

Chapter 5

An Example Grammar for Dynamic Design of a Virtual Gallery

Chapter 5 presents 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 for virtual worlds. Following the generative design grammar framework, the example grammar is developed to have four sets of design rules (layout rules, object placement rules, navigation rules and interaction rules) to address different design aspects of the virtual gallery.

The first section of the chapter briefly introduces the concepts and development of virtual galleries in general, and describes the virtual gallery that is dynamically designed, for which the example grammar is developed. The rest of the chapter illustrates the example grammar by highlighting the four sets of design rules that comprise the example grammar. The application of the example grammar will be demonstrated in Chapter 6 using a design scenario, and a detailed list of all elements of the example grammar is attached in Appendix 1.

5.1 DYNAMIC DESIGN OF A VIRTUAL GALLERY

Virtual galleries are typical examples that should be dynamically designed, in stead of pre-defined, because various changes often occur in the environments during their uses; for example, changes of activities, changes of exhibition requirements, changes of visitors, and so on. To design a virtual gallery using a generative design grammar enables different designs of the gallery being dynamically generated for different moments, in order to accommodate the changes.

5.1.1 Galleries: From Physical to Virtual

Historically speaking, galleries and museums were not initially made for the public. Nowadays, they form essential parts of public spaces in our society. Galleries and museums have gradually gone beyond the original purposes of artwork display and appreciation to provide public spaces supporting culture exchange, art education and social gathering. To design a gallery or a museum therefore is not only to design exhibition spaces, it is also to study the formation of community, the establishment of social values and the interactions among artists, visitors, and artworks.

The development of galleries and museums is always closely influenced by the evolution of our society, such as the advancement of economics, politics, science and technology. For example, the majority of galleries and museums are currently open to the public and serve their interests. However, most major galleries and museums are in fact based on private collections, which were established long before the formation of these public institutions (Newhouse 1998). This clear shift from private spaces to public spaces was mainly due to the modern movements of economics and politics in our society. The emergence of new technologies had a great impact on the development of galleries and museums:

- New technologies provoke new art forms. They inspire the artists, offer new topics and

perspectives for art thinking, and provide new design tools and media for art creation. For example, the invention of moving images at the beginning of the 20th century was enriched by the development of different media throughout the century. This eventually led to the wide recognition of the idea of media art in the 90s (Schwarz 1997).

- New technologies enable new designs of exhibition spaces. There are at least two purposes for developing new designs of exhibition spaces. Firstly, advanced building materials and techniques can improve the quality of exhibition spaces by providing, for example, better lighting and ventilation. Secondly, new designs of exhibition spaces are needed in order to accommodate the emergent art forms, for example, the Centre for Art and Media Karlsruhe in Germany is specifically designed for displaying media art.

More recently, with the advancement of digital and networked technologies, galleries and museums have become ready for the next reformation from physical to virtual. Responding to the development and application of these technologies, galleries and museums have started to use internet environments to display digital replicas from their collections, attracting a much wider range of visitors.

- A virtual gallery provides easy access and flexible viewing. People can visit the gallery without concern for time and geographical distance.
- Exhibitions in a virtual gallery are not constrained by the gallery's physical capacity. For example, the virtual Getty Museum¹ provides access to all its collections, which is rarely the case for any gallery in the physical world.

The majority of virtual galleries rely heavily on their physical counterparts. Some serve as electronic databases of digital replicas based on existing collections from the physical world. Others use digital media to simulate galleries from the physical world in order to provide virtual tours. These virtual galleries well serve the purpose of supplementing existing galleries in the physical world. However, they do not reflect the full potential of virtual galleries. The future of virtual galleries should not be limited to the expansion of the electronic databases or the refinement of the 3D simulations.

- A virtual gallery can provide exhibition spaces for digital and network-based interactive artworks which cannot be accommodated by a gallery in the physical world.
- A virtual gallery can provide a different kind of experience. Unlike conventional galleries, which provide largely passive viewing, a virtual gallery as a networked environment can be flexibly programmed to be reactive and even proactive. The traditional relations among the artists, the artworks, the visitors and the exhibition spaces can be further challenged.
- Similar ideas have been presented in many conceptual designs; for example, the Virtual Guggenheim Museum² and various entries for the New Italian Blood Virtual Museum Competition³. However, in order to realise these ideas, many design and technical issues need to be resolved.

5.1.2 A Virtual Gallery Dynamically Designed for an Artist

Based on the above discussion, the example grammar is developed for a virtual gallery that builds on the concept of a dynamic and proactive networked environment, rather than the simulation of a gallery from the physical world.

¹ <http://www.getty.edu>

² http://www.guggenheim.org/exhibitions/virtual/virtual_museum.html

³ <http://www.newitalianblood.com/virtualmuseum>

The virtual gallery is designed for an artist. It has two main purposes. The first purpose of the gallery is to provide exhibition spaces to display the artist's exhibitions. The second purpose is to provide alternative spaces supporting other activities of the artist in the virtual gallery; for example, art creation, collaboration, meeting, lecture and other public functions. The artist is provided with agencies in the virtual world, represented as a Generative Design Agent (GDA). The GDA reasons, designs and acts on behalf of the artist in the virtual world. The design component of the artist's GDA is supported by the application of the example grammar.

A conventional virtual gallery may provide similar kinds of exhibitions and alternative spaces, supporting similar kinds of activities, but the difference is that our virtual gallery is dynamically designed as needed. Similar to galleries in the physical world, the design of a conventional virtual gallery and the arrangement of its exhibitions are pre-defined prior to its use. The resultant virtual gallery serves certain specific purposes but does not take into consideration possible changes to the purposes during its use, changes which often occur when the artist and visitors interact with each other and with the gallery. In our virtual gallery, different designs of the gallery are dynamically generated, and different arrangements of the exhibitions are dynamically provided to respond to various changes occurred during the use of the gallery. Such changes can be initiated from the following sources.

- From the artist: changes of exhibition requirements, changes of activities and changes of design preferences.
- From the visitors: changes of activities and changes of group dynamics.

The visual forms of the virtual gallery provide an awareness of locations by defining a 3D ambient environment. The virtual gallery may display digital replicas of the artist's artworks from the physical world, as well as digital or network-based exhibitions that cannot be displayed in galleries from the physical world. The exhibitions are arranged and allocated in gallery areas for visiting rather than being integrated into an electronic database or a set of web pages for browsing. Visitors are represented as avatars in the virtual gallery, providing an awareness of self and others. Through these avatars, visitors are able to explore the virtual gallery and move from area to area to participate in different activities online.

5.2 THE EXAMPLE GRAMMAR OVERVIEW

Applying the generative design grammar framework, our example grammar is developed to have four sets of design rules which are applied in the sequence of layout rules, object placement rules, navigation rules and interaction rules. Each set of these design rules corresponds to a design phase of the virtual gallery.

- The application of layout rules provides layouts of the virtual gallery by allocating different areas. Each area has a purpose for accommodating certain intended activities in the virtual gallery.
- The application of object placement rules configures each area of the gallery with certain purposeful objects which provide visual boundaries of the area and visual cues for supporting the intended activities.
- The application of navigation rules specifies navigation methods in the gallery by using way finding aids and hyperlinks for assisting the visitors' navigation among different areas, and their visits in the exhibitions.
- The application of interaction rules ascribes behaviours to selected objects in each area of the gallery. Therefore, exhibitions and other intended activities can function.

Each design rule is developed by following the general structure of a design rule (4.4) presented in Chapter 4 section 4.3.

$$\text{LHO} + \text{sL} \rightarrow \text{RHO} \quad (4.4)$$

By applying the example grammar, different designs of the virtual gallery can be dynamically generated as needed. The corpus of designs generated by the grammar share similar stylistic characterisations in terms of visualisation, navigation and interaction determined by the application of layout rules, object placement rules, navigation rules and interaction rules.

5.2.1 Design Composition of a Virtual Gallery

As discussed in Chapter 4 section 4.1.1, a virtual world design can be viewed as “objects in relation”. A design of the virtual gallery, generated by the example grammar, can be analysed as a composition of virtual world objects and their properties. Using the objects and their properties as design elements, the four sets of design rules compose different aspects of the design. First of all, in terms of the purposes of the virtual gallery, the application of layout rules allocates various areas of the virtual gallery. Each area has a purpose for accommodating certain intended activities in the gallery. Changes to purposes may require the creation of new areas, adjustment and replacement of existing areas, or demolition of existing areas. For the example grammar, the virtual gallery can have five different kinds of purposeful areas. They are combined and allocated as needed. These purposeful areas are introduced in section 5.3.

Further, each purposeful area of the virtual gallery is supplemented with visual boundaries, visual cues, way finding aids and hyperlinks, and object behaviours for supporting the intended activities through the application of object placement rules, navigation rules and interaction rules. These design elements are introduced accordingly in sections 5.4 to 5.6.

In summary, the application of the example grammar dynamically composes designs of the virtual gallery by adding/subtracting different virtual world objects and their properties. Figure 5.1 is the visualisation of a virtual gallery design that is composed by applying the example grammar, using specific sets of virtual world objects and their properties developed for this grammar. Later in this chapter, for the presentation of the example grammar, each set of design rules is grouped into additive rules and subtractive rules. These two groups of design rules accommodate the two kinds of operations: addition and subtraction.

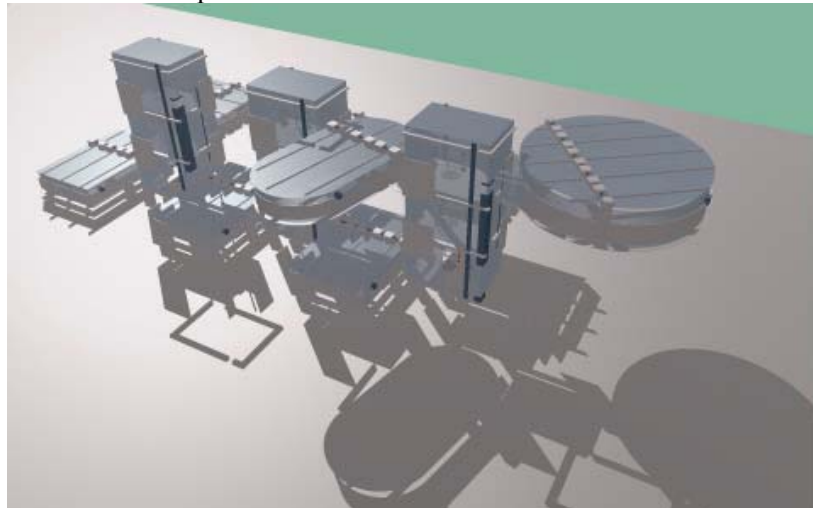


Figure 5.1. The visualisation of a virtual gallery design generated by the example grammar.

5.2.2 Meeting Design Goals

The virtual gallery is designed for specific purposes. The design generated by the example grammar needs to meet the GDA's current design goals in order to support the intended activities in the virtual gallery for the moment. As discussed in Chapter 4 section 4.4, generative design grammars connect to the GDAs' design goals via the use of state labels. As shown above in the general structure of a design rule (4.4), each rule is associated with a state label *sL* which represents a specific design context of designing the virtual gallery. In order for a design rule to be fired, besides the LHO of the design rule needed to be found in the virtual gallery, the design context represented by the state label of the rule also needs to be related to the GDA's current design goals. In this manner, the application of the example grammar is directed to generate a virtual gallery design that meets the GDA's current design goals.

