

Chapter 6

Design Demonstration: a Virtual Gallery Scenario

Chapter 6 presents a design scenario that applies the Generative Design Agent (GDA) model¹, and the example grammar illustrated earlier in Chapter 5 developed using the generative design grammar framework², for the dynamic design of a virtual gallery. The design scenario consists of eight different stages. The different stages present various changes that may occur in a virtual gallery during its use; for example, changes of activities, changes of exhibition requirements, changes of visitors, and so on. The design scenario shows how the artist's GDA reasons and dynamically generates designs of the virtual gallery. Although the design scenario is constructed with a specific kind of virtual gallery in mind, it demonstrates the effectiveness of the GDA model and generative design grammars both for dynamic designs of virtual worlds. Integrated with different design and domain knowledge, the GDA model and generative design grammars are applicable to dynamic designs of virtual worlds for other purposes.

Section 6.1 provides an overview of the design scenario. As the major content of the chapter, the middle sections present the eight stages of the scenario in sequence. For each stage, we discuss the GDA's designing and other reasoning process, show which and how the design rules are applied, and finally illustrate the generated design for the moment. In section 6.3, the detailed procedures for executing the design scenario are presented at stage 1. The descriptions of the remaining seven stages are simplified and included in sections 6.4 to 6.10, accordingly. More detail about the design scenario and its technical implementation can be found in Appendix 2. The chapter ends with a discussion, where the corpus of designs generated for the scenario are compared to demonstrate the dynamics of the designing process and to analyse the stylistic characterisations of the generated designs.

6.1 DESIGN SCENARIO OVERVIEW

The characters in the design scenario include the artist Acosta, his guest Sumi and various visitors. Acosta is provided with a GDA in the virtual gallery. Other characters are represented as general avatars which have no agency. Acosta's GDA can reason, design and act on behalf of him in the virtual gallery. The design component of the GDA is supported by the application of the example grammar. The eight stages of the design scenario present situations where various changes occur in the virtual gallery; for example, changes of Acosta and other visitor's activities, changes of Acosta's exhibitions, increase and decrease of visitor numbers, and so on. The GDA senses the changes and hypothesises design goals in order to accommodate these changes. The scenario aims at demonstrating dynamic design of the virtual gallery, therefore most goals of the GDA are related to designing. To meet these design goals, the GDA applies the example grammar to generate different designs of the virtual gallery as needed.

¹ The GDA model is elaborated in Chapter 3.

² The generative design grammar framework is presented in Chapter 4.

6.1.1 Limitations of the Design Scenario

The design scenario has its focus, and therefore limitations. Firstly, the focus of the scenario is to demonstrate the application of the GDA model and generative design grammar for dynamic design of the virtual gallery. The design scenario shows how a GDA reasons, designs and acts in the virtual gallery for some typical situations where changes occur in the gallery during its use. The scenario does not intend to address all possible situations and changes.

Secondly, an ideal virtual world should be represented by a society of GDAs where the designs of the world are dynamically generated by the GDA society, so that the designs meet the common goals of the society and reflects their common interests. To do so, the communication among GDAs needs to be addressed. Although the GDA model is applicable to multi-GDA virtual worlds, since the reasoning mechanism of the GDA model enables each GDA to reason about the virtual world as well as other GDAs in the world, agent communication is however beyond the scope of this study. To control the complexity of the scenario, as mentioned earlier, only the artist Acosta is provided with a GDA in the virtual gallery.

- When Acosta is present in the virtual gallery the virtual gallery will be dynamically designed, implemented and manipulation by his GDA, on behalf of Acosta. To a certain extent, the visitors' needs and interests in the virtual gallery are also reflected in the generated designs, as the design goals of the GDA are hypothesised based on its interpretations of the virtual gallery and different occupants' activities in the gallery.
- When Acosta is not present, the virtual gallery will be replaced by a static design. Static and dynamic designs of the virtual gallery are further discussed in section 6.1.3.

6.1.2 Generative Design Grammar Application Controls

Like any generative design grammars, the application of the example grammar is directed by a set of special state labels in order to generate designs that meet the GDA's current design goals. As illustrated in Chapter 5, each design rule of the example grammar is associated with one of these state labels. A design rule is fired only when the following conditions are met:

- The LHO of the rule is recognised in the virtual gallery, and
- The design context represented by the state label is related to the GDA's current design goals.

However, in cases where there are more than one design rule that meet the above conditions a control mechanism is needed to resolve the conflict. In general, there are three main methods for controlling the generative design grammar application. They are random selection, human designer intervention and agent learning mechanism.

- The random selection method allows the system to randomly select one design rule from the set of rules that meet the conditions.
- The human designer intervention method allows the system to turn to human designers or users for instructions once such a conflict occurs.
- The agent learning mechanism provides a more dynamic but more complex approach to allow the system to resolve such a conflict based on the GDA's previous design experiences and feedback.

The example grammar applies the human designer intervention method. When the artist's GDA finds more than one design rules that can be fired, the GDA informs the artist and waits for further instructions. In the design scenario such a case occurs twice, one at stage 2 and the other at stage 5.

6.1.3 Static and Dynamic Designs of the Virtual Gallery

In the design scenario, the virtual gallery has static and dynamic designs. The scenario starts with the login of the artist Acosta to the virtual world, where his virtual gallery is located. He is represented by a GDA in the virtual world. This marks the beginning of the virtual gallery being dynamically designed, implemented and manipulated as needed by Acosta's GDA. As Acosta is the only character of the scenario who is given agency in the virtual gallery, dynamic design of virtual worlds therefore is not possible without his presence. Prior to the start of the scenario, a static design of the virtual gallery is used in the virtual world. The design is the result of Acosta's previous visit. As shown in Figure 6.1, this static design comprises one gallery area for displaying one of Acosta's exhibitions. The gallery area connects to a reception area from floor 1 of the reception area. Without GDA, the virtual gallery is static because the design remains unchanged no matter what happens in the gallery.

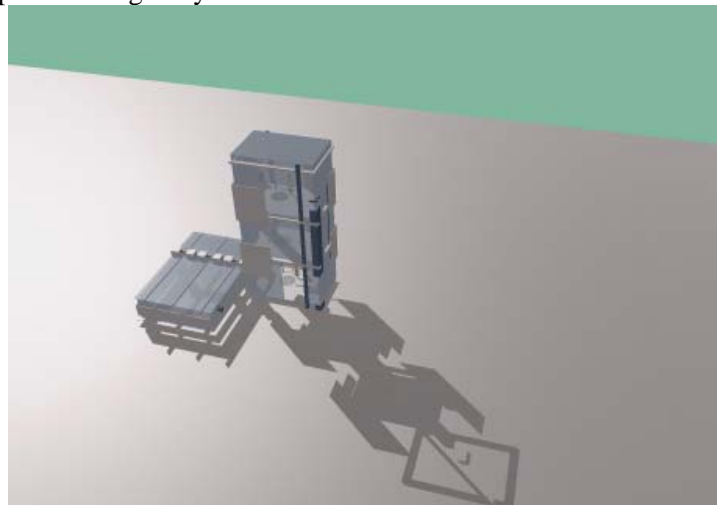


Figure 6.1. The visualisation of the static virtual gallery design used prior to the design scenario.

At the end of the design scenario, Acosta disconnects from the virtual world. His GDA applies the termination rule to terminate the grammar application before terminating its own agent program. As a result, a static design of the virtual gallery is generated once again. The dynamic designing process will re-start when Acosta comes back to the virtual gallery next time.

6.2 STAGE 1: THE ARTIST ENTERS THE VIRTUAL GALLERY

Description: at stage 1, the artist Acosta connects to the virtual world, where his virtual gallery is located. Acosta is represented by a GDA in the virtual world. At the moment, he intends to display two new exhibitions: exhibition 1 and 2 in the virtual gallery. In the initial static virtual gallery, the GDA senses eight visitors, each of whom are represented by an avatar. On behalf of Acosta, the GDA welcomes the visitors and notifies them that the virtual gallery will be temporarily under construction for arranging new exhibitions. The visitors are reminded that in a very short moment they will be invited and transported to the new exhibitions.

The GDA meanwhile demolishes the initial static virtual gallery and at the same location places the initial design of the example grammar: the layout of a reception area. With the initial design being recognised, the virtual gallery's dynamic designing process starts.

6.2.1 Layout Rule Application


The application of the design rules in a generative design grammar follows the sequence of layout rules, object placement rules, navigation rules and interaction rules. Therefore layout rules are the

first set of design rules to be fired in the application of the example grammar. Beside a special state label that represents a specific context for designing the virtual gallery, each layout rule is also associated with state label $sL=1$ that indicates the stage of the grammar application.

