Chapter 1

Introduction

Virtual worlds are networked environments designed using the metaphor of architecture that support various activities online. Designing virtual worlds considers forms and functions of these networked environments as an alternative kind of place design. According to Maher et al (2000), the phenomenon of virtual worlds can have two purposes: a simulation of the physical world or a functional virtual place. As a simulation of the physical world, a virtual world mimics places from the physical world through the use of various digital media. As a functional place, a virtual world develops independently from the physical world by supporting an extended range of online activities. Because of the use of the architectural metaphor virtual worlds may inherit many characteristics from physical built environments. The concept of place provides a way to organise our experience of the world, a world which now is made up of at least two parts: the physical world we are relatively familiar with and various virtual worlds comprised of digital bits.

From a structural perspective, a virtual world can be seen as a composition of the architectural metaphor and various computing entities. Firstly, through the use of metaphor concepts in one domain can be expressed in terms of another (Lakoff and Johnson 1980). The architectural metaphor refers designing virtual worlds to place design in the physical world: a relatively well understood and studied field. This connection forms a consistent basis for adapting knowledge of place design from the physical world for designing virtual worlds. In virtual worlds, the most recognisable effect of the architectural metaphor is the visualisation of the environments. As a result, in most cases these environments are visualised using assemblies of digital architectural models or architecture-like models. Secondly, except for input and output devices, virtual worlds are implemented entirely in computer environments. Therefore, the worlds comprise of basically computing entities which can be flexibly configured and programmed. This flexibility makes it possible to consider virtual world designs in terms of dynamics and autonomy.

The development of the above two structural parts, however, has not been well balanced. Issues that are related to the realisation of the architectural metaphor, such as design analogy, 3D modelling and visualisation, have always been the foci of designing virtual worlds. It was not until very recently that we witnessed some progress being made in the development of computing entities for adaptable, dynamic and other intelligent virtual worlds.

Current designs of virtual worlds are largely static. Typical implementations such as object-oriented virtual worlds (for example, designs using commercial platforms like Active Worlds[1], Blaxxun Platform[2], Second Life[3], Virtools[4], and so on) are constructed through placement and configuration of objects. Each object has an appearance of a 3D model in a virtual world, and

[1] http:// www.activeworlds.com
[2] http://www.blaxxun.com
[3] http:// www.secondlife.com
[4] http:// www.virtools.com

together these models visualise the environments. The objects can then be configured or programmed to have certain behaviours that allow the occupants to interact. Similar to the physical world, such designs are pre-defined prior to their uses. The resultant virtual worlds serve certain purposes but do not take into consideration possible changes to the purposes during their use, changes which often occur when the occupants interact with the environments and with each other. The modification of the virtual worlds may be made by the designers but it is rarely accessible to the virtual world occupants.

This study intends to develop a different kind of virtual world that is dynamically designed and implemented as needed, without being pre-defined prior to the use of the environment. A computational approach using rational design agents is presented. A Generative Design Agent (GDA) model is developed that specifies computational processes for reasoning and designing in virtual worlds. The GDAs serve as personal design agents to the virtual world occupants. Design formalisms for virtual worlds are also addressed in this study through the application of generative design grammars. On one hand, the grammars serve as the generative force to be applied by the GDAs for virtual world design automation. On the other hand, each grammar defines coherent stylistic characterisations shared by the virtual world designs it generates. Our approach enables designing virtual worlds to be dynamic and autonomous, without the legacy of persistent infrastructure like the physical world. The technical outcomes include the GDA model for dynamic designs of virtual worlds, and a generative design grammar framework for developing generative design grammars.

1.1 MOTIVATIONS

The motivations of this study arise from the following evaluation on the current state of virtual world designs.

- Virtual worlds can be dynamically designed as needed: like in the physical world where different places are designed and constructed for specific purposes prior to their use, currently most virtual worlds are static in a sense that the design does not necessarily reflect changing needs during the use of the environment. Compared to the physical world, virtual worlds as assemblies of computing entities are far more flexible and can be designed, implemented and manipulated for different purposes.

- The process of designing and implementing virtual worlds needs to be simplified: the current procedures for virtual world design and implementation are cumbersome and rely heavily on manual inputs. Typical procedures can include 3D modelling and creation using CAD and other digital design tools, data conversion and transfer, and final building, configuration and computer programming using virtual worlds design platforms. These procedures require different computing skills and are essentially time-consuming. It is desirable that the process of designing and implementing virtual worlds is simplified and even automated.

