Semantic Modeling for Ancient Architecture of Digital Heritage*

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Abstract

In this paper, we introduce a semantic modeling project by implementing a southeast China vernacular urban modeling system. This system converts the basic modeling components of geometry units (e.g. point, line, triangle etc.) into the semantic components (e.g. street, block, patch, house etc.). To implement the urban modeling system semantically, an XML based description and DTD[31] based verifying technology has been used to control the process of urban generation in detail, and this DTD based verifying technology can avoid the disadvantage (such as hard to control etc.) of the grammar system and to ensure the coherent architecture styles of ancient vernacular houses. Because of the advantages (accurate modeling and rapid generating) of this semantic project system, it can be applied to the preserving of the digital heritage in southeast China vernacular architecture.


Keywords: semantic, modeling, vernacular house, building design, architecture, grammars

1 Introduction

Digital heritage is a hot research topic in the past few years. The objective is to find new ways of representing, analyzing, manipulating and managing different kinds of digital cultural objects from different media sources. Nowadays, special attention was paid to surrogates of fragile physical objects. Modeling of ancient architecture such as house is one of the important works in the development of digital heritage systems. This paper addresses the semantic modeling project implementing building vernacular house of southeast China, where many ancient towns, streets or blocks are well reserved in the water country. The original motivation for our work is to building the digital heritage to reserve the architecture of southeast China, such as He Fang Street (Figure 1.) in Hangzhou (it is the Capital of South Song dynasty from 1217~1279, and now is the capital of Zhejiang province), which was a large commercial street in the past several hundred years, and Xitang, a small beautiful town located at Jiashan county, Zhejiang province, near the river, reserved blocks of residential houses of the ancient time, and the same ancient towns, Zhou Village, Tongli etc. (they are located at Jiangsu province, southeast China). They are all the treasures of Chinese culture.

The basic concept of semantic modeling project is that the semantic modeling project promotes the object from the graphical basic units (points, lines, triangles, curves etc.) to semantic portions, (for example, in a city, there are streets, districts, houses etc.). By this way, the final users can pay more attention to their special implementation, and those graphical details have been encapsulated upon the semantic portions.
When generating such construction of ancient style by computers, there are many difficulties. One of the difficulties is that the shapes of vernacular houses are much more complex than other modern buildings. The vernacular houses include two kinds of most important styles: residential houses, and commercial houses. Each type of houses has its own building style. These two kinds of houses are combined rationally to form the ancient cities by a certain ubiquity. And how to arrange these two types of house is another difficulty. So the common requirements to the modeler are: (1) most of the models can be developed automatically; (2) the buildings and objects in the scene are able to follow a certain style and able to distinguish from each other at several aspects, such as geometry and texture appearance etc.; (3) the model complexity should be suitable in case that the model is too complicated to render or too simple and lack of verisimilitude.

In our semantic modeling project, we divide the urban into components, such as street, house, gate, window, wall and roof, which constitute the semantic portions in urban modeling and are described by XML. To generate and control the urban model automatically, a production-based (this is similar to the L-system [8]) modeling method is used, which controls the detail generating process of the vernacular house. For the modeling generated by those production rules can be random and unpredictable, a DTD based verifying technology has been implemented to maintain the generated models in the coherent styles. As mentioning to the modeling generation, the grammar generation systems have achieved impressive result. It is first implemented in the plant modeling [8], [12], [13], [14], and then recently it has been used in the large-scale city building [21], [22]. The grammar generation systems cause the generated cities lack of authority in urban design, so there should be some more attention on the urban design theory implementing in city modeling [5], [16], [4].

The fundamental difference of our approach to previous work [22] is that the generation process has been promoted to a higher mankind’s semantic layer. That means the input for urban generation is not longer a series of numeric parameters, it has change to a segment description language, this will decrease the modeling complexity and modeling workload to those designers.

After addressing the aforementioned problems, we present the following contributions:

- We increase the modeling level from numeric parameters to language description, decreasing the complexity and workload to designers.
- We improved the rule grammar system, adding numeric parameters to these rules, which can generate the models more accurately.
- We divide the modeling into the XML based semantic components description and DTD based topology and combination verifying, this will solve the problem (hard to control) of grammar system.