To prepare for the application of layout rules at stage 1, Acosta's GDA performs the following reasoning:

- In the process of interpretation, the GDA interprets (1) the presence of Acosta, and that (2) Acosta currently has no studio space in the virtual gallery. The GDA also interprets that (3) Acosta intends to display two exhibitions: exhibition 1 and 2, and (4) currently the virtual gallery has no gallery space available.
- In the process of hypothesising, based on interpretation (1) and (2), the GDA hypothesises a design goal $O_{exp}^F=S$ (the personal studio area for the artist is needed in the virtual gallery). Based on interpretation (3) and (4), the GDA hypothesises the next two design goals $O_{exp}^F=g1$ (the initial standard gallery 1 area is needed in the virtual gallery) and $O_{exp}^F=g2$ (the initial standard gallery 2 area is needed in the virtual gallery).

With these design goals being hypothesised, the GDA starts the matching process in order to apply the example grammar:

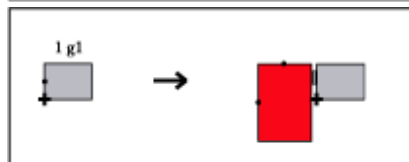
- For matching the LHOs of the design rules: the initial design  is recognised.
- For matching the state labels of the design rules³: because $O_{exp}^F=S$, $O_{exp}^F=g1$ and $O_{exp}^F=g2$ are hypothesised, therefore $sL=S$, $sL=g1$ and $sL=g2$ are matched.

Based on the above criteria, the GDA searches the design rules of the example grammar for eligible rules to apply, starting from layout rules⁴. As each layout rule is associated with state label $sL=1$ that indicates the stage of the grammar application, the matched state labels become $sL=1 S$, $sL=1 g1$ and $sL=1 g2$. The matched layout rules are:

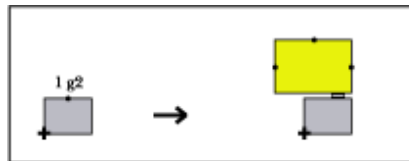
Match 1: additive layout rule 1



Match 2: additive layout rule 2

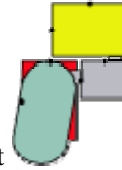


Match 3: additive layout rule 3



³ Appendix 1 provides more information about the GDA's interpretations in the virtual gallery, the design goals the GDA hypothesises based on the interpretations, and the state labels that are matched according to the design goals.

⁴ Layout rules of the example grammar are illustrated in Chapter 5 section 5.3, with more detail provided in Appendix 1.



The application of the above layout rules generates a layout for the virtual gallery which comprises a reception area, a personal studio area for the artist, a standard gallery 1 area for displaying exhibition 1, and a standard gallery 2 area for displaying exhibition 2.





6.2.2 Object Placement Rule Application

Object placement rules are the second set of design rules to be fired in the application of the example grammar. Beside a special state label that represents a specific context for designing the virtual gallery, each layout rule is also associated with state label $sL=2$ that indicates the stage of the grammar application.

Now that the layout of the virtual gallery is generated, additional reasoning is required by the GDA to continue with the application of object placement rules. In order to generate visual boundaries and visual cues for each area, the GDA needs to be provided with Acosta's design preferences for the interior of the virtual gallery and his specifications of the exhibitions.

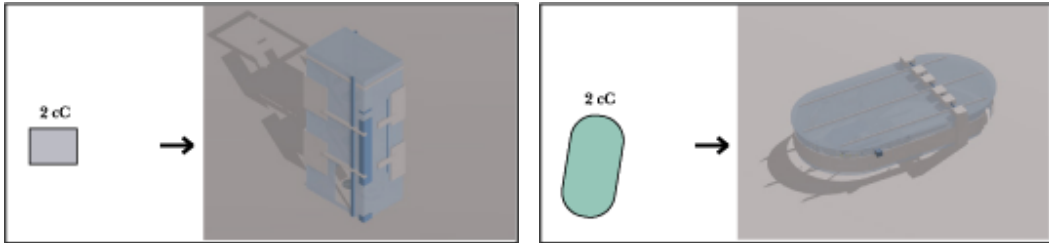
- In the process of interpretation, based on the instructions given by Acosta, the GDA interprets that (1) Acosta prefers the use of cold colours for the interior of the virtual gallery, and (2) exhibition 1 and 2 each contains various digital images in various sizes which can be arranged for displaying in the virtual gallery using configuration 1.
- In the process of hypothesising, based on interpretation (1), the GDA hypothesises a design goal $O_{exp}^F=cC$ (to apply a cold-colour scheme for the interior of the virtual gallery). Based on interpretation (2), the GDA hypothesises the next design goal $O_{exp}^F=gIM1$ (to arrange the two gallery areas for displaying digital images using configuration 1).

With these design goals being hypothesised, the GDA starts the matching process:

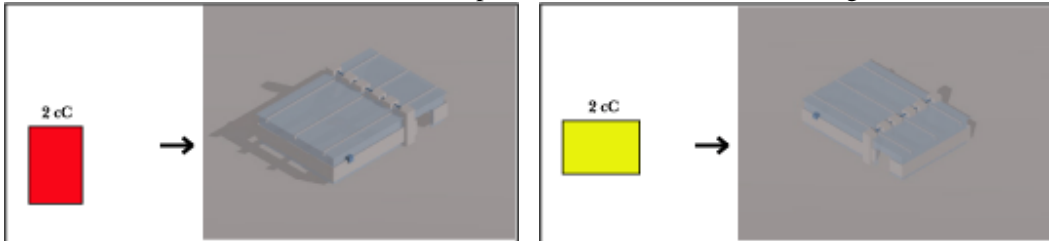
- For matching the LHOs of the design rules: , ,  and , the layouts of the four areas are recognised.
- For matching the state labels of the design rules: because $O_{exp}^F=cC$ and $O_{exp}^F=gIM1$ are hypothesised, therefore $sL=cC$ and $sL=gIM1$ are matched.

Based on the above criteria, the GDA continues the search in object placement rules⁵ for eligible rules to apply. As each object placement rule is associated with state label $sL=2$ that indicates the stage of the grammar application, the matched state labels become $sL=2 cC$ and $sL=2 gIM1$. The matched object placement rules are:

⁵ Object placement rules of the example grammar are illustrated in Chapter 5 section 5.4, with more detail provided in Appendix 1.

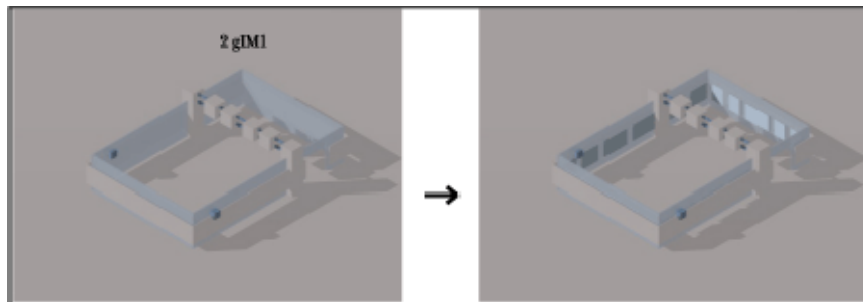


Matches 1 and 2: additive placement rules 1 (left) and 2 (right).

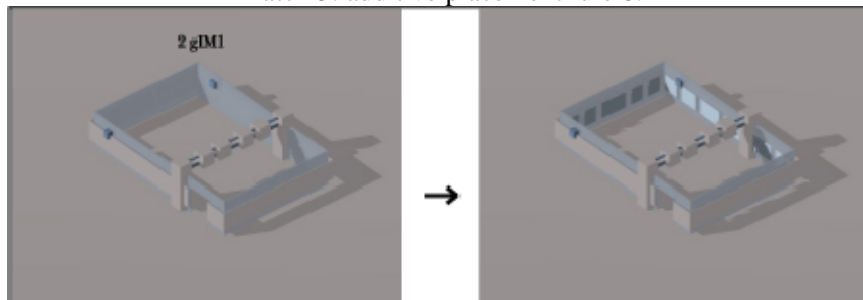


Matches 3 and 4: additive placement rules 3 (left) and 4 (right).

The application of these four object placement rules provides the 2D layout of the virtual gallery with purposeful 3D objects to define visual boundaries and provide visual cues for each area. Subsequently, for the two gallery areas, the following two object placement rules are also matched to further arrange the gallery areas for displaying the two exhibitions:



Match 5: additive placement rule 8.



Match 6: additive placement rule 9.

The result of the object placement rule application is shown in Figure 6.2. The virtual gallery has four areas: the reception area, the artist's personal studio area, a standard gallery 1 area and a standard gallery 2 area. The reception area has three floors and connects to gallery 1 from floor 1, gallery 2 from floor 2, and the studio area from floor 3.

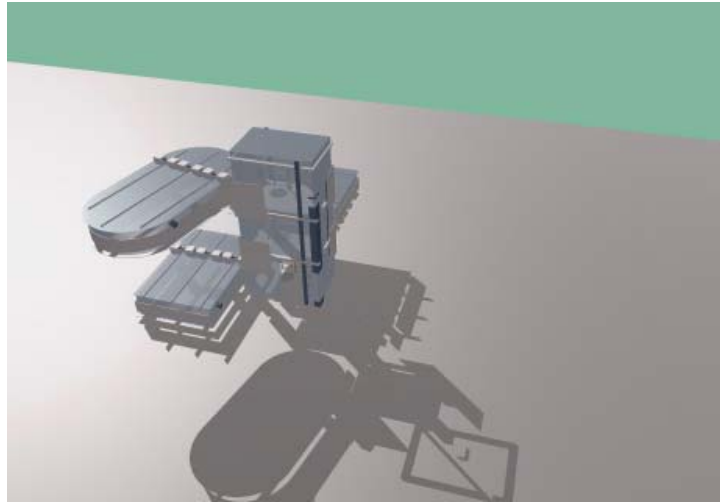


Figure 6.2. The visualisation of the virtual gallery design for stage 1.

