225-254.
Puglisi, L.P. (1999), *Hyper Architecture: Spaces in the Electronic Age*, Birkhäuser, Basel, Switzerland.
Radice, B. (1988), *Ettore Sottsass: Design Metaphors*, Rizzoli International Publications. New York.
Relph, E. (1976), *Place and Placelessness*, Pion Limited, London.
Sang, H.L., Jung, H.H., Yoon, T.L. and Tan, Y (2008), Towards Ubiquitous City: Concept, Planning, and Experiences in the Republic of Korea, in Tan, Y., Koray, V. and Scott, B. (eds.), *Knowledge-Based Urban Development: Planning and Applications in the Information Era*, IGI Global, Hershey, PA, pp. 148-169.
Schmitt, G. (1999), *Information Architecture: Basis and Future of CAAD*, Birkhäuser, Basel, Switzerland.
Singhal, S. and Zyda, M. (1999), Networked Virtual Environments: Design and Implementation, ACM Press, New York.
Smith, G., Maher, M.L. and Gero J.S. (2003), Designing 3D Virtual Worlds as a Society of Agents, *Proceedings of CAAD Futures 2003*, Kluwer Academic Publishers, the Netherlands, pp. 105-114.
Steele, F. (1981), *The Sense of Place*, CBI Publishing Company, US.
Stefik, M. (1996), *Internet Dream: Archetypes, Myths, and Metaphors*, MIT Press, Cambridge, MA.
Weber, A, Rufer-Bach, K. and Platel, R. (2007), *Creating Your World: The Official Guide to Advanced Content Creation for Second Life*, Wiley, London.
Weiser, M. (1991), The Computer for the 21st Century, *Scientific American*, 265(3), pp. 94-104.
Wertheim, M. (1999), *The Pearly Gates of Cyberspace: A History of Space from Dante to the Internet*, Doubleday, Sydney, Australia.
Whittaker, J. (2004), *The Cyberspace Handbook*, Routledge, London.
Woolley, B. (1993), *Virtual Worlds: A Journey in Hype and Hyperreality*, Penguin Books, London.