- Virtual world designs should be formalised: currently, there is a lack of well defined design principles and methods for designing virtual worlds. Some virtual worlds are designed and maintained exclusively by experts. Ironically, the occupants who inhabit the environments can rarely make any changes. Other virtual worlds are open to their virtual communities for building, and these novice designs often cause chaos. There is a need to develop design formalisms for virtual worlds. By formalising the virtual world designs, on one hand, design experts can define design languages and further extend the languages for virtual worlds. On the other hand, design novices will be provided with reference and guidance for approaching virtual world designs with quality.

- Interactions between virtual worlds and their occupants can be perceived and supported

differently: this issue is conventionally addressed by Human-Computer Interface (HCI) research whose main focus is to improve the input and output devices of the environments. Therefore, the interactions between the occupants and the virtual worlds can become more intuitive. More recently, researchers provide agencies to virtual worlds. Each agent is able to operate by itself and seeks to achieve its goal. Virtual worlds therefore not only can be passively interacted with, they can also become proactive.

Bearing the above four issues in mind, this study sets out to explore dynamic designs of virtual worlds through computational methods.

1.2 AIMS AND OBJECTIVES

The aim of this study is to establish a computational approach for the development of a different kind of virtual world that is dynamically designed, implemented and manipulated as needed during its use. This computational approach is essentially a rational design agent approach. Rational design agents are intentional, autonomous and capable of designing. Using rational design agents each virtual world occupant can be provided with a personal design agent. The agents will be capable of (1) monitoring the virtual world and the various activities that happen in the world; (2) interpreting the occupants' current needs in the virtual world and the current state of the world based on these observations; (3) hypothesising design goals in order to satisfy these needs; and finally (4) designing and implementing virtual environments, or initiating other changes in the world, according to the design goals, on behalf of the occupants. In this manner, virtual worlds will be dynamically designed, implemented and manipulated as needed for the moment. The process of designing and implementing virtual worlds will also be largely simplified and, in the case of this study, be automated by the design agents. To achieve this aim the following two objectives are set:

- To develop a rational design agent model for dynamic designs of virtual worlds.
- To develop a design formalism that is capable of describing and generating virtual world designs. The design components of these rational design agents for virtual worlds will be supported by the application of this design formalism.

1.3 CONTRIBUTIONS AND SIGNIFICANCE

This study develops and applies the GDA model and generative design grammars for dynamic designs of virtual worlds. The GDA model is a rational design agent model specifically developed for virtual worlds. Generative design grammars as a design formalism are applied by the GDAs to provide virtual world designs. The application of the GDA model and generative design grammars is demonstrated in chapter 6 using a virtual gallery scenario. The contributions of this research are highlighted in terms of the following three aspects:

- The GDA model enables and supports dynamic designs of virtual worlds. Each GDA is specifies to have five computational processes: sensation, interpretation, hypothesising, designing and action. These processes provide a basis that allows design and other domain knowledge to be integrated to the GDAs, which together support reasoning and designing in virtual worlds. GDAs therefore are able to serve as personal design agents to the virtual world occupants. In contrast to other attempts that ascribe behaviours or provide agencies to existing virtual world components, this study associates agencies with virtual world occupants in order to avoid virtual worlds being pre-defined prior to their uses. The concept of GDAs extends our current understandings of designing virtual worlds by considering dynamics and autonomy in addition to 3D modeling and object configuration. The GDA model is presented in Chapter 3.

- A generative design grammar framework is developed which provides guidelines and strategies for developing generative design grammars for virtual worlds. By applying this grammar framework, designers define generative design grammars that produce different design languages for virtual worlds, rather than predefine every detail of all possible virtual world designs. The actual design tasks are carried out by the GDAs during real-time interactions in the virtual world. Each GDA can apply different generative design grammars to produce virtual world designs for different purposes, and with different stylistic characterisations reflecting the GDA's own identity. The concept of generative design grammars is inspired by the notions of shape grammars (Stiny and Gips 1972). The application of a generative design grammar is directed by the GDA's current design goals which reflect the GDA's interpretation of the occupants' needs in the virtual worlds and the state of the worlds for the moment. In such fashion, virtual worlds are dynamically designed and implemented as needed by the GDAs on behalf of the virtual world occupants. The structure of a generative design grammar introduced in Chapter 4 shows how generative design grammars should be developed, and how stylistic characterisations of virtual world designs can be formally defined in terms of visualisation (layout and object design), navigation (the use of way finding aids and hyperlinks), and interaction (object behaviours).

- The generative power of generative design grammars is demonstrated with an example grammar developed for a virtual gallery using a design scenario. The example grammar can be directly reused for designing virtual galleries. The demonstration also shows how a specific grammar is developed by applying the generative design grammar framework. The development of the example grammar provides references to develop other generative design grammars for designing virtual worlds that serve other purposes and capture different stylistic characterisations.