6.2.3 Navigation Rule Application

Next, the GDA applies navigation rules to provide way finding aids and hyperlinks⁶ to the generated design of the virtual gallery. Navigation rules are the third set of design rules to be fired after layout rules and object placement rules in the application of the example grammar. Each layout rule is always associated with state label $sL=3$ that indicates the stage of the grammar application. In the matching process:

- For matching the LHOs of the design rules: the four areas of the virtual gallery generated at stage 1 are recognised. They are shown in Figure 6.3 from left to right: the reception area, the artist's personal area, the standard gallery 1 area and the standard gallery 2 area.
- For matching the state labels of the design rules: the design goal $O_{exp}^F=gIM1$ is related to not only the application of object placement rules, but also the application of navigation rules. Therefore, because $O_{exp}^F=gIM1$ is hypothesised, $sL=gIM1$ is hence matched.

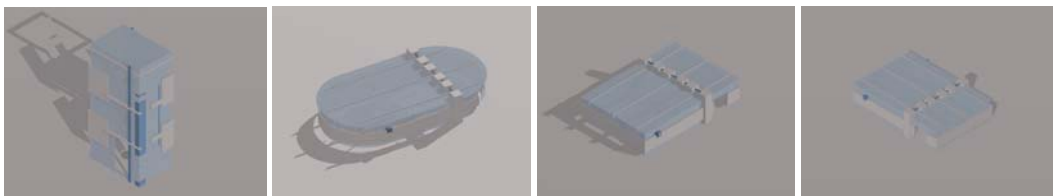
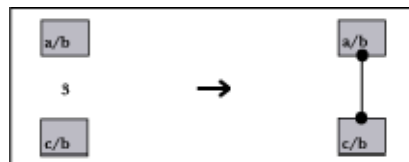


Figure 6.3. The visualisations of the four areas of the virtual gallery generated at stage 1.

Based on the above criteria, the GDA searches navigation rules⁷ of the example grammar, and the matched navigation rules are:

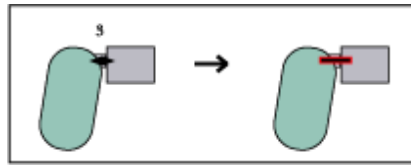
Match 1: additive navigation rule 3



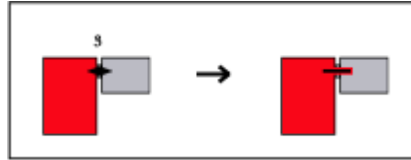
⁶ The guidelines for using way finding aids and hyperlinks in the virtual gallery are presented in Chapter 5 section 5.5.

⁷ Navigation rules of the example grammar are illustrated in Chapter 5 section 5.5, with more detail provided in Appendix 1.

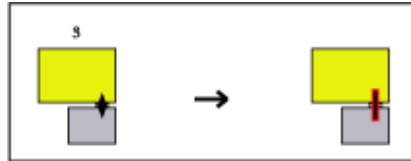
Match 2: additive navigation rule 18



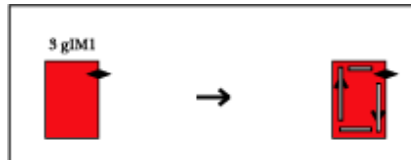
Match 3: additive navigation rule 19



Match 4: additive navigation rule 20



Match 5: additive navigation rule 4



Match 6: additive navigation rule 5



Additive navigation rule 3 is applied multiple times to connect the three floors of the reception area together with each other using hyperlink portals (warp). Additive navigation rules 4 and 5 are applied to lay paths in the two gallery areas for guiding visitors through the exhibitions. Finally, additive navigation rules 18, 19 and 20 are applied to lay paths to connect the reception area with the artist's personal studio area, and the two gallery areas, for directing visitors.

6.2.4 Interaction Rule Application

To complete the design for stage 1, the GDA applies interaction rules to ascribe appropriate behaviours to selected objects in the virtual gallery. Therefore, visitors can interact with the environment by triggering these behaviours and to participate in various intended activities. As described in Chapter 4 section 4.3.4, interaction rules are non-visual/spatial rules, they are about recognising selected objects in the virtual gallery and ascribing appropriate behaviours to these objects. Therefore, in the matching process the main concern is to match the LHOs of the design rules. The only state label used in interaction rule is sL=4, which indicates that interaction rules are the fourth, the final set of design rules to be fired in the application of the example grammar.

The GDA recognises various digital picture frame objects in the two gallery areas for displaying digital images of the exhibitions, various digital document objects in the reception area and the artist's personal studio area for storing digital information, and various hyperlink portals (warp) on different floors of the reception area. Based on these criteria, the GDA searches interaction rules⁸ of the example grammar, and the matched interaction rules are:

⁸ Interaction rules of the example grammar are illustrated in Chapter 5 section 5.6, with more detail provided in Appendix 1.

<p>Match 1: additive interaction rule1: 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>Match 2: additive interaction rule3: 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>Match 3: additive interaction 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>

Additive interaction rule 1 is applied multiple times to display digital images that form the two exhibitions using various digital picture frame objects. Additive interaction rule 3 is applied multiple times to provide information about the virtual gallery and the exhibitions in the reception area, and to store Acosta's digital tools and data in his personal studio area, using various digital document objects. Additive interaction rule 6 is applied multiple times to activate the hyperlink portals so that the visitors can warp among the three floors of the reception area to access different parts of the virtual gallery.

The final design of the virtual gallery for stage 1 is now generated with four areas: the reception area that provides information regarding the virtual gallery and the exhibitions, the personal studio area equipped with various digital tools and data for the artist, and two gallery areas that are configured for displaying Acosta's two exhibitions. In the processes of action, the GDA plans actions for implementing this generated design of the virtual gallery, and activates the planned actions via its effectors in the virtual world. Once the design for stage 1 is implemented, the GDA notifies Acosta and the visitors before transporting Acosta to his personal studio area and the visitors to the gallery areas.

For the remaining stages of the scenario, the execution of each stage follows similar procedures shown above at stage 1. In the following sections, these procedures are described in a simpler version. A more detailed presentation of these stages is provided in Appendix 2.

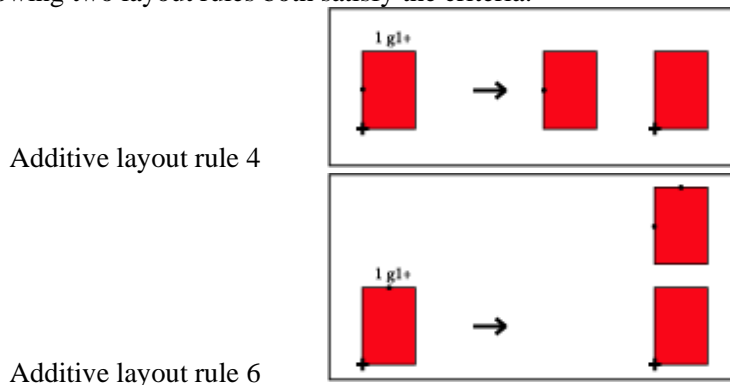
6.3 STAGE 2: EXHIBITION 1 ATTRACTS MORE VISITORS

Description: at stage 2 more visitors connect to the virtual world and visit the virtual gallery. At one point, the number of visitors in the standard gallery 1 area increases to 10. This reaches the maximum capacity of a standard gallery area⁹. Acosta's GDA senses this change and applies the example grammar to add an additional gallery area for displaying exhibition 1. Any future visitors who wish to visit exhibition 1 will be automatically transported to this newly generated gallery area, until the number of visitors in the original gallery area drops below 10.

6.3.1 Execution of the Design Scenario

The execution of stage 2 follows similar procedures shown at stage 1. In the process of interpretation, the GDA interprets the changing needs of Acosta and the visitors and changes in the virtual gallery; for example, the initial change at stage 2 is the increase of visitors in the standard gallery 1 area. Based on its current interpretations, in the process of hypothesising, the GDA hypothesises design goals; for example, one of the design goals hypothesised by the GDA at stage 2 is $O_{exp}^F = g1+$ (an additional standard gallery 1 area is needed in the virtual gallery). With new design goals being hypothesised new state labels can be matched for the search of eligible design rules in the example grammar for application.