State labels used in the example grammar are developed to represent a set of typical design contexts, limited by a virtual gallery scenario to be demonstrated in Chapter 6. The state labels used in each set of the design rules, and the conditions for matching the labels, are discussed accordingly in sections 5.3.1, 5.4.1, 5.5.1 and 5.6.1.

5.3 LAYOUT RULES

Layout rules are the first set of design rules to be fired in the application of the example grammar. There are 15 additive layout rules and 17 subtractive layout rules in total. Layout rules generate layouts of the virtual gallery by allocating different areas. The virtual gallery can have five different areas: the reception area, the gallery 1 area (standard or expanded), the gallery 2 area (standard or expanded), the artist's personal studio area, and the multi-function area. The following introduces these five areas and presents the symbols that represent them in layout rules.

- A reception area provides visitors with information regarding the virtual gallery and the exhibitions. It also provides access to other areas of the virtual gallery. The virtual gallery can have multiple reception areas. They play a vital role for supporting the circulation of the virtual gallery. Any other area of the virtual gallery always connects to a reception area. A reception area has three levels: it connects to a gallery 1 area from floor 1, to a gallery 2 area from floor 2, and to the artist's personal studio area and the multi-function area from floor 3.
- In the example grammar, in order to limit the number of design rules for implementation, the artist has a maximum of two exhibitions at a time. A gallery 1 area is arranged for exhibition 1, and a gallery 2 area is arranged for exhibition 2. The exhibitions may display digital replicas of the artist's artworks from the physical world, as well as digital or network-based artworks that cannot be displayed in galleries from the physical world. In this example grammar, these two kinds of exhibition items are called digital images and interactive installations. A gallery 1 area and a gallery 2 area each can have two sizes: a standard area and an expanded area for displaying exhibitions with different scales. The virtual gallery can have multiple gallery 1 areas and multiple gallery 2 areas as each area is designed for a limited number of visitors. The maximum number of visitors in a gallery area is set to be 10 for the comfort of the visitors' viewing and the ease of their movements in the area. In the future, these restrictions can be addressed with the use of a parametric grammar.
- The artist's personal studio area is private; it is for the artist and invited guests only. The artist uses the area to create artworks, to collaborate with other artists, and to meet with invited guests.

sL=mI: the multi-function area is needed for exhibiting visually large-scale installations.

State labels used in subtractive layout rules are:

- sL=g1-: a standard/expanded gallery 1 area is redundant.
- sL=g2-: a standard/expanded gallery 2 area is redundant.
- sL=r-: a reception area is redundant.
- sL=gR1: an expanded gallery 1 area needs to be reduced.
- sL=gR2: an expanded gallery 2 area needs to be reduced.
- sL=g-: the initial standard gallery area is not needed.
- sL=m-: the multi-function area is not needed.
- sL=cS: the current design of the virtual gallery is to be used as a static design (the virtual gallery stops being dynamically designed).

A state label represents a specific design context. The label is matched if the design context it represents is related to the GDA's current design goals in terms of designing the virtual gallery. As described in Chapter 3 section 3.3.2, the GDA's design goals can be represented by the expected function O_{exp}^F and the expected behaviours O_{exp}^B .

For example, to match sL=S, firstly in the process of interpretation, the artist's GDA interprets that:

- The artist is present in the virtual gallery (A_{int}).
- There is no studio space available in the virtual gallery for the artist (O_{int}).

Next in the process of hypothesising, the GDA hypothesises the following design goal based on the above interpretations:

- $O_{exp}^F=S$ (a personal studio area for the artist is needed in the virtual gallery).

With the design goal $O_{exp}^F=S$ being hypothesised, sL=S is matched. Other state labels used in layout rules of the example grammar and their matching conditions are given in Appendix 1. A design rule is selected for application if the LHO of the rule is found, and the state labels of the rule are matched.

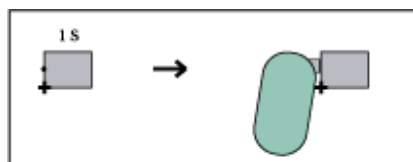
5.3.2 Additive Layout Rules

The application of additive layout rules adds different areas for generating the layout of the virtual gallery. The 15 additive layout rules developed for the example grammar are listed below. An additive layout rule implies that the LHO of the rule can be replaced by the RHO of the rule, where an additional area is added, given the following conditions:

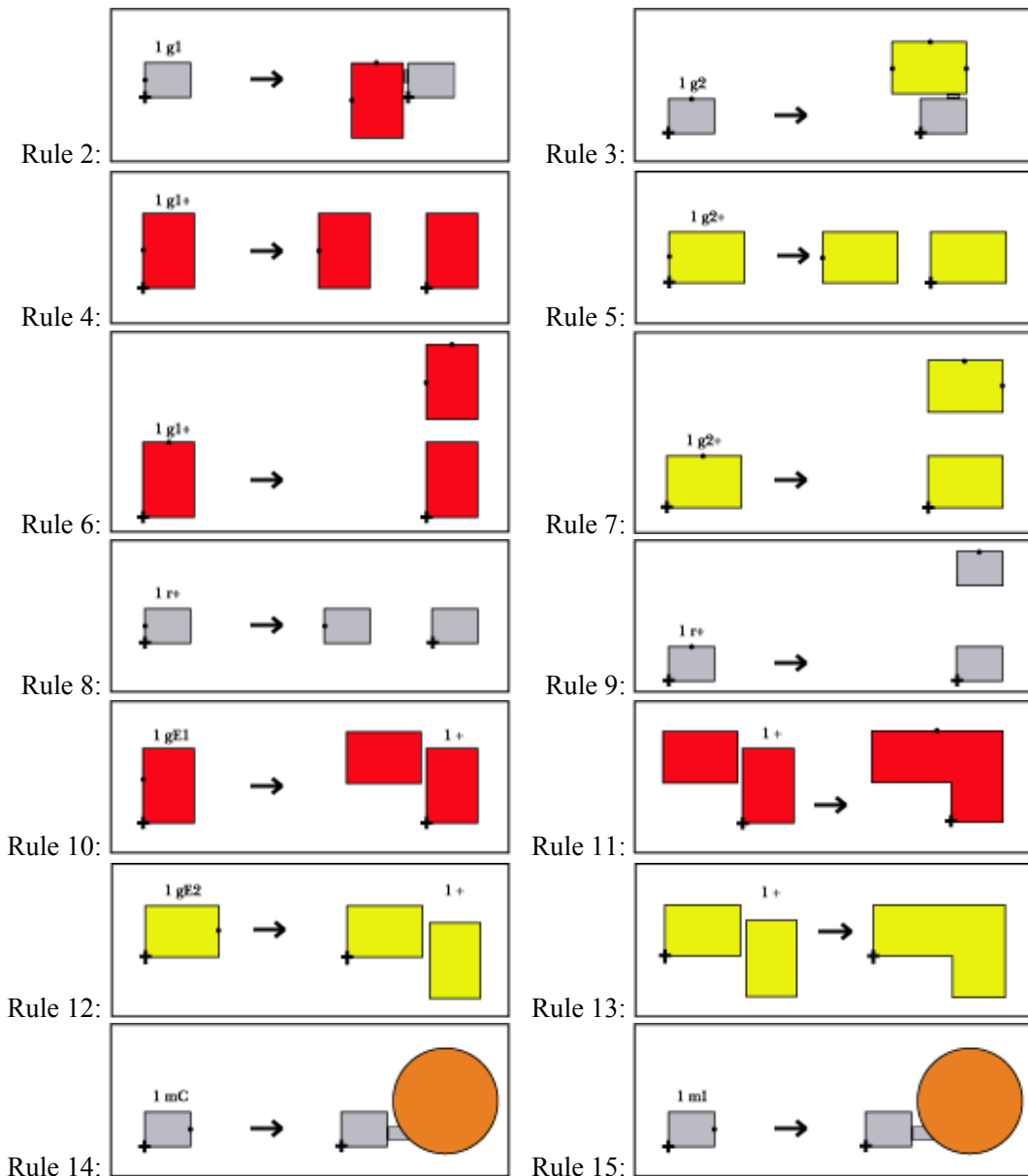
- LHO of the rule is recognised in the virtual gallery, and
- sL of the rule is matched.

For example, additive layout rule 1 shows that the artist's personal studio area can be added spatially adjacent to a reception area if:

- The reception area is found in the virtual gallery, and
- sL=S is matched.



Rule 1:



Among these 15 additive layout rules:

- Rules 1, 2, 3, 14 and 15 are applied to add the artist's personal studio area, the initial standard gallery areas and the multi-function area accordingly, adjacent to a reception area.
- Rules 4 to 7 are applied to add additional gallery areas. As mentioned earlier, for the example grammar, each gallery area is designed for a limited number of visitors, for the comfort of the visitors' viewing and the ease of their movements. Once the limit is reached, an additional gallery area will be added for future visitors.
- For the example grammar, a standard gallery area can also be expanded to accommodate more exhibition items. Rules 10 to 13 are developed for this purpose.