The next paper is organized as follows: section 2 will discuss some current applications of the digital heritage. Section 3 gives out the overview system architecture introduction, Section 4 describes the semantic portions definitions and Section 5 discusses some semantic control on topology and combination of the southeast vernacular houses modeling system. Then we give some examples of modeling in section 6. Finally we conclude in Section 7 with some discussion and directions for future work.
2 Related Works for Preservation of Digital Heritage

With the development of computer technology, more and more new technologies have been implemented in the digital heritage. There are three kinds of common computer technology involving the digital heritage. They are digital input methods, IBR (IBM) technology, 3D Modeling technology.

2.1 Digital Input Methods

This method is mainly depending on the digital input hardware, such as the digital video, digital camera, three-dimension scanner, laser scanner and CT scanner etc. It is mostly used in the statues heritage [7] reserving and solid model heritage reserving. Additionally, the laser scanner devices output is a very large points cloud data set, such as the Livio De Luca’s work [32], which should be processed by some complex methods and high performance hardware. However, the cost of that hardware (especially the scanners) restricts the broad implement for this method.

2.2 IBR and IBM Technology

IBR [6], [19] technology is to process several images to obtain the new images that are different to the original images. The main usage of IBR technology implement in digital heritage is the panorama [20]. Panorama can build the whole view of the heritage by combine multiple images of the heritage. IBM [2], [15] is also very useful in digital heritage, it rebuild the model from the images. While they only roam from these images, these tow technology still cannot offer visitors a real contact with those heritage.
2.3 3D Modeling Technology

The computer modeling techniques have been researched for a long time. Normally there are two mainly categories of modeling technology, they are manual modeling and automated modeling.

In manual modeling, the users use commercial modeling software such AutoCAD, 3D studio max, Maya etc., to design and render the heritage modeling. Although the manual modeling can generate the most accurate and complicated models (see Figure 2, the VR scene generated by 3D Studio Max), it is a time-consuming work, it will spend the designers huge of time. A typical manual model case is given by ChiuShui Chan etc. [3], building the model of traditional Chinese architecture. A higher level of manual modeling can use the VR tools, for example Vega [9], to generate model. Vega provides a series of interactive tools for building the model and a render library implement by C Language. So we can use Vega’s interactive tools to build the models and render those models by Vega’s render library in our programs.

The automated modeling can generate the models only by several parameters. The detail generation is controlled by programs. Yoav I. H. Parish [21], [11] introduced a stochastic, parametric L-system to generate the geometry for the buildings. A set of rules was set up to control the transformation, scaling, extrusion and branching of the building geometry. Another approach for architecture modeling is apart the basic units of houses, such as roof, wall, window, gate etc, and combining them to generate new buildings [10], [17].

From above description, most of these modeling techniques are all aimed to those professional modeling experts, who should be familiar with the techniques of computer graphics when they are using these modeling systems. To most of special applications, such as movie production, city planning, etc., the users should consider both the computer graphics techniques and special domain knowledge in practice, and this will restrict the implementation of the modeling systems. Therefore, in our semantic project, it will focus on the improvement for the automated grammar modeling system and the description from semantic layer.

Figure 2. Walkthrough Scene Generated by Modeling Software
3 System Architecture

Before presenting the implementation of semantic modeling, let’s review about the traditional modeling process, see Figure 3(left). In traditional modeling process, users first form the models in their cerebra and then exchange the imaged model into graphical basic units (points, lines, curves etc.). After the time consuming building process on computers, they can find whether the result is reasonable. If not, the model should be revised by passing the re-modeling process. It is a boring and time-consuming process, users have to wait the relative slow process of computer rendering or generating patiently.

The semantic modeling process can be depicted as Figure 3(right). There is a semantic layer before the modeling process, by which users can transform their model plans into the semantic description. And the available process can be brought forward the modeling process, which can avoid the long and bored re-modeling process in case of the faulty models.

There are two parts in semantic layer, the parser and the verifier. The parser is used to convert the semantic portions into graphical units, its function is similar to a translator. The verifier of the semantic layer is used to check the available of the urban models built in semantic layer, its function is similar to an auditor.

The verifier of ancient southeast China vernacular urban modeling system is based on the roadmap and the styles of buildings. The first rule is that those houses should be positioned beside the road and not on the road, so the road could be regarded as the disjunction of the houses. The styles of houses are decided by each component of the houses and the combination of these parts. The styles of components can be dealt with easily, because the styles of components are relatively finite. In fact, the arrangement of these parts is the most difficult thing to ensure the styles for the whole house. The house is established by the production of the recursion grammar, then each house can be individually written as a sequence of the grammar terms. By this way, the style ensuring work will be dealt as the
term grammar check, the verifying system only needs to check the sequences generated by the production engine and to match the sequences with the predefined styles term sequences.