Firstly, in the application of layout rules the newly matched state label is $sL=1 g1+$. The following two layout rules both satisfy the criteria:



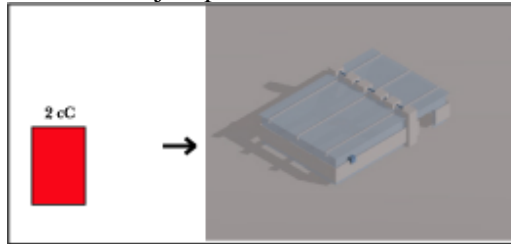
Both layout rules add an additional gallery area in the virtual gallery. Additive layout rule 4 expands the layout of the virtual gallery along the X axis, and additive layout rule 6 expands the layout along the Y axis. The GDA turns to Acosta for further instructions. In the design scenario, Acosta prefers to expand the layout of the virtual gallery along the Y axis, therefore the GDA applies additive layout rule 6.

⁹ As discussed in Chapter 5 section 5.3, for this example grammar, a gallery area has two different sizes and 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.

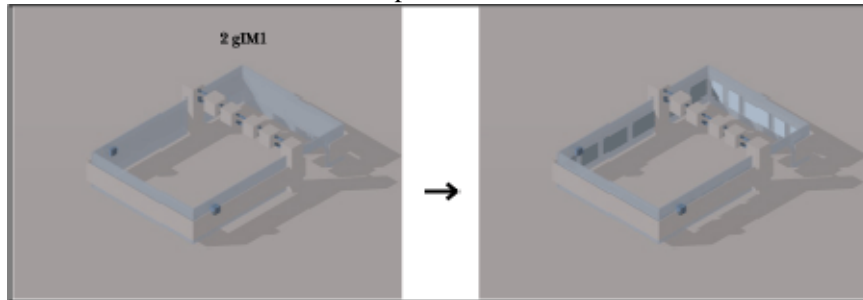


With the application of other relevant layout rules, a layout of the virtual gallery is generated for stage 2 of the design scenario.

Secondly, in the application of object placement rules the newly matched state labels are $sL=2\ cC$ and $sL=2\ gIM1$. The matched object placement rules are:



Additive placement rule 3.



Additive placement rule 8.

Additive placement rule 3 is applied to define visual boundaries and provide visual cues for the newly generated gallery area, and this gallery area is further arranged for displaying exhibition 1 by applying additive placement rule 8. The result of the object placement rule application is shown in Figure 6.4.

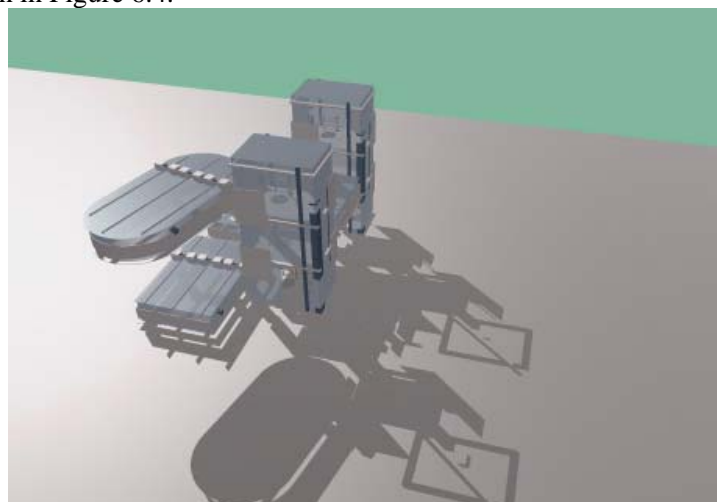


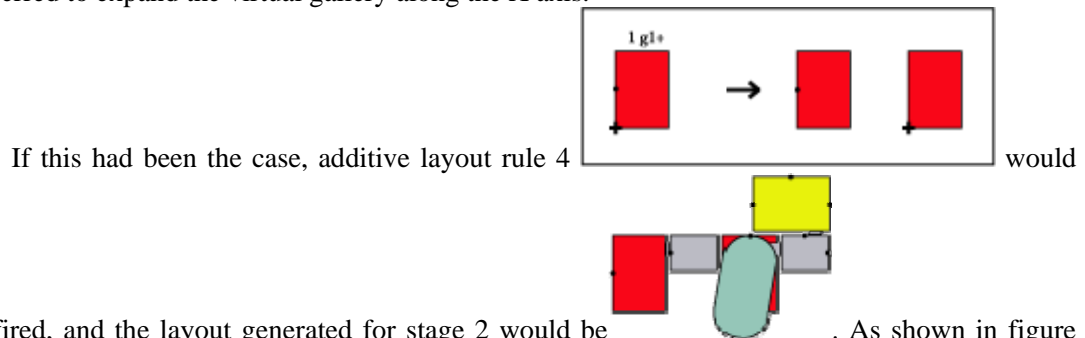
Figure 6.4. The visualisation of the virtual gallery design for stage 2.

To complete the design, the GDA searches and applies appropriate navigation rules to provide way finding aids and hyperlinks to connect with the newly generated areas, and, finally, the GDA searches and applies appropriate interaction rules to ascribe behaviours to selected objects in the newly generated areas when it is necessary.

Compared to the design generated for stage 1, the current design has an additional gallery area (a standard gallery 1 area) for displaying exhibition 1. An additional reception area is also generated to connect the newly generated gallery area with the rest of the virtual gallery.

6.3.2 An Alternative Design of the Virtual Gallery for Stage 2

As mentioned earlier, the application of layout rules for stage 2 can have two different ways to expand the virtual gallery. An alternative design could have been generated if Acosta had preferred to expand the virtual gallery along the X axis.



As shown in figure 6.5, this would change the design of the virtual gallery for stage 2, and subsequently change all the designs generated for the rest of the design scenario.

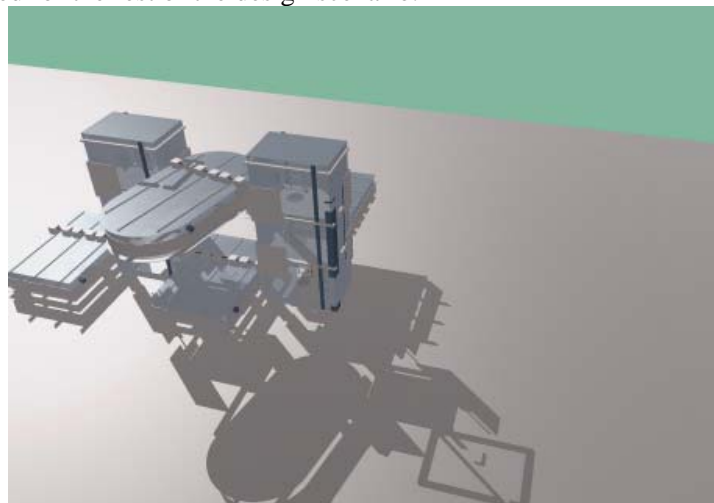


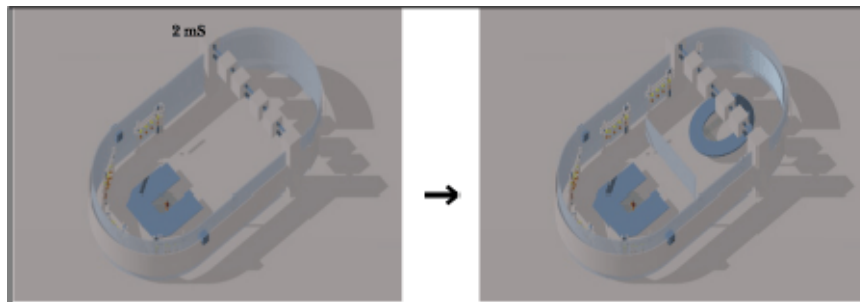
Figure 6.5. The visualisation of the alternative design at stage 2.

6.4 STAGE 3: AN INVITED GUEST ENTERS THE VIRTUAL GALLERY

Description: at stage 3 Acosta is browsing some digital information in his personal studio area. He instructs his GDA to organise a meeting venue for him and his guest Sumi, who will be arriving in the virtual gallery soon. The GDA applies the example grammar to arrange a meeting area inside Acosta's personal studio area. When Sumi connects to the virtual world the GDA welcomes her on behalf of Acosta and transports her directly to the newly generated meeting area.

For the execution of stage 3, in the process of interpretation, the GDA interprets the changing needs of Acosta and the visitors and changes in the virtual gallery; for example, the changing need of Acosta at stage 3 reflects his request for a meeting venue. Based on its current interpretations, in the process of hypothesising, the GDA hypothesises a design goal $O_{exp}^F=mS$ (to configure a meeting area in the artist's personal studio area). With the new design goal being hypothesised, new state labels can be matched for the search of eligible design rules in the example grammar for application.

To configure a meeting area in Acosta's personal studio area does not require the application of layout rules since the personal studio area has been generated at stage 1. In the application of object placement rules the newly matched state label is $sL=2 mS$. The matched object placement rule is:



Additive placement rule 22.

As the meeting area is arranged inside Acosta's personal studio area it is not necessary to provide way finding aids and hyperlinks separately for this area. Therefore, navigation rules are also not fired at stage 3. To complete the design, the GDA searches and applies appropriate interaction rules to ascribe behaviours to activate various meeting facilities in the newly arranged meeting area.