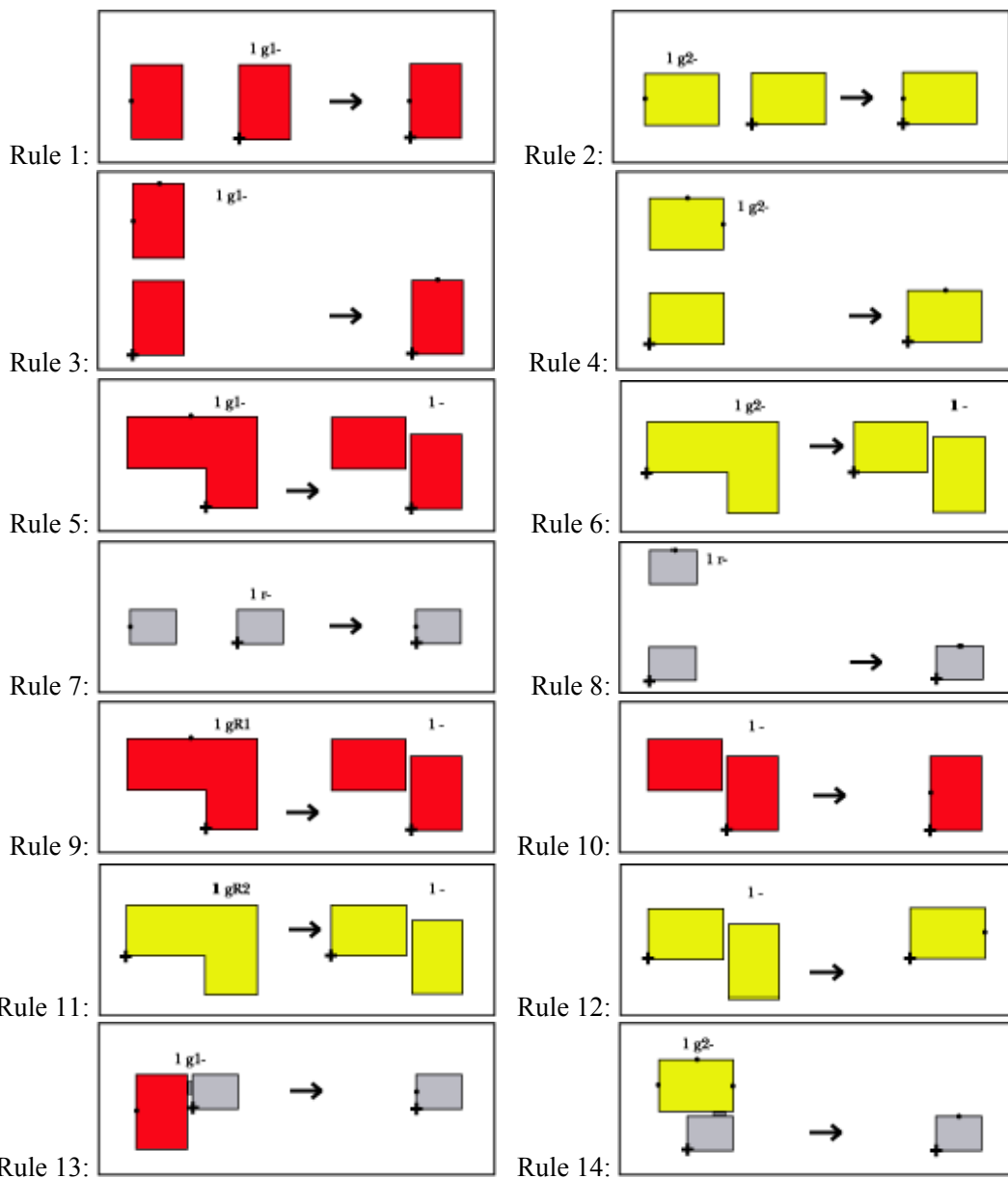
5.3.3 Subtractive Layout Rules

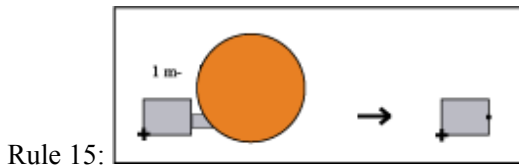
The application of subtractive layout rules subtracts different areas for generating the layout of the virtual gallery. The 17 subtractive layout rules developed for the example grammar are listed below. A subtractive layout rule implies that the LHO of the rule can be replaced by the RHO of the rule, where one or more areas are subtracted, given the following conditions:

- LHO of the rule is recognised in the virtual gallery, and
- sL of the rule is matched.

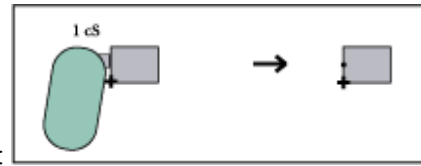
For example, subtractive layout rule 16 shows that the artist's personal studio area can be subtracted if:

- The artist's personal studio area is adjacent to a reception area in the virtual gallery, and
- sL=cS is matched.

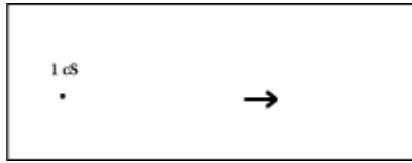




Rule 15:



Rule 16:



Rule 17:

Among these 17 subtractive layout rules:

- Subtractive layout rules 13 to 16 are applied to subtract the initial standard gallery areas, the multi-function area and the artist's personal studio area accordingly.
- As shown in additive layout rules, additional gallery areas can be added to accommodate more visitors. Once these areas become redundant, subtractive layout rules 1 to 6 can be applied to subtract these additional gallery areas.
- Additive layout rules 10 to 13 enable standard gallery areas to be expanded to accommodate more exhibition items. On the contrary, subtractive layout rules 9 to 12 reduce expanded gallery areas to standard gallery areas.
- Subtractive layout rule 17 is a termination rule. Spatial labels can be removed by applying this rule so that the application is terminated.

5.4 OBJECT PLACEMENT RULES

Object placement rules are the second set of design rules to be fired in the application of the example grammar. There are 24 additive placement rules and 9 subtractive placement rules in total. After a layout of the virtual gallery is produced, object placement rules further configure each area to provide visual boundaries of the area and visual cues for supporting various intended activities through object placements. The objects appear in the virtual gallery as various 3D models. Besides the symbols introduced in section 5.3, additional symbols and illustrations used in object placement rules are illustrated in Figures 5.2 to 5.10.

Figures 5.2 to 5.5 illustrate the visual boundaries of different areas in the virtual gallery. For the example grammar, it is assumed that the artist prefers cold-colour scheme for the design of the virtual gallery. The following visual boundaries are illustrated using a cold-colour scheme.

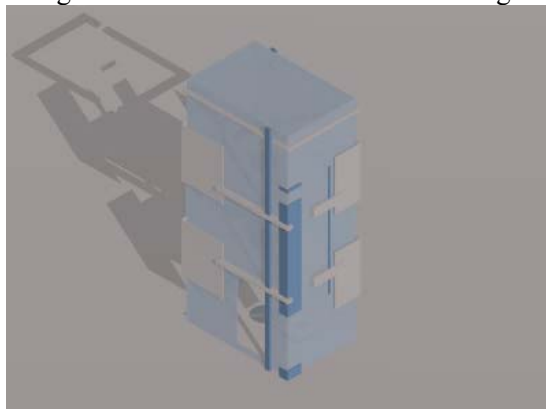


Figure 5.2. The visual boundaries of a reception area.

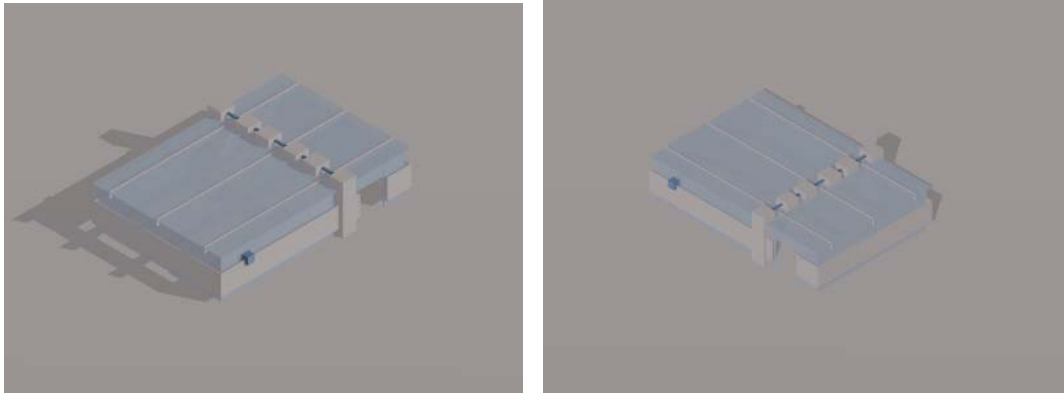


Figure 5.3. The visual boundaries of a standard gallery 1 area (left) and a standard gallery 2 area (right).

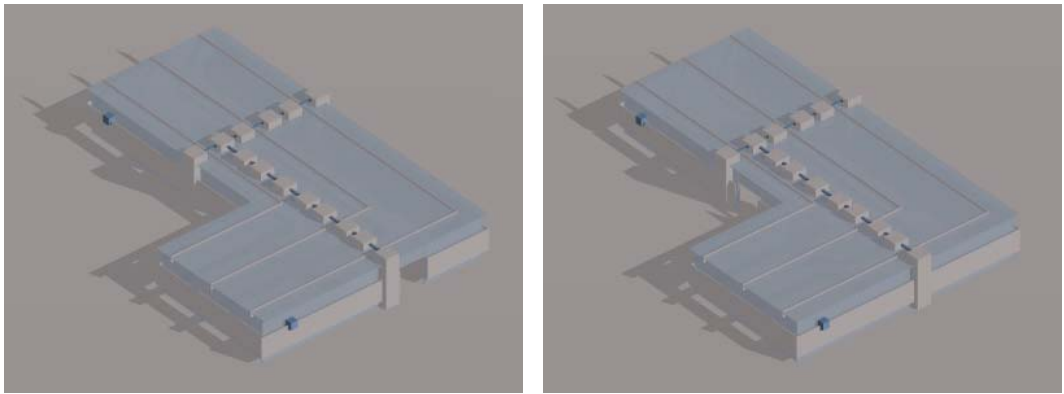


Figure 5.4. The visual boundaries of an expanded gallery 1 area (left) and an expanded gallery 2 area (right).

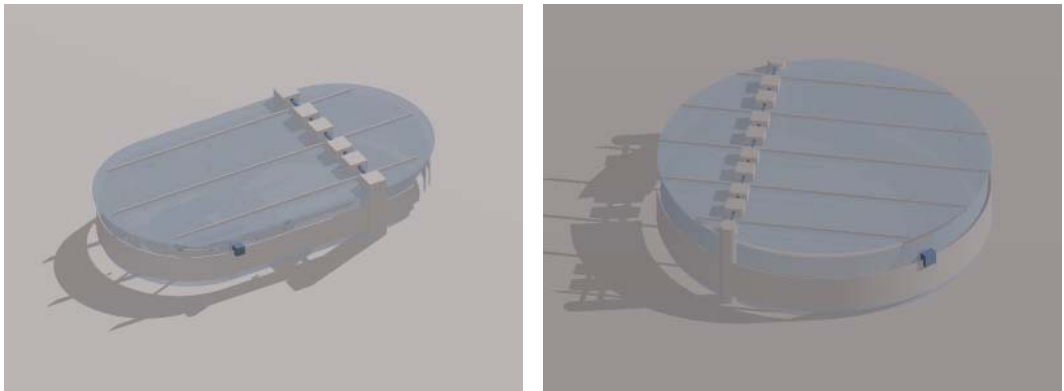


Figure 5.5. The visual boundaries of the artist's personal studio area (left) and the multi-function area (right).

Figures 5.6 to 5.10 show various purposeful objects that are placed inside the virtual gallery. As shown in Figure 5.6, a helpdesk is placed in a reception area to provide information about the virtual gallery and the exhibitions. The information is visualised by the warm-colour cubes placed on the frame-like partition behind the desk. Another frame-like partition is also placed in a reception area for storing hyperlink portals for assisting navigation. The portals are visualised by the warm-colour cubes. By rolling over these cubes, the destinations of the hyperlink portals will

be shown, and by clicking on the cubes, the visitors will be transported to different designated locations in the virtual gallery.