The detail system architecture of the semantic modeling process is shown in Figure 4. In the first step, users should specify the urban map for generation, the semantic architecture components are also specified as the input data. Then the city generator module will match the roadmap with the buildings’ block size and patch size automatically and generate the corresponding models in the description format. The style checking is processed by the city generator with the guiding of user specified building style format (DTD), and only the right style models can be forward to the next step for rendering. Before outputting the final model images, the city generator also provides an interactive toolkit (AASMT), see Figure 16, to adjust the models.

![Figure 4. System implementation of the semantic modeling](image)

4 Semantic Portions of Vernacular House

The key problem in semantic modeling project is the definition of semantic portions. The vernacular houses of South-east China have similar styles in the components, so the houses can be disassembled into several reusable parts, each special house could be regarded as the assembling of these parts. In our method, these parts constitute the terms of the recursion production controller, which controls the houses’ generation. While several components of the vernacular houses, such as the conjunct walls, the roofs and the gate window walls, have complex constructions and different styles from the other architectures. The styles of these special parts will be introduced in the follows.

4.1 Components Definition & Semantic Parser

The components terminology of vernacular houses is defined as the follows table 1:
<table>
<thead>
<tr>
<th>Components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street</td>
<td>Consists of a road and two lines of houses</td>
</tr>
<tr>
<td>Zone</td>
<td>Consists of several blocks with the same house type in a certain permutation.</td>
</tr>
<tr>
<td>Block</td>
<td>Houses with certain house types separated by roads.</td>
</tr>
<tr>
<td>House</td>
<td>Consists of a base, several gates, one roof, more than four walls and several windows.</td>
</tr>
<tr>
<td>House type</td>
<td>There are two types, commercial and residential.</td>
</tr>
<tr>
<td>House style</td>
<td>The style of houses built in different epoch or region.</td>
</tr>
<tr>
<td>Roof</td>
<td>Consists of a lot of shells organized in a certain manner.</td>
</tr>
<tr>
<td>Window</td>
<td>Consists of the window frame and texture-based hole.</td>
</tr>
<tr>
<td>Gate</td>
<td>Consists of gate frame and the texture-based hole.</td>
</tr>
<tr>
<td>Base</td>
<td>A platform on which the house is built.</td>
</tr>
<tr>
<td>Texture</td>
<td>Consists of several small texture tiles.</td>
</tr>
<tr>
<td>Shell</td>
<td>The smallest element that cannot be divided in a house.</td>
</tr>
<tr>
<td>Wall</td>
<td>Including street wall and conjunct wall.</td>
</tr>
<tr>
<td>Con jurct wall</td>
<td>It is a wall that shared by two houses.</td>
</tr>
<tr>
<td>Street wall</td>
<td>It is a wall adjacent to a street, including gate window wall and shop wall.</td>
</tr>
<tr>
<td>Gate window wall</td>
<td>It is a street wall of a residential house. (Since it can be divided into wall, gate and window, we can construct a model differing from these three components)</td>
</tr>
<tr>
<td>Shop wall</td>
<td>It is a street wall of a commercial house. (Since the shop wall is too complicated to be modeled, we plan to use texture to represent it.)</td>
</tr>
</tbody>
</table>
The city (or urban) can be divided into block, street, zone, road etc. The house can be divided into three portions: roof, base and wall, each of these portions can be subdivided into some portions.

Based on the analysis of the house functional components, a hierarchy of the components is built up (Figure 5). For example, gate, window and wall can be organized as gate window wall; gate window wall or shop wall, conjunct wall and roof can be organized as house, etc. Figure 6 gives out a sample example for the semantic components for the Southeast China vernacular house.
4.2 Conjunct Walls in Vernacular House

The conjunct wall refers to the wall between two houses, it can be used to separate the two houses of different families in the southeast vernacular houses. Conjunct wall consists of two parts: the roof ornament, and the wall body. The roof ornament is a specialty of Chinese traditional architectures, which also exists in all the wall components. It looks like a mini-roof of the southeast vernacular house. The roof ornament of a wall is a simplified common roof, which has no centerline and inclines outside the yard of the vernacular house, this will drain the water outside when raining. So it uses not only as the ornament but also as the simple drain system in vernacular houses. This design will quite useful in the vernacular house, as there is quite much rain in the whole years of China southeast.