In terms of significance of the research, the development of the GDA model and the generative design grammar framework provides new perspectives to understand and develop virtual worlds.

- In general, there can be two common directions for research that relates to virtual worlds. One looks at the impact of the emergence of virtual worlds on other fields; for example, sociology, education, design, economy and so on. The other aims at enhancing various aspects of existing virtual worlds; for example, 3D modelling and visualisation, visual optimisation, place-making in virtual worlds, navigation in virtual worlds, HCI, interactions and so on, in order to better support activities online. Both directions tend to treat virtual worlds as designed artifacts which have resulted in the virtual domain. This study takes a different approach to challenge how virtual worlds are conventionally designed and implemented, rather than focusing on static virtual world components that have resulted from the design and implementation process.

- Designing virtual worlds as a new area lacks well defined design theories and principles. Current examples may apply design knowledge that exists by drawing an analogy to other design areas like architecture and web design. These references indeed serve as a good starting point. However, this starting point needs to be bypassed somehow in order to fully realise the potentials of virtual worlds and reflect their characteristics. To define principles for a design area requires tremendous inputs of theoretical development and design practice. The generative design grammar framework developed in this study provides a computational approach that can be adopted to start formally defining design languages for virtual worlds.

1.4 THESIS OVERVIEW

1.4.1 Background

Chapter 2 reviews three areas that closely influence the formation of this thesis: designing virtual worlds, agent models and shape grammars. The first part introduces the concept of virtual worlds and provides a historical review of the development of virtual worlds. Topics such as design metaphors and place making in virtual worlds are examined. An evaluation of various virtual world design platforms is also presented. The second part specifically looks at virtual world designs and categorises virtual world designs in terms of their stylistic characterisations. The third part reviews agent computing in general, with a focus on the use of agent models for 3D virtual worlds. The final part introduces the shape grammar algorithm which inspires the development of generative design grammars.

1.4.2 Computational Model of a Generative Design Agent

Chapter 3 presents the GDA model. The five computational processes of the GDA model are sensation, interpretation, hypothesising, designing and action. The chapter first discusses the representations of virtual worlds. These representations are then used to illustrate each computational process of the GDA model. The GDA model is next further analysed in terms of a design model. The chapter ends with a discussion that highlights the advantages and differences of applying the GDA model for dynamic designs of virtual worlds.

1.4.3 A Generative Design Grammar Framework

Chapter 4 singles out the design component of a GDA. The design component of a GDA is supported by the application of a generative design grammar. The first half of the chapter distinguishes generative design grammars from shape grammars, and discusses why generative design grammars as a design formalism are appropriate for virtual worlds. The second half of the chapter presents the generative design grammar framework. The structure of a generative design grammar and the structure of the basic components of a grammar - design rules - are illustrated with examples. At the end of the chapter the characteristics of generative design grammars in general, and issues of applying the generative design grammar framework for developing generative design grammars, are discussed.

1.4.4 An Example Grammar for Dynamic Design of a Virtual Gallery

Chapter 5 illustrates a generative design grammar for the dynamic design of a virtual gallery. This grammar serves as an example to demonstrate the application of the generative design grammar framework for developing generative design grammars. Following the generative design grammar framework, this example grammar is developed to provide different kinds of design rules to address different design aspects of a virtual gallery. The full list of these design rules is provided in Appendix 1.

1.4.5 Design Demonstration: a Virtual Gallery Scenario

Chapter 6 presents a design scenario demonstrating the application of the GDA model and generative design grammars for dynamic designs of virtual worlds. The design scenario is constructed in the context of a virtual gallery for an artist. Different stages of the scenario are used to present various changes that may occur in a virtual gallery; for example, changes of activities, changes of exhibition requirements, changes of visitors, and so on. In the execution of the scenario, the artist is represented as a GDA in the virtual gallery. On behalf of the artist, the GDA applies the example grammar illustrated in Chapter 5, to dynamically provide virtual galley designs as needed in order to address the changes occurring at different stages of the scenario. More details regarding the application of the example grammar, the reasoning of the artist's GDA, and the technical implementation of the scenario are included in Appendix 2.

1.4.6 Discussion and Future Research

In the final chapter, the first half summarises this research and discusses the application of the GDA model and generative design grammars both for dynamically designing virtual worlds and formalising virtual world designs. The refinement of the current research is also discussed. The second half of the chapter presents three possible future extensions of this research. The future extensions focus on the development of multi-GAD virtual worlds and virtual worlds design styles.