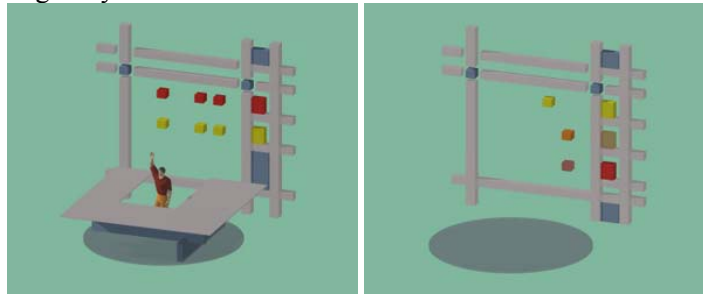


Figure 5.6. A helpdesk (left) and a frame-like partition with hyperlink portals (right) in a reception area.

Figure 5.7 shows different objects that are used to arrange the gallery areas and the multi-function area for exhibition purposes.

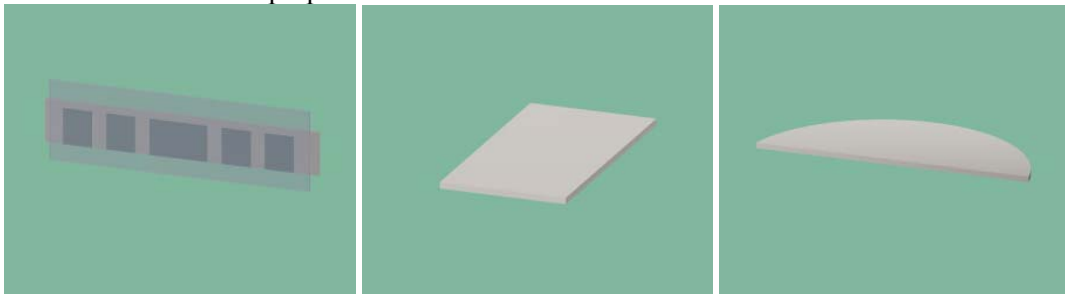


Figure 5.7. A partition for displaying digital images (left), two different stands for displaying interactive installations (middle and right)

In the artist's personal studio area, digital tools and information visualised by warm-colour cubes are stored on the frame-like partitions. Figure 5.8 illustrates three different kinds of partitions used for such purposes. The rest of the symbols and illustrations used in object placement rules are illustrated in Figures 5.9 and 5.10.

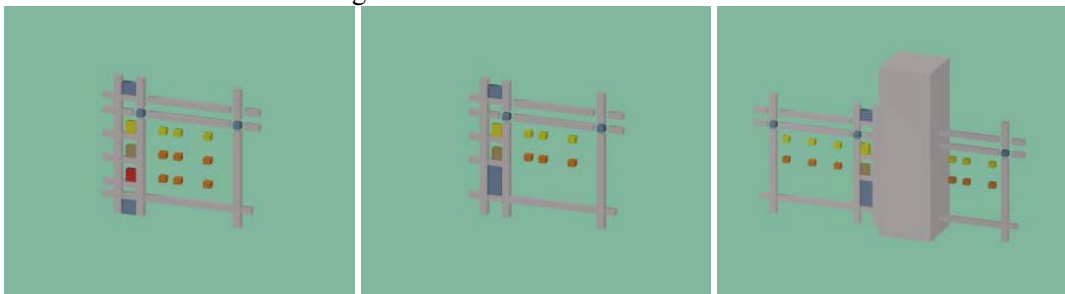


Figure 5.8. Frame-like partitions used in the artist's personal studio area for storage purposes.

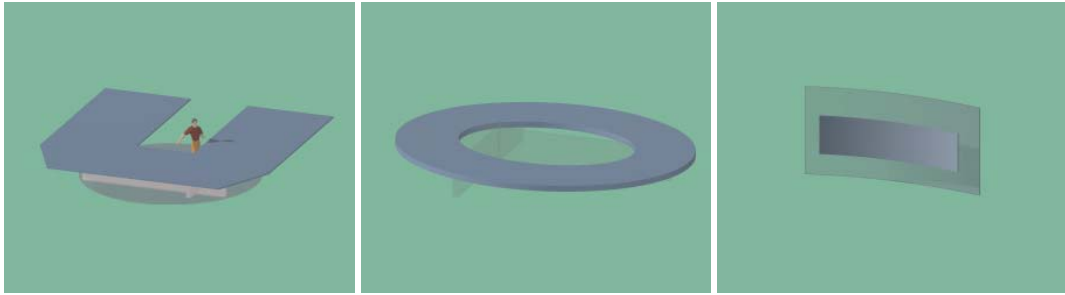


Figure 5.9. A working desk for the artist (left), a meeting table (middle) and a presentation screen (right).

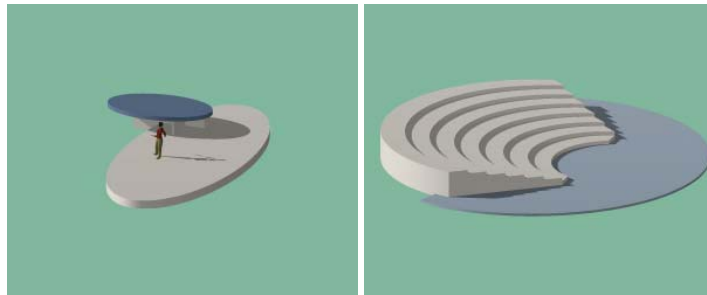


Figure 5.10. Conference facilities: a podium (left) and an auditorium (right).

5.4.1 State Labels

For the example grammar, the state labels developed for object placement rules can be roughly divided into two groups: state label 2 and state labels used in additive placement rules. Subtractive placement rules share the same group of state labels, defined earlier in section 5.3.1, for subtractive layout rules.

sL=2 is used in all object placement rules indicating that they are the second set of design rules to be fired in the application of the example grammar.

State labels used in additive placement rules are:

- sL=cC: to apply a cold-colour scheme for the interior of the virtual gallery.
- sL=gIM1: to arrange a gallery area for displaying digital images using configuration 1.
- sL=gIM2: to arrange a gallery area for displaying digital images using configuration 2.
- sL=gIM3: to arrange a gallery area for displaying digital images using configuration 3.
- sL=gIM4: to arrange a gallery area for displaying digital images using configuration 4.
- sL=gIS1: to arrange a gallery area for displaying interactive installations using configuration 1.
- sL=gIS2: to arrange a gallery area for displaying interactive installations using configuration 2.
- sL=gIMS: to arrange a gallery area for displaying both digital images and interactive installations.
- sL=mS: to configure a meeting area in the artist's personal studio area.
- sL=mMc: to arrange the multi-function area as a conference venue.
- sL=mMi: to arrange the multi-function area for exhibiting visually large-scale installations.

A state label represents a specific design context. The label is matched if the design context it represents is related to the GDA's current design goals in terms of designing the virtual gallery.

As described in Chapter 3 section 3.3.2, the GDA's design goals can be represented by the expected function O_{exp}^F and the expected behaviours O_{exp}^B .

For example, to match $sL=mS$, firstly in the process of interpretation, the artist's GDA interprets that:

- The artist requests a meeting venue for a small group of participants (A_{int} or E_{int}).
- The virtual gallery has no meeting facility (O_{int}).

Next in the process of hypothesising, the GDA hypothesises the following design goal based on the above interpretations:

- $O_{exp}^F=mS$ (to configure a meeting area in the artist's personal studio area).

With the design goal $O_{exp}^F=mS$ being hypothesised, $sL=mS$ is matched. Other state labels used in object placement rules of the example grammar and their matching conditions are given in Appendix 1. A design rule is selected for application if the LHO of the rule is found, and the state labels of the rule are matched.

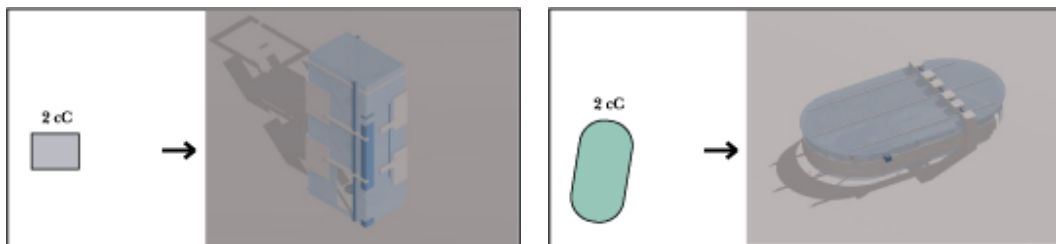
5.4.2 Additive Placement Rules

Two kinds of additive placement rules are developed for the example grammar. The first kind is rather straight forward. They provide the 2D layout of the virtual gallery with 3D objects. The 7 additive placement rules of such a kind are listed below. An additive placement rule of the first kind implies that the LHO of the rule (the layout of an area) can be replaced by the RHO of the rule, where relevant 3D objects are provided to define visual boundaries and specify purposeful objects for the area in the virtual gallery, given the following conditions:

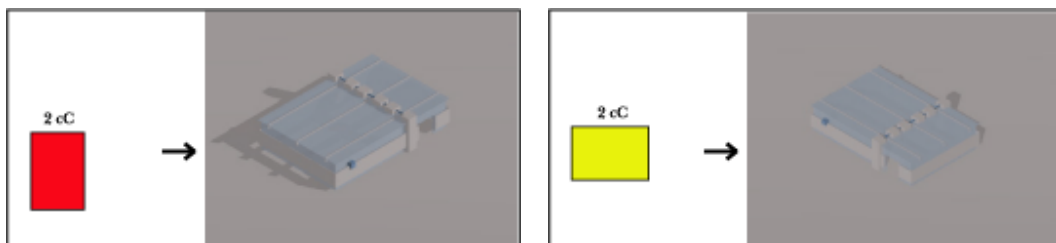
- LHO of the rule is recognised in the virtual gallery, and
- sL of the rule is matched.

For example, additive placement rule 3 shows that a standard gallery 1 area can be provided with relevant 3D objects, to define visual boundaries, and specify purposeful objects for the area if:

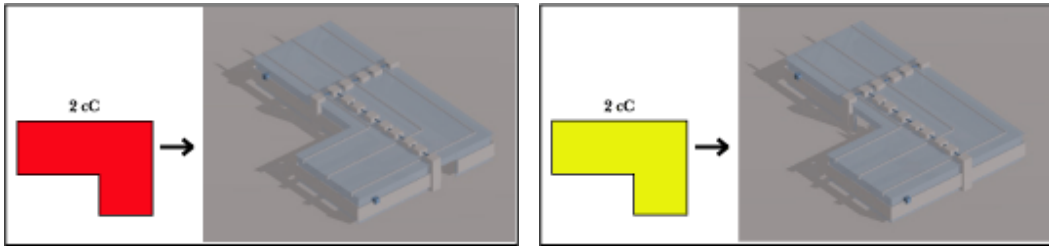
- The layout of a standard gallery 1 area is found in the virtual gallery, and
- $sL=cC$ is matched.



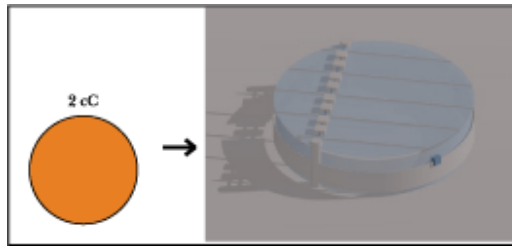
Additive placement rule 1 (left) and 2 (right).