The wall body of a conjunct wall normally is irregular geometry. Figure 7 gives out the four types of the irregular conjunct wall bodies. The conjunct wall of B in Figure 7 is the wall with roof ornament.

![Four Styles of Conjunct Walls](image)

Figure 7. Four styles of the conjunct walls

In our semantic description system, the conjunct wall can be described by the several parameters, the length and the width of the wall which refers the minimal container box of the wall, the thickness of the wall, the geometry (polygon) of the wall, and the texture of the wall etc. The wall ornament is optional based on the position of the conjunct wall.

4.3 Roofs in Vernacular House

The roofs of southeast China vernacular houses may be the most notable style symbol. The geometry of the roofs is normally inclined toward the floors, which can be helpful to the water drain in raining days. There are three types of the roofs in vernacular houses, they are common roof, cone roof and half-pyramid roof. A typical common roof is displayed in Figure 8. According to the Figure 8, we can see that the common roof can be described by the parameters of the length of the roof, the width of the roof, the grade of the roof and the center axes width of the roof.

![Common Roof](image)

Figure 8. The common roof in southeast China vernacular house

Cone roof consists of three parts: one center point, several centerlines emitted from the center point and a cone-shaped roof surface. In the implementation view, the center point is a little cylinder,
several centerlines are several cuboids and the cone-shaped roof surface can be constructed by sweeping a rectangle through a circle. So the attributes that a cone roof must have:
a) Radius and height of the center point;
b) Length, width, height and the number of the centerlines;
c) Length, thickness and joint angle between the cone surface and the perpendicular bisector;
d) Location and Relative height of the center point.

Having some similarity with the cone roof, pyramid roof can also be divided into three parts: one center point, several centerlines emitted from the center point and several triangular roof surfaces separated by the centerlines. Half-pyramid roof appears when a pyramid roof connects with a common roof or connects with a wall. Therefore half of the pyramid roof is cut down by the connecting wall. So the attributes that a pyramid roof must have:
a) Radius and height of the center point;
b) Length, width, height and the number of the centerlines;
c) Joint angle between the centerlines and the perpendicular bisector;
d) The thickness of the triangular roof surfaces.

4.4 Gate Window Walls in Vernacular House

The gate window wall refers the wall that contains the windows and gates. The geometry of the gate window wall is regular, then the attributes of the walls, the gates and the windows are simple, such as the length, width, height, position, texture etc. However, their combination styles may be varied. So the description for those styles is quite a challenge. The previous works such as the shape grammar [23] [24] [25] [26] [27] [28] [29] and the split grammar [11] in architecture have provided a grammar method for the approach. As many of the research works are carried out to generating the architecture automatic by the grammar recursion, we adopt a technique named grid template technique, which is similar to the split grammar, to maintain the right styles of the gate window wall in vernacular house.

The grid template is grid geometry, normally the grid, which corresponds to the gate window wall, is divided into several cells, Figure 9, and each cell in the grid contains a window or a wall. Then the combination styles depend on the grid styles, each grid presents a combination style of the gate window wall. This grid is also called the style template. The grid template can be used as the verifying for our house generating system [22]. The details for the template presentation will be introduced in section 5.

Figure 9. The grid template for the gate window wall
5. Semantic Control on Topology and Combination

The definition of the semantic components of vernacular house only finishes the first step of the semantic modeling, another important approach for semantic modeling is the topology control and the combination control between those semantic components. In fact, the semantic modeling project can be viewed as one kind of language system. The semantic components are the basic vocabularies. And the semantic control on topology and combination are the language grammars. The right vocabularies assembling random cannot present the right meaning, only those right vocabularies assembling under the grammars can present the right meaning. So the semantic control on topology and combination are quite important to present and model the vernacular houses’ styles rightly.

The topology control mainly concerns the plane position relationship among the houses and walls. The combination control mainly concerns the compounding relationship among all the semantic components defined in previous section.

Obviously the description for grammar is more difficult than the description of vocabularies. In our approach, a XML based description and DTD based verifying technology has been adopted.

5.1 Semantic Control on Topology

In our semantic modeling project, these components are the basic functional parts that aim to the urban builders who do not need to grasp those profound techniques of computer graphics. The only thing that they should do is to design the topology of components. Here, we use a XML [18] based knowledge representation method to depict the topology of components.