The current design of the virtual gallery is the same as the design generated for stage 2, except that a meeting area is now arranged inside Acosta's personal studio area.

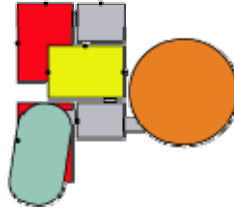
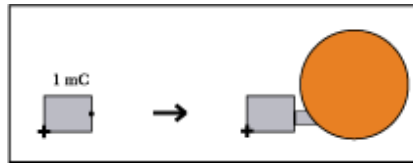
6.5 STAGE 4: THE ARTIST DECIDES TO GIVE A PUBLIC TALK

Description: at stage 4 Acosta decides to give a public talk to highlight the current exhibitions after the meeting with Sumi. He instructs his GDA to organise a venue for the public function. The GDA applies the example grammar to generate the multi-function area in the virtual gallery and arranges the area as a conference venue. After Acosta finishes the preparation for the talk the GDA sends an invitation to the visitors on behalf of Acosta and transports those who accept the invitation to the multi-function area.

For the execution of stage 4, in the process of interpretation, the GDA interprets the changing needs of Acosta and the visitors and changes in the virtual gallery; for example, the changing need of Acosta at stage 4 reflects his request for a venue to host a public talk. Based on its current interpretations, in the process of hypothesising, the GDA hypothesises design goals; for example, one of the design goals hypothesised by the GDA at stage 4 is $O_{exp}^F=mC$ (the multi-function area is needed as a conference venue). With new design goals being hypothesised, new state labels can be matched for the search of eligible design rules in the example grammar for application.

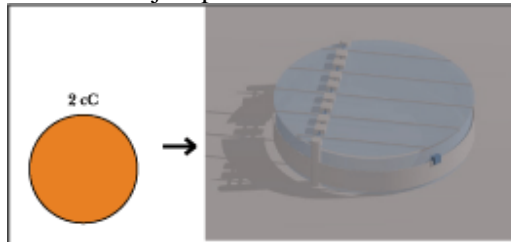
Firstly, in the application of layout rules the newly matched state label is $sL=1 mC$. The matched layout rule is:

Additive layout rule 14

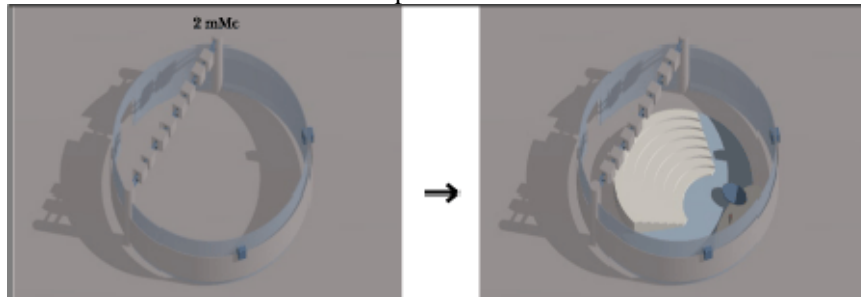


By applying this layout rule, a layout of the virtual gallery is generated for stage 4. The multi-function area is added.

Secondly, in the application of object placement rules the newly matched state labels are $sL=2\ cC$ and $sL=2\ mMc$. The matched object placement rules are:



Additive placement rule 7.



Additive placement rule 23.

Additive placement rule 7 is applied to define visual boundaries and provide visual cues for the newly generated multi-function area, and this area is further arranged as a conference venue by applying additive placement rule 23. The result of the object placement rule application is shown in Figure 6.6.

To complete the design, the GDA searches and applies appropriate navigation rules to provide way finding aids and hyperlinks to connect with the multi-function area, and, finally, the GDA searches and applies appropriate interaction rules to ascribe behaviours to activate various conference facilities in the multi-function area.

Compared to the design generated for stage 3, the current design of the virtual gallery has a venue for public functions, that is, the multi-function area is arranged as a conference venue for hosting the artist's public talk.

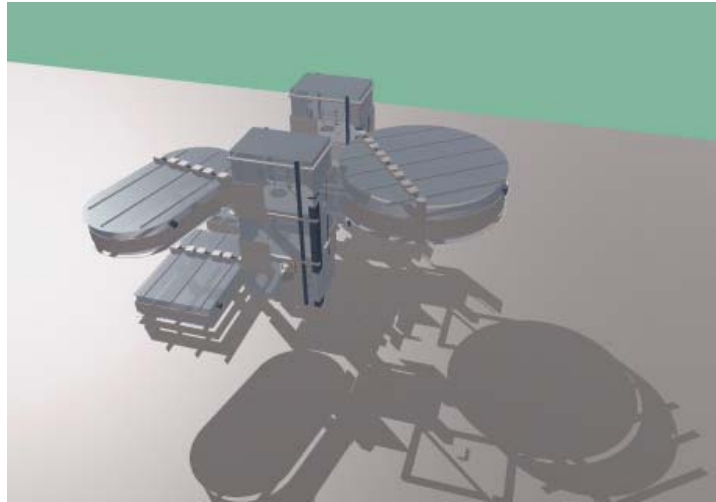


Figure 6.6. The visualisation of the virtual gallery design for stage 4.

6.6 STAGE 5: EXHIBITION 2 ATTRACTS MORE VISITORS

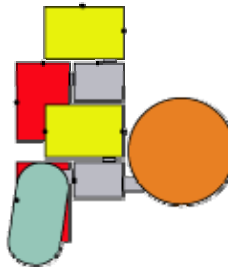
Description: after the talk some visitors remain in the multi-function area for discussion with Acosta. The rest return to the exhibitions. At one point, the number of visitors in the standard gallery 2 area increases to 10. This reaches the maximum capacity of a standard gallery area¹⁰. Acosta's GDA senses this change and applies the example grammar to add an additional gallery area for displaying exhibition 2. Any future visitors who wish to visit exhibition 2 will be automatically transported to this newly generated gallery area until the number of visitors in the original gallery area drops below 10.

6.6.1 Execution of the Design Scenario

For the execution of stage 5, in the process of interpretation, the GDA interprets the changing needs of Acosta and the visitors and changes in the virtual gallery; for example, the initial change at stage 5 is the increase of visitors in the standard gallery 2 area. Based on its current interpretations, in the process of hypothesising, the GDA hypothesises design goals; for example, one of the design goals hypothesised by the GDA at stage 5 is $O_{exp}^F = g2+$ (an additional standard gallery 2 area is needed in the virtual gallery). With new design goals being hypothesised, new state labels can be matched for the search of eligible design rules in the example grammar for application.

Stage 5 is very similar to stage 2, where a design goal $O_{exp}^F = g1+$ (an additional standard gallery 1 area is needed in the virtual gallery) is hypothesised. Following the same procedures shown at stage 2, the GDA matches new states labels, searches and applies appropriate layout rules, object placement rules, navigation rules and interaction rules to generate an additional gallery area to accommodate more visitors for exhibition 2.

¹⁰ As discussed in Chapter 5 section 5.3, for this example grammar a gallery area has two different sizes and 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 application of layout rules generates a layout of the virtual gallery for stage 5. The design of the virtual gallery for this stage is shown in Figure 6.7. Compared to the design generated for stage 4, the current design of the virtual gallery has an additional gallery area (a standard gallery 2 area) for displaying exhibition 2.

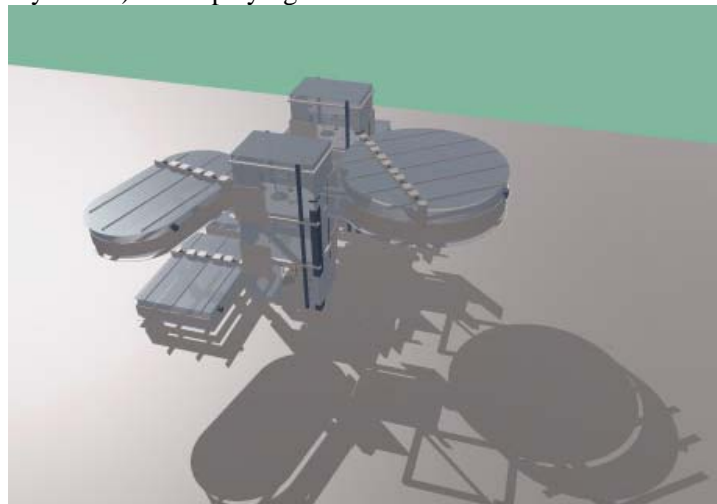
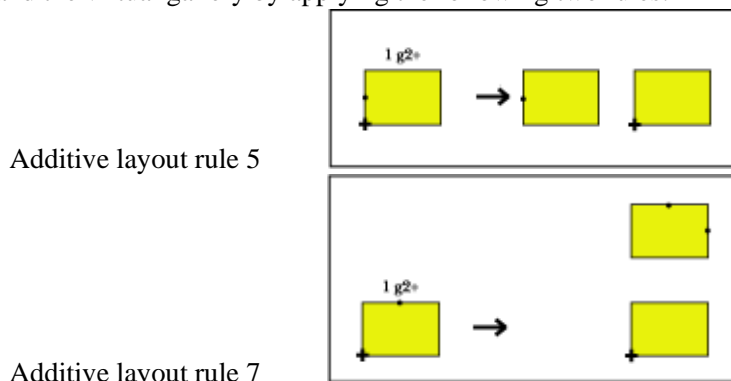


Figure 6.7. The visualisation of the virtual gallery design for stage 5.