Additive placement rule 3 (left) and 4 (right).



Additive placement rule 5 (left) and 6 (right).



Additive placement rule 7.

Figures 5.11 to 5.14 show the interior of each area in the virtual gallery after additive placement rules 1 to 7 are applied.

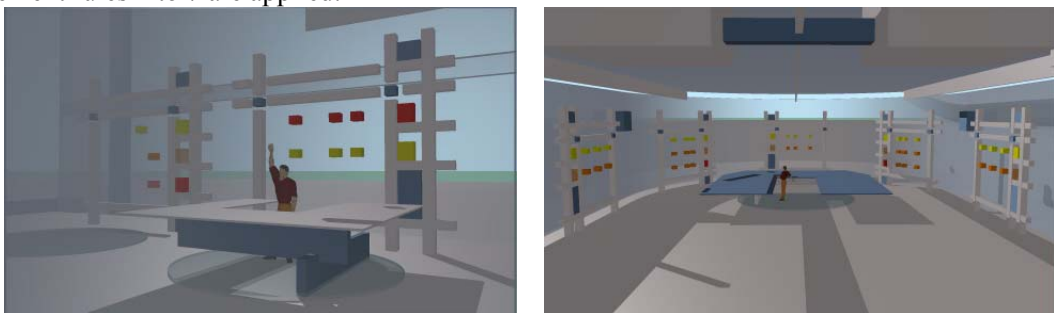


Figure 5.11. Interior views of a reception area (left) and the artist's personal studio area (right).

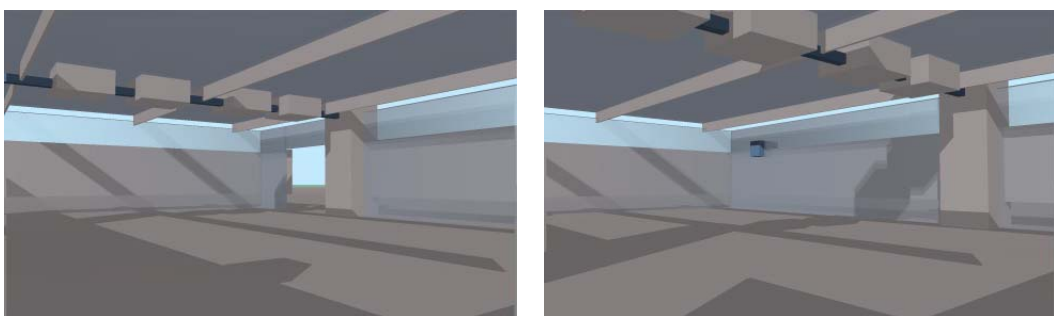


Figure 5.12. Interior views of a standard gallery 1 area (left) and a standard gallery 2 area (right).

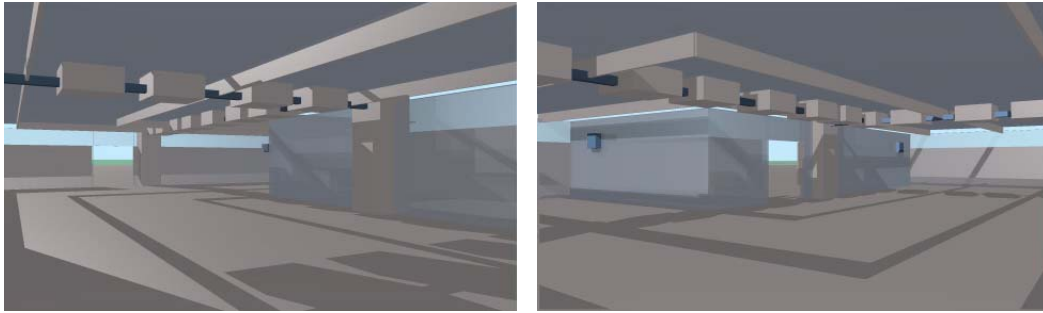


Figure 5.13. Interior views of an expanded gallery 1 area (left) and an expanded gallery 2 area (right)

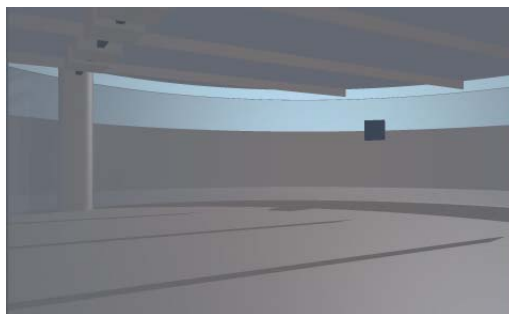


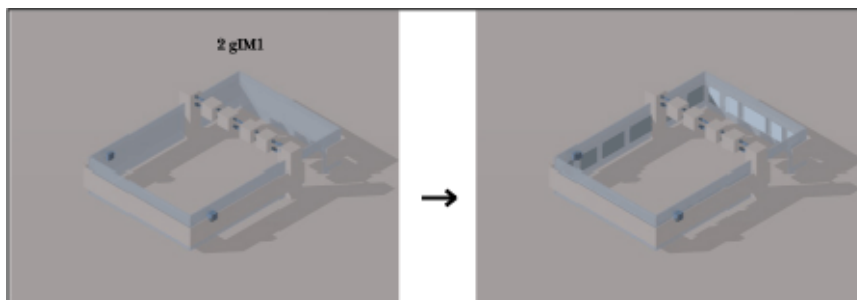
Figure 5.14. An interior view of the multi-function area.

The second kind of additive placement rules further arrange each area for different purposes. They are illustrated below from rules 8 to 24. In these illustrations, the roof of each area is removed in order to show the interior of each area.

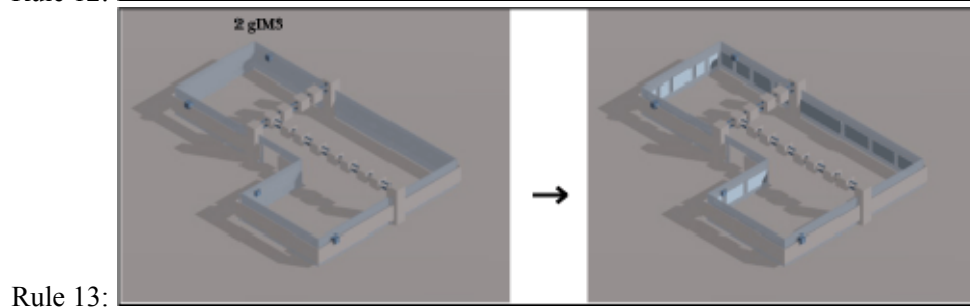
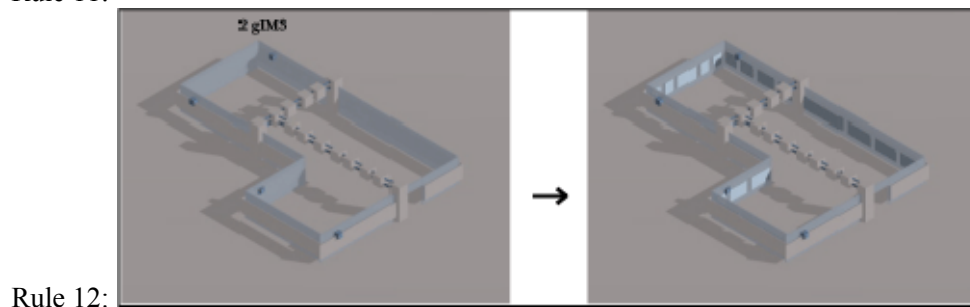
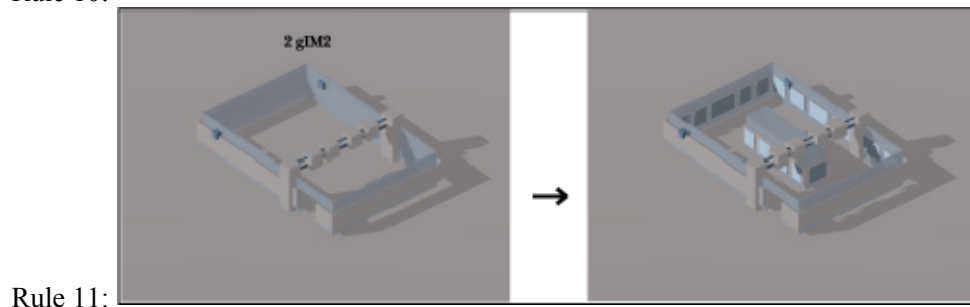
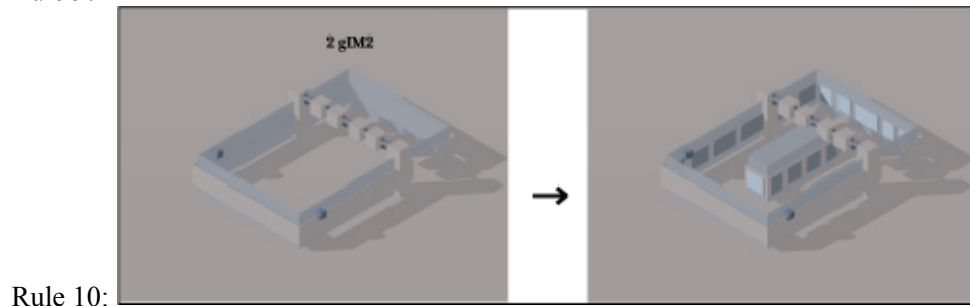
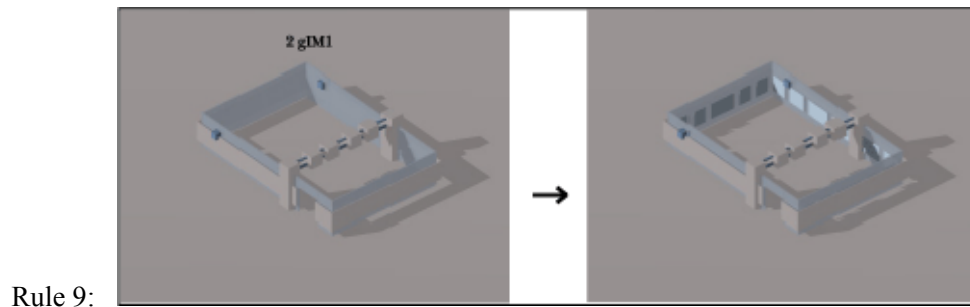
Rules 8 to 21 are applied to arrange the gallery areas for different exhibitions. As stated earlier, the exhibitions in the virtual gallery may display digital replicas of the artist's artworks from the physical world, as well as digital or network-based exhibitions that cannot be displayed in galleries from the physical world. For the example grammar, the two kinds of exhibition items that the virtual gallery accommodates are digital images and interactive installations. Digital images are rendered on the surfaces of digital picture frame objects. Interactive installations are assemblies of objects with behaviours that can be interacted with in the virtual gallery.