![Diagram of a typical topology in Southeast China vernacular house](image)

**Figure 10.** A typical topology existing in Southeast China vernacular house. The vernacular house units is a rounding architecture normally; it includes the center yard, a shop wall, gate/window wall, two conjunct walls and tow houses.

In Figure 10, we give a typical topology existing in southeast China vernacular house. It is a block unit in our semantic modeling system, constituted by a north house, a central yard and a south house. By adopting the XML based description method, we can obtain the result as follows:

```xml
<Block BlockName="Block1">
  <House housename="NorthHouse">
    <Layout layouttype="BorderLayout">
      <RUWK+RXVH &HQWHU>
      <DUG 6RXWK+RXVH &RQMXQFW ZDOO>
      <6KRSZDOO *DWHZLQGRZ ZDOO &RQMXQFW ZDOO>
    </Layout>
  </House>
  <Conjunct wall>
    <Center Yard>
      <SouthHouse>
        <Gate/window wall>
      </SouthHouse>
    </Center Yard>
  </Conjunct wall>
</Block>
```
After parsing this segment of XML code, a hierarchy structure of the typical vernacular house has been maintained in modeling system, which can be sent to rendering module for generation. Before the generation step the detail sizes of the components will be checked by the improved control rules system, which will be introduced in the next section. Only when the maintained vernacular house structure that parsed from XML based semantic description can meet the requirement of these improved control rules, then the rendering step can be processed. Figure 11 shows the generation result of the above XML code.

Figure 11. Typical vernacular house in Southeast China

There are six typical topologies of the vernacular house in southeast China, listed in table 3 (Appendix A). Similarly, those six topologies can also be described by the XML styles as same as the example given in Figure 12. In Table 3, the description of ration means the corresponding relationship among the length of the house, the width and the length of the topological block. The length and the width in this table refer the length and width of the whole topological block. The examples in table 3
are all generated from the XML based description automatically by our Ancient Architecture Semantic Modeling Toolkits (AASMT) show in Figure 16.

Figure 12. Topology, Description, 3D-Model for the Semantic Implementations

5.2 Semantic Control on Combination

In the modeling process, there should be some rules to ensure the validity of the generated urban buildings. In our previous system [22], we present a recursion grammar engine drives the urban modeling system. The terms in the production rules are constituted of those components defined in previous section 4.1. In this recursion system, the texture has become one kind of terms that are controlled by the production system. These productions can divide the whole city into basic elements, box, cone, cylinder, and texture etc, which can increase the efficiency of the modeling greatly. However, this recursion grammar system also has their common weakness, that it is hard to control their generation results (Actually we have to design a verifying system to ensure and check the generation results in our previous system). So we promote the rule recursion grammar system, adding the ratio factor to each of these rules. Then when the generation system controls the modeling process, it has to obey both the components combination relationship, which is controlled by the recursion rules, and the components ratio.

The improved productions are defined as follows.

\[
\begin{align*}
\{ \text{CITY} &:: ( \text{ROAD} ), ( \text{BLOCK} ) ; \\
(R_{\text{road}} (\text{Width}, \text{Length}, \text{Height}, \text{Number})) ; [R_{\text{block}}(\text{Width}, \text{Length}, \text{Height}, \text{Number}) ] \\
\} \\
\{ \text{BLOCK} &:: ( \text{PATCH} ), ( \text{BLOCK} ) \mid \varepsilon ; \\
\end{align*}
\]
\[
\begin{align*}
\{ \text{PATCH} &: ( \text{CONJUNCT\_WALL1} ), ( \text{HOUSE} ), ( \text{PATCH} ) \mid \varepsilon ; \\
\{ \text{R}_{\text{conjunct\_wall}}(\text{Width, Length, Height, Number}) &: \text{R}_{\text{house}}(\text{Width, Length, Height, Number}) &: \text{R}_{\text{patch}}(\text{Width, Length, Height, Number}) \}
\end{align*}
\]

\[
\begin{align*}
\{ \text{HOUSE} &: ( \text{BASE} ), ( \text{WALL} ), ( \text{ROOF} ) ; \\
\{ \text{R}_{\text{base}}(\text{Width, Length, Height, Number}) &: \text{R}_{\text{wall}}(\text{Width, Length, Height, Number}) &: \text{R}_{\text{roof}}(\text{Width, Length, Height, Number}) \}
\end{align*}
\]

From the above rules definition, the rule defines both the combination relationship and the ratio relationship. Here the ratio includes four parameters, they are width, length, height, number. The first three parameters give out the outline ratio relationship between those components, and the number parameter describes the components number ratio between components.