6.6.2 Alternative Designs of the Virtual Gallery for Stage 5

Similar to stage 2, the application of layout rules for stage 5 can also have two different ways to expand the virtual gallery by applying the following two rules:



Additive layout rule 5 expands the layout of the virtual gallery along the X axis, and additive layout rule 7 expands the layout along the Y axis. In the scenario, Acosta once again prefers to expand the layout of the virtual gallery along the Y axis, therefore the GDA applies additive layout rule 7.

For both stages 2 and 5, as discussed, there are two different ways to expand the layout of the virtual gallery. Figure 6.8 shows the two different layouts of the virtual gallery that can be generated for stage 2. Based on these two layouts for stage 2 the subsequent stages can each have

two different layouts generated for the virtual gallery. The two layouts of the virtual gallery that can be generated for stage 4 are illustrated in Figure 6.9.

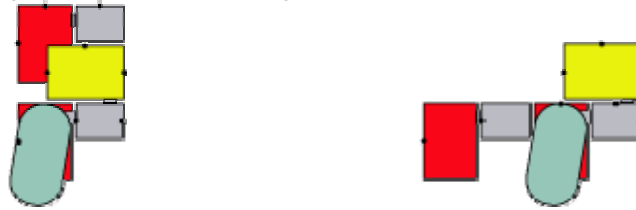


Figure 6.8. The two layouts that can be generated for stage 2.

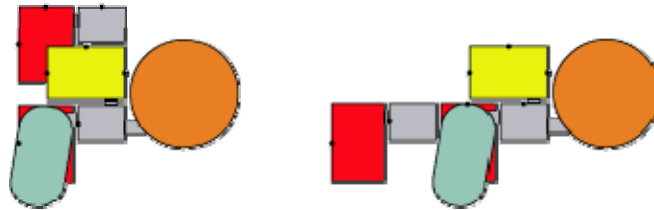


Figure 6.9. The two layouts that can be generated for stage 4.

Based on the two layouts shown in Figure 6.9, by alternating the application of additive layout rules 5 and 7 three alternative layouts of the virtual gallery can be generated for stage 5, besides the one shown earlier in section 6.6.1. The alternative layouts are illustrated in Figure 6.10. Each of these alternatives would change the design of the virtual gallery for stage 5, and subsequently change all the designs generated for the rest of the design scenario.

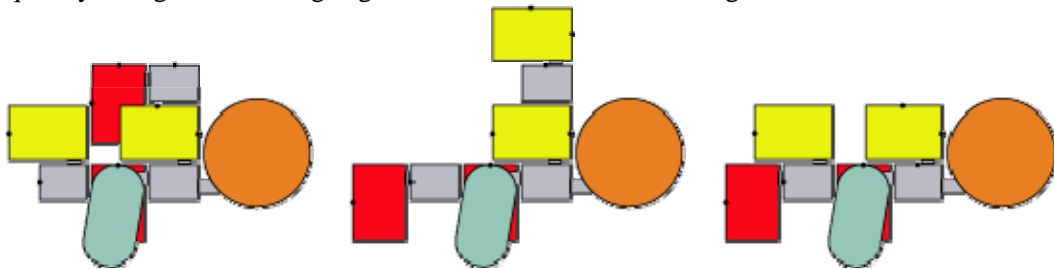


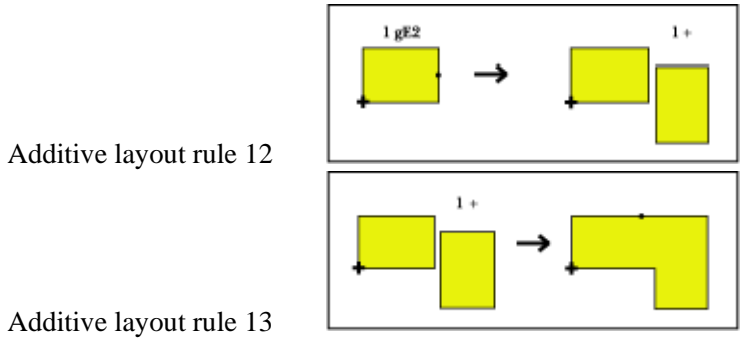
Figure 6.10. The three alternative layouts that can be generated for stage 5.

6.7 STAGE 6: THE ARTIST CHANGES EXHIBITION 2

Description: at stage 6, Acosta returns to his personal studio area. He decides to modify exhibition 2 by adding more exhibition items. Acosta instructs his GDA to accommodate the changes. On behalf of Acosta, the GDA informs the visitors about the changes and applies the example grammar to expand and rearrange both gallery 2 areas in order to display the new exhibition 2.

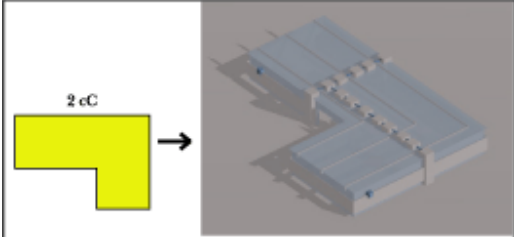
For the execution of stage 6, in the process of interpretation, the GDA interprets the changing needs of Acosta and the visitors and changes in the virtual gallery; for example, the changing need of Acosta at stage 6 reflects his changes of exhibition 2. Bases on its current interpretations, in the process of hypothesising, the GDA hypothesises design goals; for example, one of the design goals hypothesised by the GDA at stage 6 is $O_{exp}^F = gE2$ (the two standard gallery 2 areas need to be expanded). With new design goals being hypothesised, new state labels can be matched for the search of eligible design rules in the example grammar for application.

Firstly, in the application of layout rules, the newly matched state label is $sL=1 gE2$. The matched layout rules are:

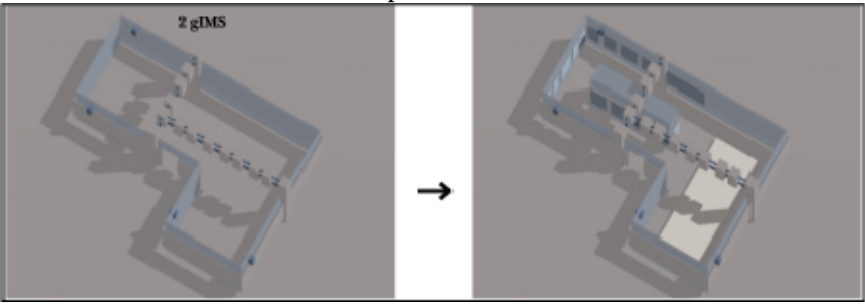


By applying the above rules, a layout of the virtual gallery is generated for stage 6. The two standard gallery 2 areas are expanded.

Secondly, in the application of object placement rules the newly matched state labels are sL=2 cC and sL=2 gIMS. The matched object placement rules are:



Additive placement rule 6.



Additive placement rule 21.

Additive placement rule 6 is applied to define visual boundaries and provide visual cues for the newly generated expanded gallery 2 areas¹¹, and the areas are further arranged for displaying the new exhibition 2 by applying additive placement rule 21. The result of the object placement rule application is shown in Figure 6.11.

To complete the design, the GDA searches and applies appropriate navigation rules to provide way finding aids and hyperlinks to connect with the expanded gallery 2 areas, and,

¹¹ At stage 6, before the application of additive placement rules, various subtractive placement rules are applied to remove excessive objects from the previous design. These rules are provided in Appendix 2.

finally, the GDA searches and applies appropriate interaction rules to ascribe behaviours to selected objects in these newly generated areas, when it is necessary.

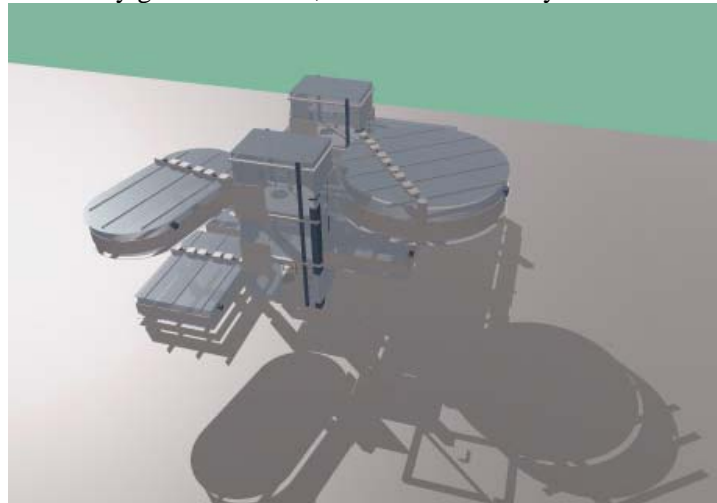


Figure 6.11. The visualisation of the virtual gallery design for stage 6.