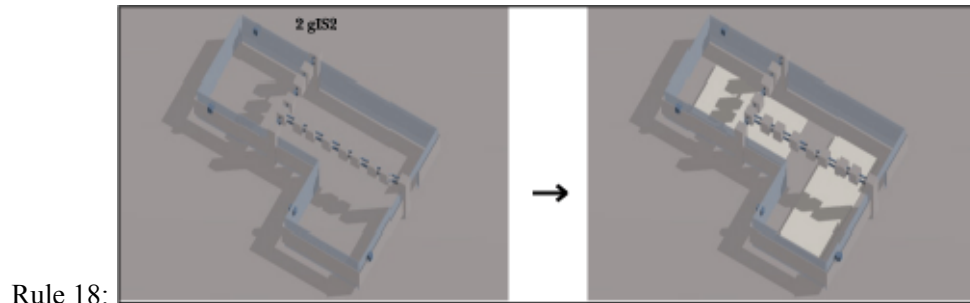
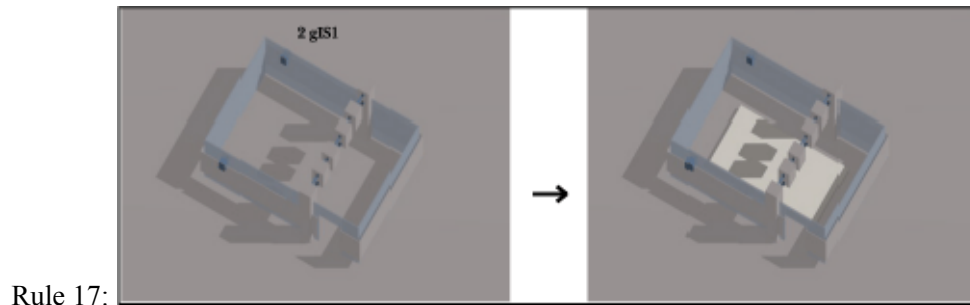
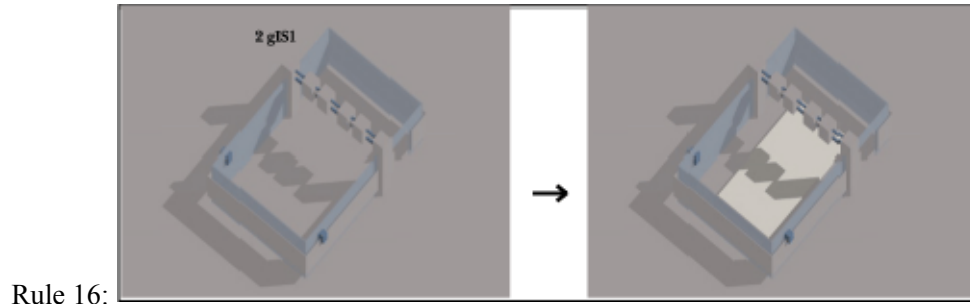
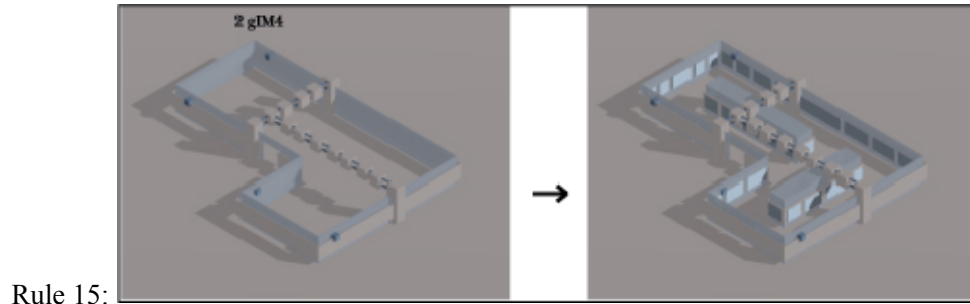
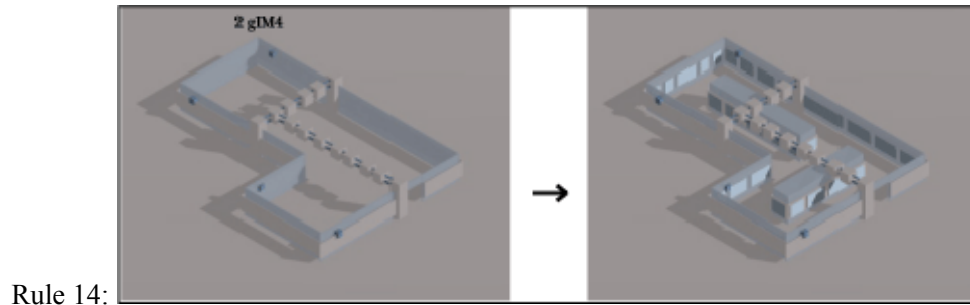
The following rules provide seven different configurations to arrange gallery areas for exhibitions containing different items and in different scales. For example, additive placement rule 8 shows that a standard gallery 1 area can be arranged for displaying digital images using configuration 1 if:

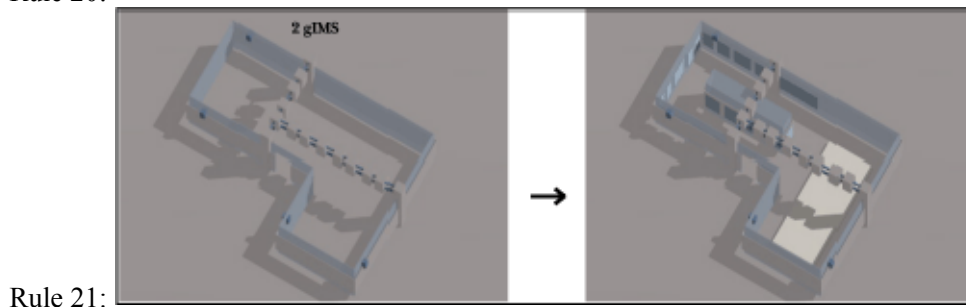
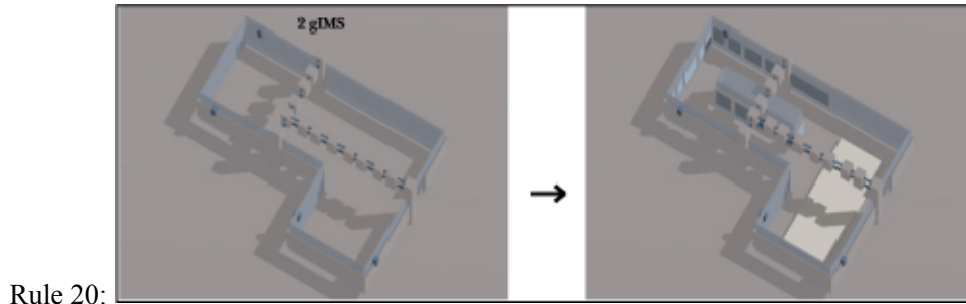
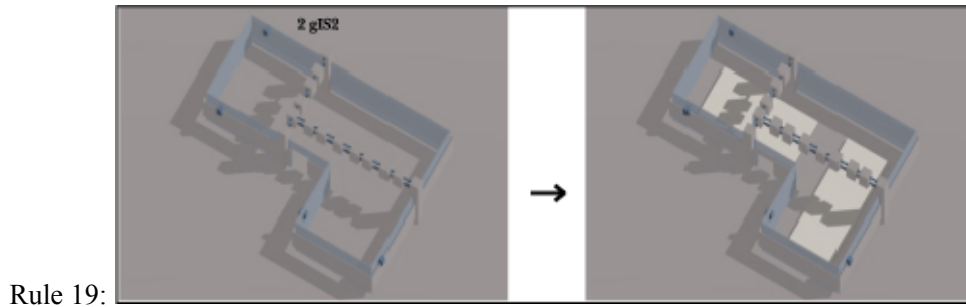
- A standard gallery 1 area is found in the virtual gallery, and
- $sL=gIM1$ is matched.



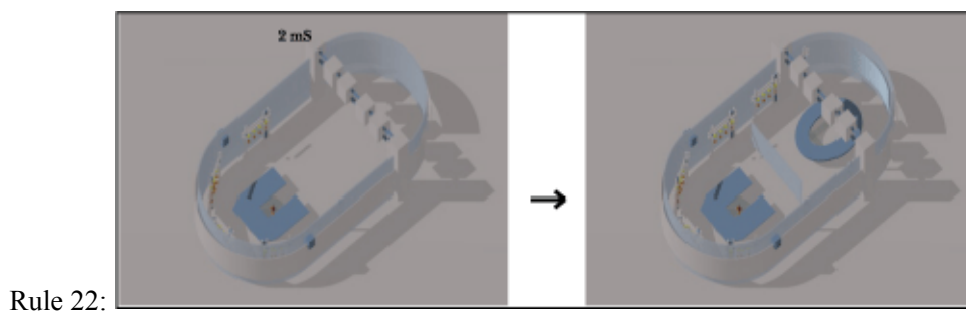
Rule 8:

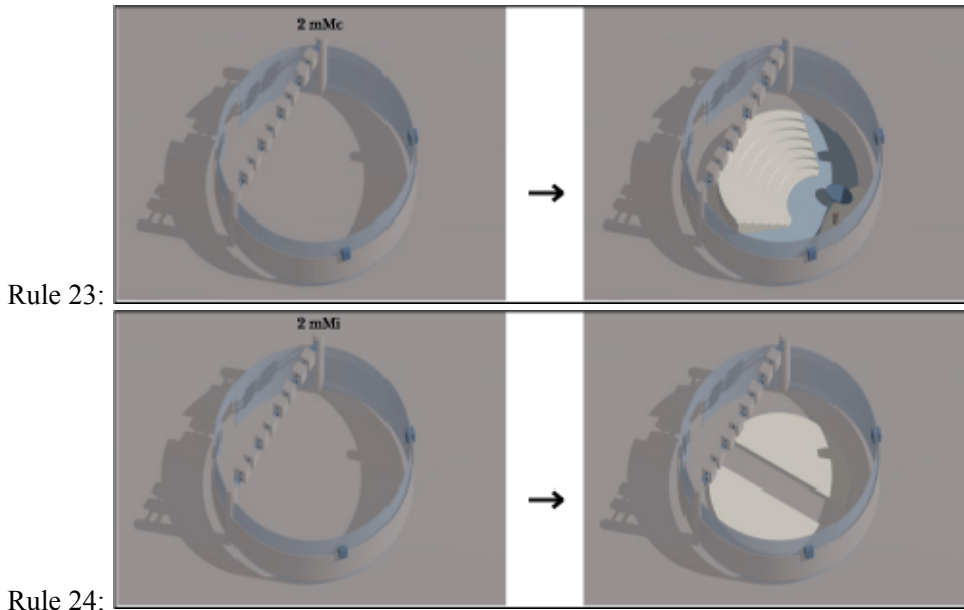






Additive placement rule 22 is applied to arrange a meeting area inside the artist's personal studio area. Additive placement rules 23 and 24 are applied to arrange the multi-function area. Rule 23 arranges the area as a conference venue for various public events serving a large crowd of participants. Rule 24 arranges the area for exhibiting visually large-scale installations.