As the rule based recursion system has achieved many successful implementations such as the system in [22], [21], [11]. It is more suitable for the automatic modeling than verifying whether the architecture style is rational. The simple constraint rules cannot describe all the styles of complex ancient architectures. On the other side, once the artists illustrate the ancient architecture by the rule terms directly, how can we know the style of the architecture obeys the constraint rules in those recursive systems? So a more expressive technology for the semantic modeling is desired.

As the topology and the semantic components are all described by the XML, the DTD [] has been used as the verifying protocols. Table 3 gives a tree viewed DTD verifying grammar for the components combination. A more detail DTD file is listed in Appendix B.

In our modeling system, the XML DTD also implements those control rules. The urban models can be multi-instances, but the style of one kind of model is the same one. So the DTD supported by the XML technique can provide a flexible control policy to regulate the whole style and integrity of models.

Figure 13. A wrong example generated by the city engine without the DTD controlling
5.3 Roadmap Description and Control

Another special component in our semantic project is the road in southeast China. Normally the spare space outside the patches and blocks in the semantic components can all be viewed as the roads. However, this condition can not be true for all the cases, sometimes, there may be some other additional components that lie on the spare space. And the styles of different roads in patches may be varied. So the roads should be distinguished and marked individually.

The description for the roadmap is also implemented by the XML. We use the “road” tag to describe the road component, and each road contains four default properties which are list in table 2.
Table 2 The default properties for the road components

<table>
<thead>
<tr>
<th>Property</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Identity</td>
<td>by this identity we can differ the road components in the description</td>
</tr>
<tr>
<td>Road Name</td>
<td>A name that the user assigns for the road</td>
</tr>
<tr>
<td>Road Texture</td>
<td>The render texture of the road components</td>
</tr>
<tr>
<td>Road Geometry Information</td>
<td>The position information of the road components</td>
</tr>
</tbody>
</table>

The road geometry information is described by four basic geometry elements, the point, linestring, box and polygon which are similar with the GML (Geography Markup Language) [30]. So we can process the topology by invoking the GML interfaces. The DTD definitions for the four elements are given as follows:

1. Point element, the basic unit
   ```xml
   <!ELEMENT Point (X, Y, Z)>  
   <!ELEMENT X (#PCDATA)>  
   <!ELEMENT Y (#PCDATA)>  
   <!ELEMENT Z (#PCDATA)>  
   ```
2. Linestring element
   ```xml
   <!ELEMENT LineString (Point,Point)>  
   ```
3. Box element
   ```xml
   <!ELEMENT Box (Point,Point)>  
   ```
4. Polygon element
   ```xml
   <!ELEMENT Polygon (Point+)>  
   ```

As the roadmap information and the semantic components description language are coherent, we can use a unified description parser for these objects. So the parser should be compatible on both the GML and our XML based ancient architecture description language.

6 Experiments Results

Here we present some images generated as the output of the semantic urban modeling system (Figure 15, 16, 17, 18). All the images are performed on a real-time system, and the render are implemented in Java3D based on the semantic geometry description files. Figure 15 are the two different styles of the textures for the vernacular houses. And Figure 16 show some simple vernacular houses in the right styles. Shown in Figure 17 are the screenshots of the interactive adjusting toolkit AASMT. This toolkit will display both the tree view of the modeling in hierarchical structures (left view) and the visualization of the models (right-up view), then users can adjust the parameters in the tree structures directly, and the visualization of the models will adjust as the parameters changing. The interactive adjusting result is show in Figure 17(b), and the Figure 17(a) is the model before adjusting. The final Figure 18 shows the streets which are consisted of the vernacular houses of southeast China.
Figure 15. Two styles of the texture components generated by the production system. Style 1 is a texture generated for planar wall, Style 2 is the texture generated for two layers’ wall with a roof.

Figure 16. Two types of houses and Block generated by our system. The left one (a) is a Residential house, center one (b) is a business house, and the right (c) one is a block.