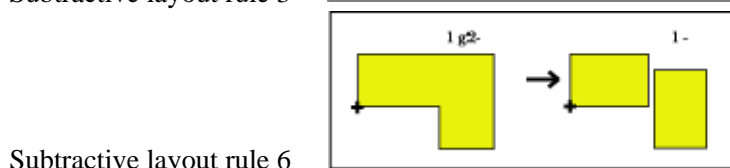
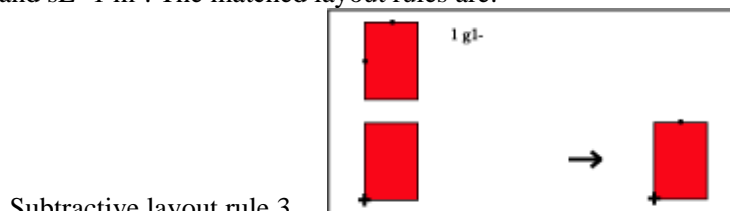
Compared to the design generated for stage 5, the current design of the virtual gallery has expanded the two gallery 2 areas for displaying the new exhibition 2 which has more exhibition items.

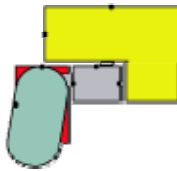
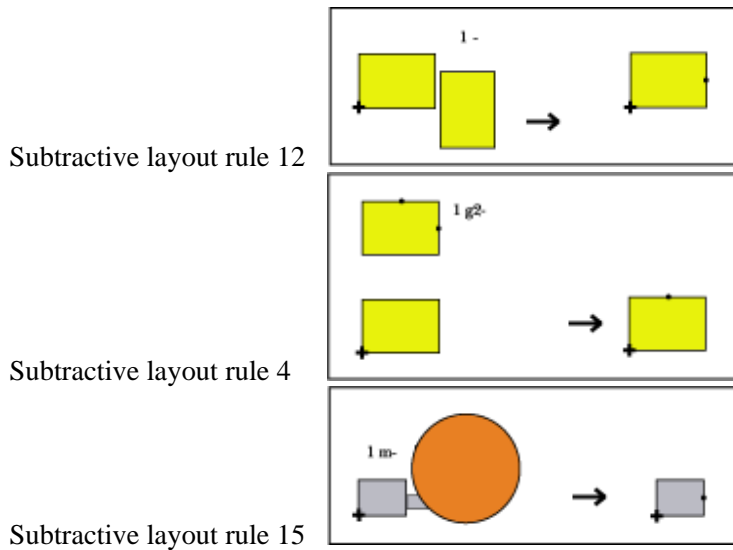
6.8 STAGE 7: SOME VISITORS LEAVE THE VIRTUAL GALLERY

Description: at stage 7, more and more visitors disconnect from the virtual world. At one point, one of the gallery 1 areas has no visitor. Acosta's GDA senses this change and applies its generative design grammar to remove this gallery area. Similar situations soon occur in one of the gallery 2 areas and in the multi-function area.

For the execution of stage 7, in the process of interpretation, the GDA interprets the changing needs of Acosta and the visitors and changes in the virtual gallery; for example, the main change at stage 7 is the decrease of visitors in the virtual gallery. Based on its current interpretations, in the process of hypothesising, the GDA hypothesises design goals; for example, one of the design goals hypothesised by the GDA at stage 7 is $O_{exp}^F = g1-$ (a standard gallery 1 area is redundant). With new design goals being hypothesised, new state labels can be matched for the search of eligible design rules in the example grammar for application.

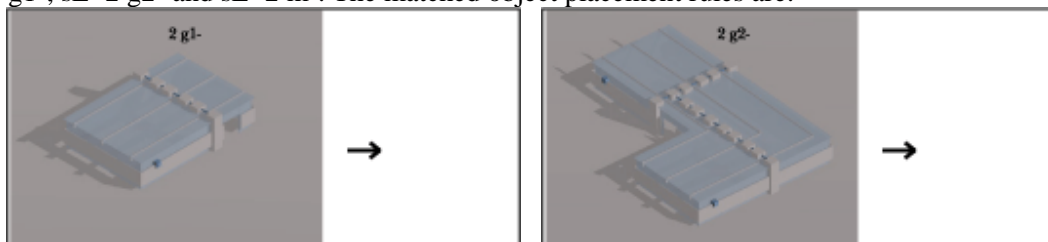
Firstly, in the application of layout rules the newly matched state labels are $sL=1\ g1-$, $sL=1\ g2-$ and $sL=1\ m-$. The matched layout rules are:



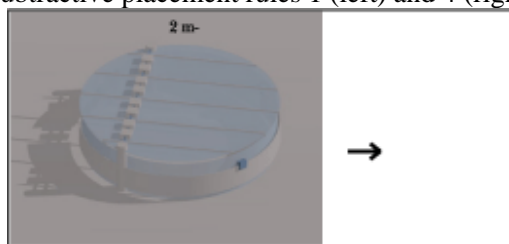


By applying the above rules, a layout of the virtual gallery is generated for stage 7. Relevant gallery areas and the multi-function area are removed.

Secondly, in the application of object placement rules the newly matched state labels are $sL=2\ g1-$, $sL=2\ g2-$ and $sL=2\ m-$. The matched object placement rules are:



Subtractive placement rules 1 (left) and 4 (right).



Subtractive placement rule 9.

The above subtractive placement rules are applied to demolish the visual boundaries and visual cues of the relevant gallery areas and the multi-function area. To complete the design, the GDA searches and applies appropriate navigation rules to demolish any excessive way finding aids and hyperlinks due to the removal of the areas. No interaction rule is applied at stage 7 because behaviours are automatically extinguished once the objects to which they are ascribed are removed.

Figure 6.12 shows the visualisation of the virtual gallery design generated for stage 7. Compared to the design generated for stage 6, two gallery areas (a standard gallery 1 area and an expanded gallery 2 area) and the multi-function area are removed in the current design. A reception area is also removed due to the removal of the above areas.

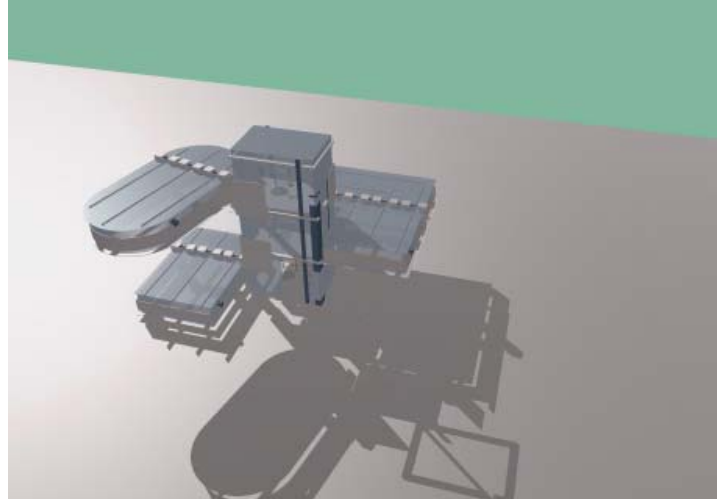


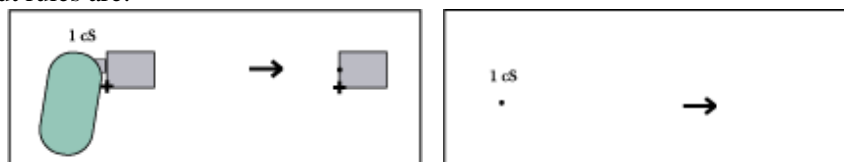
Figure 6.12. The visualisation of the virtual gallery design for stage 7.

6.9 STAGE 8: THE ARTIST LEAVES THE VIRTUAL GALLERY

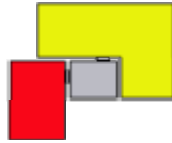
Description: at the final stage of the design scenario the artist disconnects from the virtual world. The GDA records the current design of the virtual gallery for future references. The GDA then applies the example grammar to remove Acosta's personal studio area and removes all spatial labels of the design to terminate the example grammar application, before terminating its own agent program. This generates a static design of the virtual gallery. Visitors can continue their visits to the exhibitions. The design is static as all areas of the virtual gallery will remain unchanged no matter what happens in the gallery. The dynamic design process will re-start when Acosta returns to the virtual gallery next time.

For the execution of the final stage, in the process of interpretation, the GDA interprets the changing needs of Acosta and the visitors and changes in the virtual gallery; for example, the key change at this final stage is Acosta's disconnection from the virtual world. Based on its current interpretations, in the process of hypothesising, the GDA hypothesises a design goal $O_{exp}^F=cS$ (the current design of the virtual gallery is to be used as a static design and the gallery stops being dynamically designed). With the new design goal being hypothesised, new state labels can be matched for the search of eligible design rules in the example grammar for application.