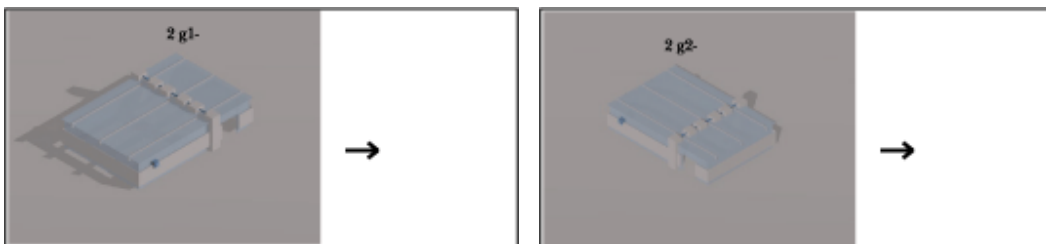
5.4.3 Subtractive Placement Rules

Subtractive placement rules are closely related to the subtractive layout rules. They are directed by the same group of state labels introduced in section 5.3.1. Subtractive spatial placement rules remove visual boundaries and purposeful objects from each area of the virtual gallery. The 9 subtractive placement rules developed for the example grammar are listed below. A subtractive placement rule implies that the LHO of the rule can be replaced by the RHO of the rule, where an area of the virtual gallery is removed, given the following conditions:

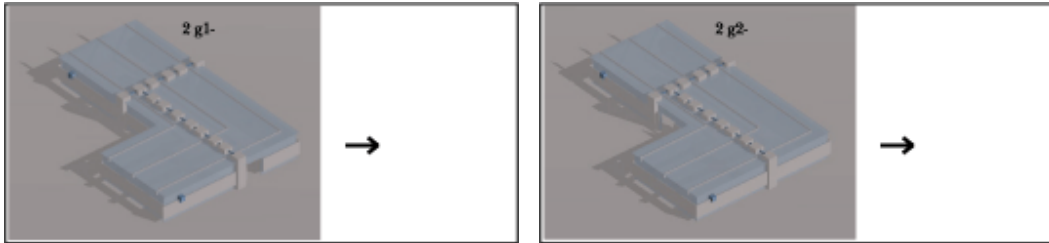
- LHO of the rule is recognised in the virtual gallery, and
- sL of the rule is matched.

For example, subtractive placement rule 8 shows that the artist's personal studio area can be removed if:

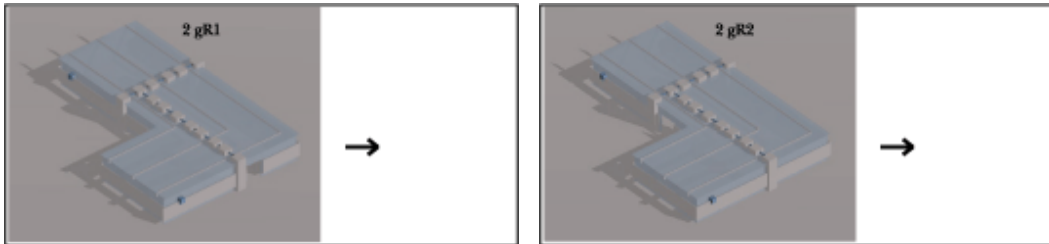
- The artist's personal studio area is adjacent to a reception area in the virtual gallery, and
- $sL=cS$ is matched.



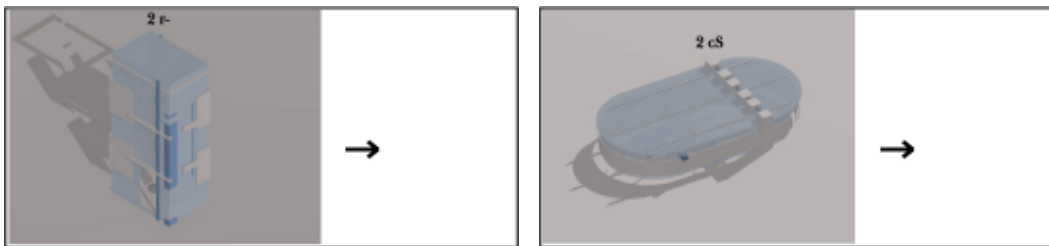
Subtractive placement rule 1 (left) and 2 (right).



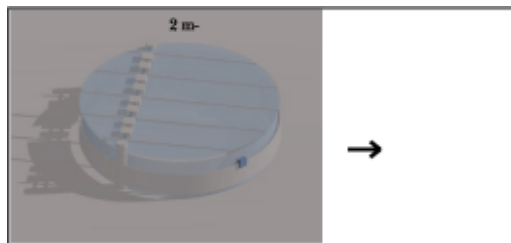
Subtractive placement rule 3 (left) and 4 (right).



Subtractive placement rule 5 (left) and 6 (right).



Subtractive placement rule 7 (left) and 8 (right).



Subtractive placement rule 9.

5.5 NAVIGATION RULES

Navigation rules are the third set of design rules to be fired in the application of the example grammar after layout rules and object placement rules. There are 23 additive navigation rules and 6 subtractive navigation rules in total. Navigation rules provide way finding aids and hyperlinks in the virtual gallery to assist the visitors' navigation among different areas and their visits in the exhibitions.








For the example grammar, the main navigation method for short-distance travel in the virtual gallery is through "walking" by the avatars. The main navigation method for long-distance travel in the virtual gallery is through the use of hyperlinks. These two main methods are enriched to include the following guidelines.

- Any gallery area, the artist's personal studio, or the multi-function area is always spatially adjacent to a reception area, connected via openings.

- The virtual gallery can have multiple reception areas in order to connect with all other areas of the gallery. Any two reception areas are accessible to each other via hyperlink portals (teleport⁴).
- A reception area has three levels: it connects to a gallery 1 area from floor 1, to a gallery 2 area from floor 2, and to the artist's personal studio area and the multi-function area from floor 3. Any two floors of a reception area are accessible to each other via hyperlink portals (warp⁴).
- A path is laid between two spatially adjacent areas connected via openings for directing visitors.
- Paths are laid in each gallery area for guiding visitors in the exhibition.

Based on these guidelines, it is noted that the reception areas serve as nodes for the circulation in the virtual gallery. For example, a design of the virtual gallery may comprise a standard gallery 1 area, a standard gallery 2 area and the artist's personal studio area, all connected to a reception area. If a visitor intends to reach gallery 2 from gallery 1, his/her avatar first walks to floor 1 of the reception area by following the path laid between gallery 1 and the reception area. From floor 1 of the reception area, the avatar warps to floor 2 of the reception area where gallery 2 is spatially connected. The avatar then follows the path to reach gallery 2.

Besides the symbols that have been introduced in the earlier sections, additional symbols are used in navigation rules.

-  or : an opening to connect two spatially adjacent areas.
- : a pair of hyperlink portals that teleports GDAs/avatars between any two locations in the virtual gallery. In the example grammar, this kind of hyperlink portal is used in different reception areas of the virtual gallery.
- : a pair of hyperlink portals that warps GDAs/avatars between any two locations in the virtual gallery. In this example grammar, this kind of hyperlink portal is used in different floors of a reception area.
- : a path laid between two spatially adjacent areas for directing visitors from one area to the other.
- : a path laid in a gallery area for guiding visitors in an exhibition.
-  and : any two different floors of a reception area.

5.5.1 State Labels

Navigation rules share some of the state labels, defined earlier in section 5.4.1, for object placement rules. The only states label specifically developed for navigation rules is state label 3.

sL=3 is used in all navigation rules indicating they are the third set of design rules to be fired in the application of the example grammar.

5.5.2 Additive Navigation Rules

The application of additive navigation rules adds way finding aids and hyperlinks to the generated design of the virtual gallery. Like most virtual world objects, way finding aids and hyperlinks appear as 3D models in the virtual gallery. However, for the ease of presentation, navigation rules are illustrated in 2D plan view. The 23 additive navigation rules developed for the example grammar are listed below. An additive navigation rule implies that a part of the generated design

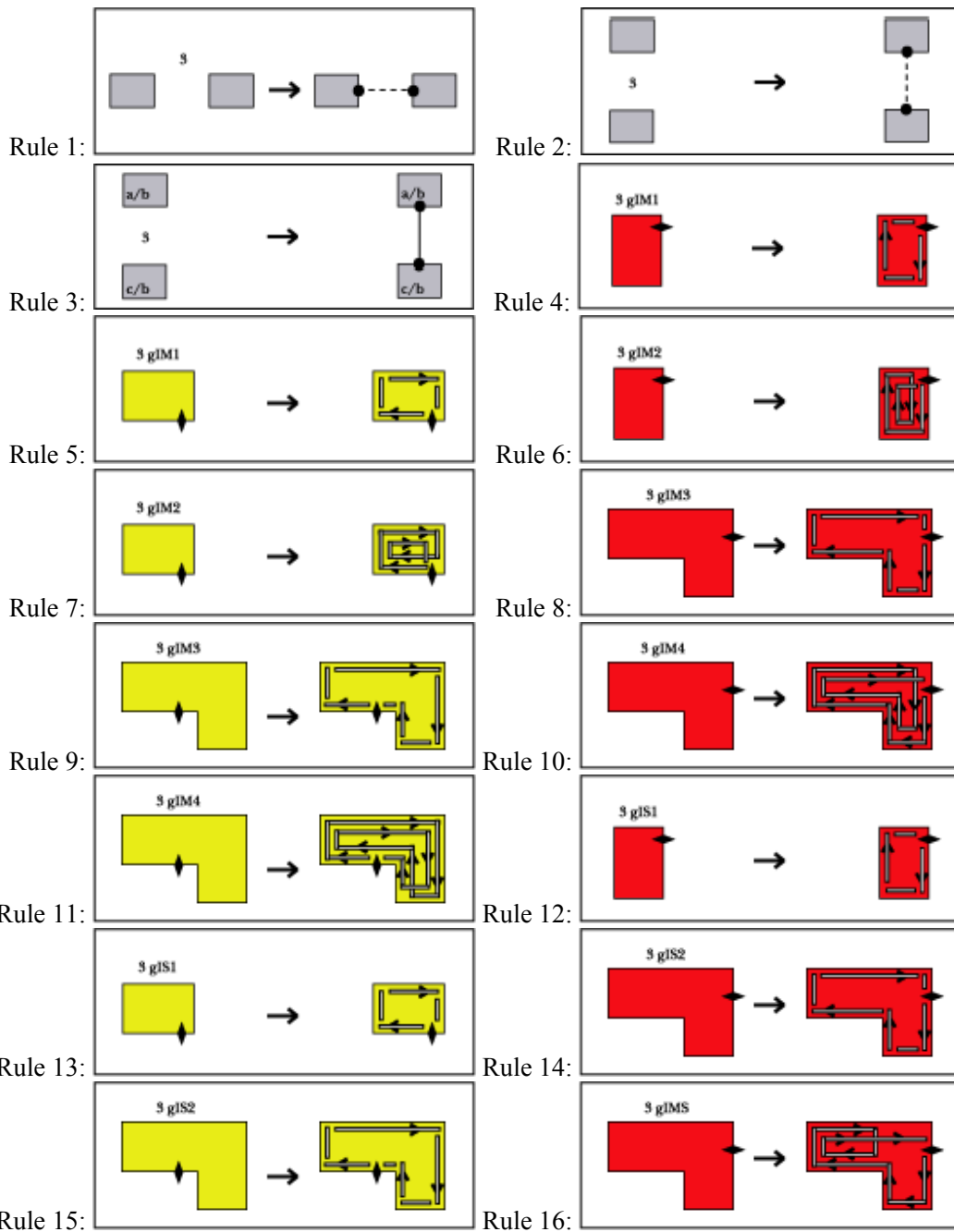
⁴ The difference between teleport and warp portals is discussed in Chapter 4 section 4.3.3.