Figure 17. Ancient Architecture Semantic Modeling Toolkits (AASMT), left view is the tree structure of the ancient architecture model, and the right-down view is the XML description for current construction, and the right-up view is the visualization of the architecture models.
7 Conclusion and Future Work

This paper discusses a semantic modeling project of vernacular houses of southeast China by separating the whole models into several functional components, such as gate, window, wall, and roof etc. In semantic modeling, the modeling process can be more understandable and controllable because the modeling process is presented by unify description. And the unify description provides more intelligent grammar for the modeling, so users can focus to the urban design and can ignore the trivial graphics drawing when generating their models. The corresponding constraint rules is also given, which can avoid the disadvantages existing in the recursion grammar system. The productions based grammar system can ensure the similar style of the vernacular houses of southeast China. Moreover, the vernacular houses have been decomposed into some functional components, which are organized by productions. This will offer more details for the houses’ generation.

We envision several possible directions for future work. First, the future work may focus on the smart distribution of vernacular houses based on the different functions of the city, extending more DTD for different styles of the architecture such as modern architectures, European architectures etc.. Second, the style for multiple houses integrating environment is also an interesting work. Third, the fast and effective methods for corresponding virtual environment generation should be more concerned, which could be used in virtual navigation [1].

Acknowledgements

This project is supported by Natural Science Foundation of China (No.60402010), and it is also partially supported by China 973 Program (No.2002CB312106).

References

VRST ’97, pp.173-180.


HTTPS://PORTAL.OPENGEOSPATIAL.ORG/FILES/?ARTIFACT_ID=7174

[31] HTTP://WWW.W3SCHOOLS.COM/DTD/DEFAULT.ASP

# Appendix A

Table 3. Six typical house topologies in southeast China vernacular house

<table>
<thead>
<tr>
<th>Topology</th>
<th>Description of Ratio</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>House</strong></td>
<td></td>
<td><img src="image1.jpg" alt="House Diagram" /></td>
</tr>
<tr>
<td><strong>Yard</strong></td>
<td></td>
<td><img src="image2.jpg" alt="Yard Diagram" /></td>
</tr>
<tr>
<td><strong>House</strong></td>
<td></td>
<td><img src="image3.jpg" alt="House Diagram" /></td>
</tr>
<tr>
<td><strong>Side House</strong></td>
<td>0.8<em>HouseLength&lt;length&lt;1.5</em>HouseLength</td>
<td><img src="image4.jpg" alt="Side House Diagram" /></td>
</tr>
<tr>
<td><strong>Yard</strong></td>
<td>1.5<em>HouseLength&lt;length&lt;2</em>HouseLength</td>
<td><img src="image5.jpg" alt="Yard Diagram" /></td>
</tr>
<tr>
<td><strong>Side House</strong></td>
<td>2<em>HouseLength&lt;length&lt;2.5</em>HouseLength</td>
<td><img src="image6.jpg" alt="Side House Diagram" /></td>
</tr>
<tr>
<td><strong>Yard</strong></td>
<td>1.3<em>HouseLength&lt;width&lt;2</em>HouseLength</td>
<td><img src="image7.jpg" alt="Yard Diagram" /></td>
</tr>
<tr>
<td><strong>House</strong></td>
<td>2<em>HouseLength&lt;width&lt;2.8</em>HouseLength</td>
<td><img src="image8.jpg" alt="House Diagram" /></td>
</tr>
<tr>
<td><strong>Yard</strong></td>
<td>Or</td>
<td><img src="image9.jpg" alt="Yard Diagram" /></td>
</tr>
<tr>
<td><strong>House</strong></td>
<td>0.8<em>HouseLength&lt;length&lt;1.5</em>HouseLength</td>
<td><img src="image10.jpg" alt="House Diagram" /></td>
</tr>
<tr>
<td><strong>Yard</strong></td>
<td>0.8<em>HouseLength&lt;width&lt;1.3</em>HouseLength</td>
<td><img src="image11.jpg" alt="Yard Diagram" /></td>
</tr>
<tr>
<td><strong>House</strong></td>
<td></td>
<td><img src="image12.jpg" alt="House Diagram" /></td>
</tr>
</tbody>
</table>

*Note: Images of examples are not provided in this text representation.*
Appendix B

