

## Chapter 7

### Discussion and Future Research

This research starts with the aim of establishing 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. Two objectives are set up for achieving the aim:

- 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.

The aim and objectives have been achieved. A Generative Design Agent (GDA) approach to dynamic designs of virtual worlds has been developed and presented. The main components of this approach include the GDA model and the generative design grammars framework. The GDA model is a rational design agent model for virtual worlds. The design components of the GDAs are supported by the application of generative design grammars. The development of a specific generative design grammar applies the generative design grammar framework by integrating appropriate design and domain knowledge for implementing the design rules. Different generative design grammars are able to generate virtual world designs for different purposes and with different stylistic characterisations. The application of the generative design grammar framework has been demonstrated through the development of an example grammar illustrated in Chapter 5. The effectiveness of the application of the GDA model and generative design grammars both for dynamic designs of virtual worlds has been demonstrated in Chapter 6 using a design scenario of a virtual gallery.

In the remaining sections, sections 7.1 to 7.3 summarise this research and discuss 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. Finally section 7.4 presents three possible future extensions of this research.

#### 7.1 DYNAMIC DESIGNS OF VIRTUAL WORLDS USING GENERATIVE DESIGN AGENTS

The GDA approach to dynamic designs of virtual worlds is distinctive, and this reflects on the following aspects.

- The GDA approach provides agencies to the virtual world occupants, rather than existing virtual world components like walls, doors, rooms, buildings and so on. GDAs serve as personal design agents to the virtual world occupant and reason, design and act in virtual worlds on behalf of the occupants. Shifting the agencies from existing virtual world components to virtual world occupants frees virtual worlds from being pre-defined. GDAs as rational design agents are applied to dynamically design virtual worlds for

different purposes during the use of the worlds, rather than to reason about and modify existing designs of the virtual worlds.

- The GDA model is especially developed to reason about and design dynamic, non-static virtual worlds, since a GDA perceives the representation of a virtual world in three different views:  $W = W_{\text{ext}} \cup W_{\text{int}} \cup W_{\text{exp}}$ .
- The GDA approach changes the roles of human designers in designing virtual worlds. The use of rational design agents automates the design and implementation processes of virtual worlds. Human designers develop generative design grammars that describe and generate different design languages for the virtual worlds, rather than pre-define every detail of all possible virtual world designs. The GDAs carry out the actual design tasks by applying generative design grammars during the uses of the virtual worlds. Different generative design grammars can be applied to generate virtual world designs for different purposes and with different stylistic characterisations. Using a special set of state labels, the application of a generative design grammar is always directed to meet the GDA's current design goals that are related to designing virtual worlds. In this manner, virtual worlds are dynamically designed, implemented and manipulated as needed for the moment. The GDA approach turns designing virtual worlds into an internal process that occurs inside the worlds and is influenced by the worlds. Previously, the design process was largely controlled by human designers outside the virtual worlds.

## **7.2 FORMALISING VIRTUAL WORLD DESIGNS USING GENERATIVE DESIGN GRAMMARS**

Generative design grammars not only support the GDA's design components but also provide a computational approach that can be adopted to start formally defining design languages for virtual worlds. By applying the generative grammar framework, different generative design grammars can be developed through the integration of relevant design and domain knowledge. As a design formalism, generative design grammars describe and generate languages of virtual world designs that capture specific stylistic characterisations. The four sets of design rules (layout rules, object placement rules, navigation rules and interaction rules) of a generative design grammar are applied in different stages to handle visual/spatial as well as non-visual/spatial problems in designing virtual worlds. These different sets of design rules are developed to control the way virtual world designs are composed, according to specific design considerations, in terms of syntax (visualisation: layout and object design), and semantics (navigation and interaction). In this manner, virtual world designs are generated with stylistic characterisations in mind. As shown in Chapter 6 Figure 6.14, designs generated by a generative design grammar share certain stylistic characterisations in terms of visualisation, navigation and interaction. These shared stylistic characterisations provide a sense of coherency to all design instances.

## **7.3 DISCUSSION AND REFINEMENT**

When applying the GDA approach to practice for designing virtual worlds various issues are open for discussion.