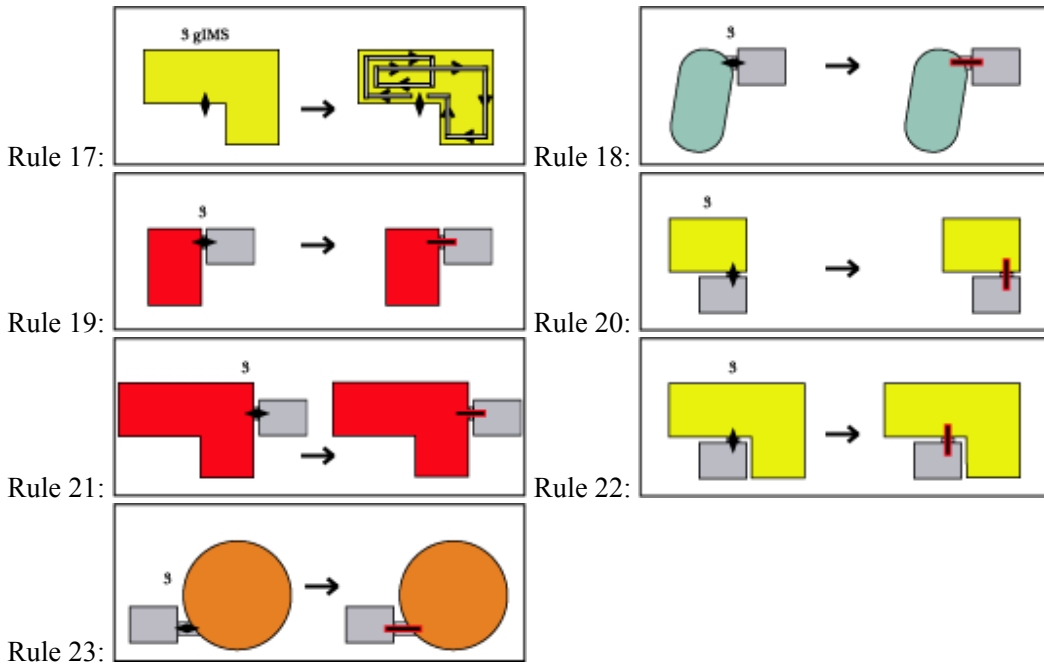
(represented by its 2D layout) shown in the LHO of the rule can be replaced by the RHO of the rule, where way finding aids or hyperlinks are added, given the following conditions:

- LHO of the rule is recognised in the virtual gallery, and
- sL of the rule is matched.

For example, additive navigation rule 4 shows that paths can be laid for a standard gallery 1 area to guide visitors through the exhibition if:

- The standard gallery 1 area is found in the virtual gallery, and
- sL=gIM1 is matched.





- Among these 23 additive navigation rules:
- Rules 1 to 3 are applied to add hyperlinks to reception areas of the virtual gallery.
 - Rules 4 to 17 are applied to lay paths in gallery areas to guide the visitors through different exhibitions.
 - Rules 18 to 23 are applied to lay paths between different areas of the virtual gallery for directing the visitors when the areas are connected via openings.

5.5.3 Subtractive Navigation Rules

Subtractive navigation rules are not visual/spatial. They are mainly about recognising the connections among different areas in the virtual gallery and removing way finding aids and hyperlinks once the connections are lost or change. The 6 subtractive navigation rules developed for the example grammar do not operate at a visual/spatial level. They are described in the form of “IF... THEN...”.

<p>Rule 1. sL=3 IF: A pair of hyperlink portals (teleport) connects reception area a with reception area b. AND Reception area a is not sensed in the virtual gallery. AND/OR Reception area b is not sensed in the virtual gallery. THEN: Remove the hyperlink portals.</p>
<p>Rule 2. sL=3 IF: A pair of hyperlink portals (warp) connects floor a with floor b in a reception area. AND Floor a is not sensed in the reception area. AND/OR Floor b is not sensed in the reception area.</p>

THEN: Remove the hyperlink portals.
<p>Rule 3. sL=3 IF: A path is laid in a gallery area for guiding visitors in an exhibition. AND The layout of the gallery area changes. AND/OR The visual boundaries of the gallery area change. THEN: Remove the path.</p>
<p>Rule 4. sL=3 IF: A path connects a reception area with the artist's personal studio area. AND The reception area is not sensed in the virtual gallery. AND/OR The artist's personal studio area is not sensed in the virtual gallery. THEN: Remove the path.</p>
<p>Rule 5. sL=3 IF: A path connects a reception area with a gallery area. AND The reception area is not sensed in the virtual gallery. AND/OR The gallery area is not sensed in the virtual gallery. THEN: Remove the path.</p>
<p>Rule 6. sL=3 IF: A path connects a reception area with the multi-function area. AND The reception area is not sensed in the virtual gallery. AND/OR The multi-function area is not sensed in the virtual gallery. THEN: Remove the path.</p>

5.6 INTERACTION RULES

Interaction rules are the final set of design rules to be fired in the application of the example grammar. There are only 6 additive interaction rules in total. Subtractive interaction rules are not explicitly defined and are discussed in section 5.6.3. Interaction rules ascribe appropriate behaviours to selected objects in the virtual gallery. Therefore, visitors can interact with the environment by triggering these behaviours to participate in various intended activities.

Similar to subtractive navigation rules, interaction rules do not operate at a visual/spatial level. Interaction rules developed for the example grammar are described in the form of "IF... THEN...".

5.6.1 State Labels

sL=4 is the only state label used in interaction rules indicating they are the final set of design rules to be fired in the application of the example grammar.

5.6.2 Additive Interaction Rules

The example grammar has two different kinds of additive interaction rules. One supplements object placement rules and the other supplements navigation rules. Object placement rules define visual boundaries for each generated area of the virtual gallery and place purposeful objects in the areas. The first kind of the interaction rules (rules 1 to 4) ascribes behaviours to selected objects so that exhibitions and other intended activities can function. The other kind of interaction rules (rules 5 and 6) looks for way finding aids and hyperlinks generated by navigation rules and ascribe appropriate behaviours to activate them.

<p>Rule 1. sL=4 IF: The 3D model of a digital picture frame object is recognised within a gallery area. AND The digital picture frame object is currently not configured. THEN: Render the appropriate digital image onto the surface of the 3D model from the artist's exhibition. AND Enable the digital image to be enlarged and accessed from the web browser.</p>
<p>Rule 2. sL=4 IF: The 3D model of an object that forms a part of an interactive installation is recognised within a gallery area or the multi-function area. AND The object is currently not configured. THEN: Ascribe appropriate behaviours to the object according to the artist's exhibition requirements.</p>
<p>Rule 3. sL=4 IF: The 3D model of a digital document object is recognised within a reception area, the artist's personal studio area, or the multi-function area. AND The digital document object is currently not configured. THEN: Attach the relevant digital information to the object. AND Enable the detail of the information to be accessed from the web browser.</p>
<p>Rule 4. sL=4 IF: A 3D model of a digital projector object is recognised in the multi-function area or the artist's personal studio area. AND The digital projector object is currently not configured. THEN: Load the conference/meeting materials to the object for presentation.</p>
<p>Rule 5. sL=4 IF: The 3D models of a pair of hyperlink portals (teleport) are recognised connecting two reception areas. AND The portals are currently not configured. THEN: Detect the coordinates of the portals. AND</p>

Activate the portals using the detected coordinates.
<p>Rule 6. sL=4 IF: The 3D models of a pair of hyperlink portals (warp) are recognised connecting two different floors of a reception area. AND The portals are currently not configured. THEN: Detect the coordinates of the portals. AND Detect any obstacle between these two locations. IF: No obstacle exists. THEN: Activate the portals using the detected coordinates. IF: Any obstacle exists. THEN: Change the hyperlink portals (from warp to teleport). AND Activate the portals using the detected coordinates.</p>

5.6.3 Subtractive Interaction Rules

For the example grammar, subtractive interaction rules do not need to be explicitly defined. The application of additive interaction rules ascribes appropriate behaviours to selected objects in the virtual gallery. The programming scripts that support the behaviours become attributes of the objects. Therefore, when other design rules of the grammar are applied to remove or make changes to the objects any attributes previously associated with the objects will be automatically removed.

5.7 SUMMARY

Following the generative design grammar framework, the example grammar for the dynamic design of a virtual gallery has been developed to have four sets of design rules: layout rules, object placement rules, navigation rules and interaction rules. These four sets of design rules have been presented in sections 5.3 to 5.6.

5.7.1 Purposes of the Example Grammar

The example grammar demonstrates the application of the generative design grammar framework for developing generative design grammars for virtual worlds. This grammar provides examples to expound the structure and basic components of generative design grammars introduced in Chapter 4. This grammar also provides examples to demonstrate various concepts of applying generative design grammars for dynamic designs of virtual worlds; for example, the use of state labels for directing the grammar application in order to produce virtual world designs that meet the current design goals of the GDA.

It is noted that generative design grammars draw inspiration from the shape grammar formalism and are adapted for designing virtual worlds. The example grammar illustrated in this chapter is an example of a kind of generative design grammar which intends to be applied for the dynamic design of a specifically kind of virtual gallery, rather than extending research on shape grammars.

5.7.2 Limitations

There are limitations in the current configuration of the example grammar. However, as the example grammar illustrated in this chapter is only an example of a kind of generative design grammar, and therefore, the limitations listed below do not necessarily apply to other generative design grammars.

Firstly, each set of design rules in the example grammar is grouped into additive rules and subtractive rules. The design generation of the virtual gallery is by adding/subtracting different virtual world objects and their properties. This method of design generation is adequate and suitable to demonstrate the concept of dynamic designs of virtual worlds for this study. Using this example grammar the dynamic design of the virtual gallery clearly reflects on the addition/subtraction of different areas and various purposeful objects and properties as needed. However, this is not the only way to generate virtual gallery; for example, to implement the example grammar as a parametric grammar will enable the virtual gallery to be generated through parametric design. This will also free the grammar from current restrictions regarding the sizes and capacity of various gallery areas.

Secondly, object placement rules in the example grammar are rigid. The varieties of the generated outcomes are limited and these rules should be enriched in the future. Although the current object placement rules provide visual boundaries to each area of the virtual gallery and arrange the interior of the area in a very limited way, they are efficient in demonstrating the use of object placement rules and their roles in a generative design grammar. However, in order to produce more interesting designs, object placement rule will need to include more design parameters that enable wider varieties of design variations.