DTD for the house description:

```xml
<?xml version="1.0" encoding="GB2312" ?>
<!ATTLIST CITY:Allotment
    type (house | leftsidehouse | rightsidehouse | yard) #REQUIRED
>
<!ELEMENT CITY:Block (CITY:Name, CITY:BoundedBy, CITY:BlockMember)>
<!ELEMENT CITY:BlockMember (CITY:Patch*)>
<!ELEMENT CITY:BoundedBy (CITY:Box | CITY:LineString | CITY:Polygon)>
<!ATTLIST CITY:BoundedBy
    type (Box | LineString | Polygon) #REQUIRED
>
<!ELEMENT CITY:BoundingWall (#PCDATA)>
<!ELEMENT CITY:Box (CITY:Point,CITY:Point)>
<!ELEMENT CITY:City (CITY:CityModel)>
<!ATTLIST CITY:City
    xmlns:CITY CDATA #REQUIRED
>
<!ELEMENT CITY:CityMember (CITY:Road*, CITY:Block*)>
<!ELEMENT CITY:CityModel (CITY:Name, CITY:BoundedBy, CITY:CityMember)>
<!ELEMENT CITY:FirstFloorWall (CITY:BoundedBy, CITY:Height, CITY:Thickness, CITY:Texture)>
<!ELEMENT CITY:FirstWall (CITY:FirstFloorWall, CITY:SecondFloorWall?, CITY:SecondRoof?)>
<!ATTLIST CITY:FirstWall
    type (GateWindowWall | ShopWall | ConjunctWall ) #REQUIRED
>
<!ELEMENT CITY:ForthWall (CITY:Name, CITY:BoundedBy, CITY:Thickness)>
<!ATTLIST CITY:ForthWall
    type (GateWindowWall | ShopWall | ConjunctWall ) #REQUIRED
>
<!ELEMENT CITY:Height (#PCDATA)>
<!ELEMENT CITY:House (CITY:Wall, CITY:Roof)>
<!ATTLIST CITY:House
    type (residential | commercial) #REQUIRED
    floor (1 | 2) #REQUIRED
>
<!ELEMENT CITY:Length (#PCDATA)>
<!ELEMENT CITY:LineString (CITY:Point,CITY:Point)>
<!ELEMENT CITY:Name (#PCDATA)>
<!ELEMENT CITY:Patch (CITY:Name?, CITY:BoundedBy?, CITY:PatchTexture?, CITY:PatchMember?)>
<!ATTLIST CITY:Patch
    type (1 | 2 | 3 | 4 | 5 | 6 | 7) #REQUIRED
>`
<!ELEMENT CITY:PatchMember (CITY:Allotment+, CITY:BoundingWall?)>
<!ELEMENT CITY:PatchTexture (#PCDATA)>
<!ELEMENT CITY:Point (CITY:X, CITY:Y, CITY:Z)>
<!ELEMENT CITY:Polygon (CITY:Point+)>
<!ELEMENT CITY:Road (CITY:Name, CITY:BoundedBy)>
<!ELEMENT CITY:Roof (CITY:Name, CITY:BoundedBy, CITY:Length, CITY:Texture)>
<!ATTLIST CITY:Roof
    type CDATA #REQUIRED>
>
<!ELEMENT CITY:SecondFloorWall (CITY:BoundedBy, CITY:Height, CITY:Thickness, CITY:Texture)>
<!ELEMENT CITY:SecondWall (CITY:Name, CITY:BoundedBy, CITY:Thickness)>
<!ATTLIST CITY:SecondWall
    type (GateWindowWall | ShopWall | ConjunctWall ) #REQUIRED>
>
<!ELEMENT CITY:SideHouseWall (CITY:BoundedBy, CITY:Height, CITY:Thickness, CITY:Texture)>
<!ELEMENT CITY:SlantAngle (#PCDATA)>
<!ELEMENT CITY:Texture (#PCDATA)>
<!ELEMENT CITY:Thickness (#PCDATA)>
<!ELEMENT CITY:ThirdWall (CITY:FirstFloorWall, CITY:SecondFloorWall?, CITY:SecondRoof?)>
<!ATTLIST CITY:ThirdWall
    type (GateWindowWall | ShopWall | ConjunctWall ) #REQUIRED>
>
<!ELEMENT CITY:Wall (CITY:FirstWall, CITY:SecondWall, CITY:ThirdWall, CITY:ForthWall)>
<!ELEMENT CITY:X (#PCDATA)>
<!ELEMENT CITY:Y (#PCDATA)>
<!ELEMENT CITY:Z (#PCDATA)>