### **7.3.1 Dynamic Virtual World Designs vs. Static Virtual World Designs**

This research establishes the GDA approach for the development of a different kind of virtual world that is dynamically designed, implemented and manipulated as needed. This kind of virtual world responds to possible changes to the purposes of the world during its use and contrasts to other virtual worlds that are static and pre-defined. Virtual worlds in the context of this study are essentially functional online places, the GDA approach is applicable to and desirable for most

virtual worlds that are to be developed as functional online places supporting a wide range of activities. In these virtual worlds, changes to the purposes of the worlds often occur when the occupants interact with the worlds and with each other. However, it is not intended to replace all static virtual world designs with dynamic designs. Static virtual world designs are efficient in cases where the purposes of the virtual worlds are unchanged or rarely require changes; for example, virtual worlds developed for simulation purposes (in particular those simulate a specific physical built environment) and virtual worlds developed for communication purposes (online chatting and video conferencing) only.

### **7.3.2 Architecture of the Moment or Architecture of Confusion**

Applying the GDA model and generative design grammars, virtual worlds can be perceived as a kind of architecture of the moment, since the worlds are dynamically designed as needed during their use. The quality of being dynamic and autonomous is desirable. However, abrupt changes of the virtual worlds without careful consideration may easily confuse the virtual world occupants.

To avoid generating virtual world designs with confusion, firstly, we may make use of generative design grammars to provide a sense of coherency to different designs of the same virtual world, by applying the same generative design grammar or different generative design grammars that capture similar stylistic characterisations.

Secondly, the knowledge of the GDA for interpretation and hypothesising should be carefully selected and integrated to the GDA, since the application of a generative design grammar is always directed to meet the current design goals hypothesised by the GDA that reflect its interpretation regarding the current needs of the virtual world occupants and the current state of the virtual world. Without correct interpretation and hypothesising the generated virtual world designs are not only confusing but also useless and disturbing. It is especially subtle for the GDA to correctly interpret the current needs of the virtual world occupants. A series of questions may arise from here; for example, How should a GDA interpret, by receiving instructions from the occupants explicitly, by guessing the occupants' intentions based on their activities or from its learning experience? How precise can the interpretation be? What kind of interpretation should lead to changes of virtual world designs? This series of questions should be further studied. When dealing with this issue the virtual gallery design scenario presented in Chapter 6 has tried to achieve a sense of balance:

- For changes that are considered as common in the virtual gallery (such as the presence of the artist and the visitors and the increase/decrease of visitor number) the artist's GDA will actively interpret. The GDA may then design and act if it is necessary.
- For changes that are considered as less common or more complicated in the virtual gallery (such as the needs for meeting/conference venue and the artist's decision to change the content of the exhibitions) the artist's GDA will wait for explicit instructions. The GDA may then design and act if it is necessary.

Finally, it is also suggested that the virtual world occupants should be informed about the changes made to the environments they inhabit; for example, in the virtual gallery design scenario the artist's and the visitors are always notified beforehand about the changes to be made to the areas that they currently inhabit.

### **7.3.3 Useful Designs vs. Surprising Designs**

Generative design grammars both adopt the descriptive and generative nature of shape grammars, and modify some of the original shape grammar properties to suit the purpose of designing virtual worlds. As discussed in Chapter 4, generative design grammars are restricted. The application of a generative design grammar is controllable and predictable to a certain extent so that the generated designs can be useful to serve as functional online places for the purpose of this study. The purpose of generating virtual world designs that meet the GDAs' design goals has been given

higher priority over the urge of maintaining emergence and ambiguity for generative design grammar applications. However, for the virtual worlds that have less demand on functional aspects generative design grammars may be developed to be less restricted. Therefore, more diverse and interesting designs may be generated.

#### **7.3.4 Refinement of the Current Research**

To demonstrate the application of the GDA model and generative design grammars both for dynamic designs of virtual worlds, an example grammar for the dynamic design of a virtual gallery has been developed and a virtual gallery design scenario has been constructed and implemented. As discussed in the end of Chapters 5 and 6, the example grammar and the design scenario both have limitations. In the future studies, these limitations will be re-examined to refine the current research:

- To consider parametric design for the dynamic design of the virtual gallery.
- To enrich the design rules especially object placement rules of the example grammar so that more interesting virtual gallery designs may be generated.
- To expand the example grammar and the design scenario to examine the above issues discussed in sections 7.3.1 to 7.3.3.
- To research on other virtual world design platforms<sup>1</sup> in order to develop a more desirable environment for dynamic designs of virtual worlds.