Firstly, in the application of layout rules the newly matched state label is $sL=1 cS$. The matched layout rules are:

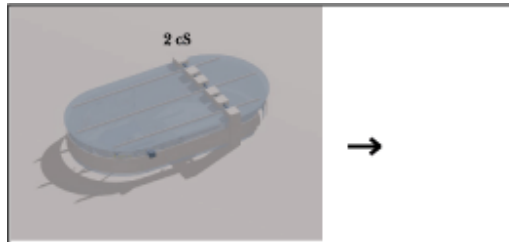


Subtractive layout rules 16 (left) and 17 (right).



The application generates the layout of a static design for the virtual gallery. Subtractive layout rule 16 is applied to remove the layout of Acosta's personal studio area, and subtractive layout rule 17 is applied multiple times to remove all spatial labels from the design so that the application of the example grammar can be terminated.

Secondly, in the application of object placement rules the newly matched state label is $sL=2$ cS. The matched object placement rule is:



Subtractive placement rule 8.

Subtractive placement rule 8 is applied to demolish visual boundaries and visual cues of the studio area. To complete the design, the GDA searches and applies appropriate navigation rules to remove any excessive way finding aids and hyperlinks due to the removal of the studio area. No interaction rule is applied in the final stage because behaviours are automatically extinguished once the objects to which they are ascribed are removed.

The generated static design of the virtual gallery is visualised in Figure 6.13. The static design comprises a standard gallery 1 area, an expanded gallery 2 area, and a reception area that connects to the two gallery areas.

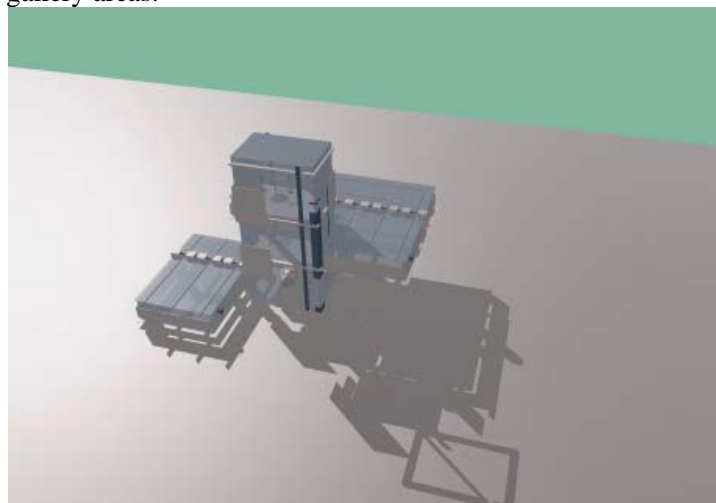


Figure 6.13. The visualisation of the static virtual gallery design generated in the end of the design scenario.

6.10 DISCUSSION

The design scenario for the dynamic design of a virtual gallery has been described in sections 6.2 to 6.9. Completing the design scenario, the artist's GDA has dynamically generated eight designs of the virtual gallery for the eight stages of the design scenario. Figure 6.14 shows how the virtual gallery changes from stage 1 to stage 8. The designs of the virtual gallery generated for the

scenario are visualised in sequence from the top to the bottom in the left-hand-side column of the figure. The layouts of these designs are illustrated in the right-hand-side column of the figure. As discussed in sections 6.3 and 6.6, alternative designs could have been generated if the artist had preferred to expand the virtual gallery in a different dimension at stages 2 and 5. These alternative designs are presented in the forms of their layouts, also in the right-hand-side column. They are marked with a darker background colour to contrast the ones that are generated for the scenario.

6.10.1 Purposes of the Design Scenario

Although the design scenario is constructed in the context of a specific kind of virtual gallery for an artist and it is developed with a set of limitations as described in section 6.1.1, the scenario demonstrates the effectiveness of the GDA model and generative design grammars both for dynamic design of virtual worlds in general.

The eight stages of the design scenario present the following changes that may occur in the virtual gallery during its use:

- Stage 1: the artist becomes present in the virtual gallery.
- Stage 2: the number of visitors increases.
- Stage 3: the artist and an invited guest plan to have a meeting.
- Stage 4: the artist plans to give a public talk.
- Stage 5: the visitors are distributed differently in the virtual gallery.
- Stage 6: the artist decides to change one of the exhibitions.
- Stage 7: the number of visitors decreases.
- Stage 8: the artist disconnects.

The execution of the design scenario shows that the artist's GDA reasons about the above changes and applies the example grammar illustrated in Chapter 5 to dynamically design and implement the virtual gallery in order to address these change. Aiming to satisfy the GDA's current design goals, the application of the example grammar is directed by a special set of state labels so that each generated design of the virtual gallery provides appropriate areas equipped with visual boundaries, visual cues, way finding aids and hyperlinks, and other purposeful objects to support the intended activities of the virtual gallery for each stage. The comparison of the eight different virtual gallery designs generated for the eight stages of the design scenario are shown in Figure 6.14.

6.10.2 Stylistic Characterisations of the Virtual Gallery Designs

The design scenario also demonstrates the capability of generative design grammars as a design formalism for virtual worlds. As discussed in Chapter 4 section 4.1.3, a generative design grammar is able to describe and generate a design language for virtual worlds that captures certain stylistic characterisations shared by all design instances. The corpus of virtual gallery designs generated for the design scenario presents a small set of samples from the design language defined by the example grammar presented in Chapter 5. Although these virtual gallery designs are generated for different purposes, at different moments during the use of the virtual gallery, they provide a similar impression by sharing a sense of design coherency. The stylistic characterisations shared by these generated virtual gallery designs can be outlined from the following three aspects.





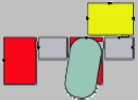


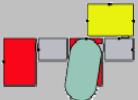

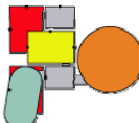
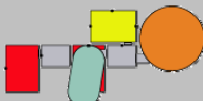


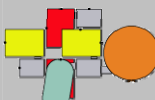
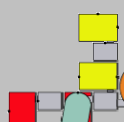
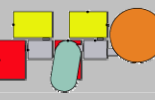

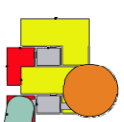
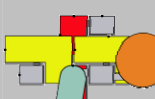
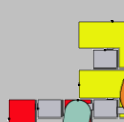
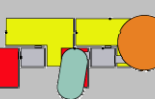

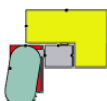


3D Visualisation	Layout			
Stage 1 				
Stage 2 				
Stage 3 				
Stage 4 				
Stage 5 				
Stage 6 				
Stage 7 				
Stage 8 				

Figure 6.14. The corpus of virtual gallery designs generated for the design scenario.

- Visualisation: the virtual gallery designs generated by the example grammar are coherent in terms of the spatial relations defined for different areas of the virtual gallery, and the use of forms and colour schemes for visualising the virtual world objects.
- Navigation: the generated virtual gallery designs follow the same guidelines for providing way finding aids and hyperlinks to assist the visitors' navigation in the virtual gallery.
- Interaction: the generated virtual gallery designs also have similarities in activating object behaviours. Therefore, similar experiences can be gained and applied to assist the visitors participating in activities in the virtual gallery.

6.10.1 Technical Implementation

In terms of the technical implementation of the design scenario, the GDA is implemented on the base of the KCDCC AW agent package¹². Each stage of the scenario is implemented in a virtual world developed using Active Worlds¹³. The design rules of the example grammar, and a general rule base for supporting the GDA's reasoning, are written using Jess¹⁴, a rule-based scripting language (Friedman-Hill 2003). The source codes of the implementation are included in the attached CD-ROM. The CD-ROM also includes digital movies with aural narratives that demonstrate dynamic design of the virtual gallery at different stages. The references to the source codes and the digital movies are outlined in Appendix 2. The implemented designs for the eight stages of the design scenario are shown in Figures 6.15 and 6.16.

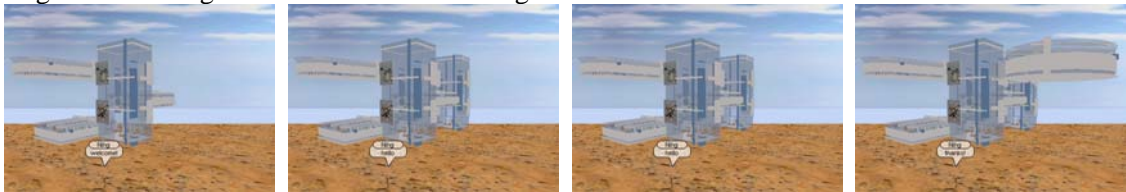


Figure 6.15. The implemented designs for the design scenario (from left to right): stages 1 to 4.



Figure 6.16. The implemented designs for the design scenario (from left to right): stages 5 to 8.

¹² The KCDCC AW agent package is developed by Dr. Greg Smith and Prof. Mary Lou Maher in the Key Centre of Design Computing and Cognition at the University of Sydney. More information about this agent package can be found in Dr. Greg Smith's web site: http://www.arch.usyd.edu.au/g_smith/awagent.html

¹³ <http://www.activeworlds.com>

¹⁴ <http://herzberg.ca.sandia.gov/jess>