### **7.4 FUTURE RESEARCH**

Beside the refinement of the current research, the GDA approach to dynamic designs of virtual worlds can be enhanced from three future extensions. They are the quality control of virtual world designs (section 7.4.1), the agent communication in virtual worlds (section 7.4.2), and design styles of virtual worlds (section 7.4.3).

#### **7.4.1 Quality Control of Virtual World Designs**

The virtual world designs produced by a generative design grammar are currently determined by the design knowledge and other domain knowledge that are integrated in the grammar in the forms of the four sets of design rules. The current GDA model requires the foreknowledge to be defined and integrated by human designers. In future studies, more dynamic alternatives can be explored; for example, a process of learning can be integrated in the GDA model to enable the GDA to learn from its past design experiences, and use these experiences to update and enrich its generative design grammar.

As to design evaluation, currently the application of a generative design grammar is directed by the use of states labels to generate a virtual world design that meets the GDA's current design goals. The implementation of the virtual world design triggers the GDA to start a new cycle of reasoning and designing. The cycle is recursive until the generated design satisfies the GDA's current design goals. The assessment of the design is based on the GDA's own criteria, which are integrated as the foreknowledge. In future studies, this internal evaluation process can be enriched by including selected external inputs; for example, mechanisms can be applied to collect feedback from the virtual world occupants for design assessment. The use of external evaluation mechanisms means that less design constraints need to be placed in the generative design grammar for directing the grammar application. Therefore, the generative design grammar can

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<sup>1</sup> The design scenario has been demonstrated in a virtual world developed using Active Worlds (<http://www.activeworlds.com>). Appendix 2 includes more information regarding the technical implementation of the design scenario.

become less restricted. This change can potentially increase the generative power of the grammar to produce more diverse and interesting designs. The external evaluation mechanisms can also be used to direct and access the learning process of the GDA.

#### **7.4.2 Agent Communication in Designing Virtual Worlds**

In the current study, the development of the GDA model focuses on detailing the five computational processes which are specifically developed for a GDA to reason, design and act in virtual worlds. Designing virtual worlds so far is explored as individual acts of the GDAs. Currently in a shared virtual world represented by multiple GDA, when a design problem arises it is assumed that a dominant GDA will reason, design and act on behalf of the occupants. However, the reasoning mechanism of the GDA model enables each GDA to reason about the virtual worlds as well as other elements in the worlds, including other GDAs. This means that the GDA model is able to accommodate agent communication. With agent communication, virtual worlds can be designed collaboratively by multiple GDAs. The significance of studying designing virtual worlds as collaborative acts reflects on the following aspects:

- To consider designing virtual worlds as collaborative acts by multiple GDAs increases the complexity, and broadens the inputs, for the generation of virtual world designs. Design decision making therefore can be less linear. The generated virtual world designs should more closely reflect the common needs and characteristics of the virtual community, and therefore better serve and represent the community.
- Agents are especially suitable for engineering complex, distributed systems (Jennings 2000). By providing the GDAs with the capability of collaborative designing, a multi-GDA virtual world becomes a distributed system for self-designing. Each GDA contributes to the current design of the virtual world to support their common activities of the moment. The virtual world acts as a kind of spatial components of its occupants, evolving together with the virtual community.
- During collaborative designing, participated GDAs may each have a different generative design grammar that produces a different design language for virtual worlds. This leads to the study of virtual world design styles in a social scale. The issues regarding virtual world design styles are discussed in the next section.

In summary, agent communication is able to bring complexity and depth to dynamic designs of virtual worlds. However, the increase of complexity may also lead to the increase of challenges or conflicts in the design process. For example, a concern would be the possible delay of design generation due to the negotiation among different GDAs.

#### **7.4.3 Design Styles of Virtual Worlds**

A generative design grammar formally describes and generates virtual world designs through the four sets of design rules. The generated designs share certain stylistic characterisations in terms of visualisation, navigation and interaction. The categorisation of the design rules provides a base to expand and detail these current categories for defining virtual world design styles.

In virtual worlds that are collaboratively designed by multiple GDAs, design styles can be studied at a different scale. In a multi-GDA virtual world, different GDAs may have different generative design grammars since different people may have different design preferences. Each design grammar can generate a unique language of designs in a particular style. During collaborative designing, this can lead to the study of virtual world design styles in a social scale. Various research questions can arise from this future extension; for example, Can individual design styles influence each other? How can different design styles transform and morph to serve common interests? Is there a common design style shared by the virtual community, and What is the effect of this common style on the virtual worlds and their occupants?