A shape grammar for teaching the architectural style of the Yingzao fashi

Volume 2, Figures

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Figure 1a. The derivation of the sample design. The design consists of 16 elements (separated vertically): 7 drawings and 9 descriptions. These are grouped in 7 subdesigns. The computation has 7 stages (separated horizontally). Each stage involves a different combination of elements. The principal elements are shown in light grey; the secondary elements in medium grey.
Figure 1b. The derivation of the sample design, reorganized by subdesign.
The upper two charts show what is known: plan diagrams (for dian halls only) indirectly sanctioned in the text (light grey) and extant buildings (bullets).

The lower two charts show for each building type one possible sublanguage \( \Omega'' \) of legal designs (medium grey). Others are possible.

The left two charts are for dian halls, which are higher-ranked than ting halls.

The right two charts for ting halls, which are lower-ranked and, we might assume, smaller than dian halls. The text says nothing about the size of ting hall plan diagrams.

Figure 2. Sublanguages of plan diagram subdesigns. Source: Chen (1992; 1993)
**initial $o$**

\[
\begin{array}{c}
\text{(en, $\beta$)} \\
A
\end{array}
\]

**initial $u$**

\[i = 0\]

**initial $v$**

\[j = 0\]

<table>
<thead>
<tr>
<th>Rule</th>
<th>Diagram 1</th>
<th>Diagram 2</th>
<th>Diagram 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>$i \leftarrow i+1$</td>
<td>$A_2$</td>
<td>$A_3$</td>
<td>$A_4$</td>
</tr>
<tr>
<td>$j \leftarrow j+2$</td>
<td>$A_5$</td>
<td>$A_6$</td>
<td>$A_7$</td>
</tr>
</tbody>
</table>

**Figure 3. Rules for generating plan diagrams (stage A).**
Figure 4. Derivation of a $7 \times 4$ plan diagram (stage A).
Figure 5. Derivation of a $5 \times 6$ plan diagram (stage A).
Figure 6a. The corpus of section diagrams consists of drawings with descriptions, of 18 ting halls from 4 to 10 rafters deep. Of the 18, five are of 10-rafter buildings. These are shown here. The drawings are at least 200 years more recent than the text proper, but they are still useful for our purpose. From Liang (1983, 313–315).
An 8-rafter building, centrally divided, with 3 columns. 8-jia chuan wu, fen xin, yong 3 zhu.

An 8-rafter building, 2-rafter beam in front and back, with 4 columns. 8-jia chuan wu, qian hou rufu, yong 4 zhu.

An 8-rafter building, centrally divided, a 2-rafter beam in front and back, with 5 columns. 8-jia chuan wu, fen xin, qian hou rufu, yong 5 zhu.

An 8-rafter building, a 3-rafter beam in front and back, with 4 columns. 8-jia chuan wu, qian hou 3-chuan fu, yong 4 zhu.

An 8-rafter building, 1-rafter beam [and 2-rafter beam] in front and back, with 6 columns. 8-jia chuan wu, qian hou zhaqian [rufu], yong 6 zhu.

An 8-rafter building, 2-rafter beam in front, 6-rafter beam in back, with 3 columns. 8-jia chuan wu, rufu dui 6-chuan fu, yong 3 zhu.

Figure 6b. The corpus of section diagrams consists of drawings with descriptions, of 18 ting halls from 4 to 10 rafters deep. Of the 18, six are of 8-rafter buildings. From Liang (1983, 316–318).
A 6-rafter building, centrally divided, with 3 columns. *6-jia chuan wu, fen xin, yong 3 zhu.*

A 10-rafter building, a 2-rafter beam abutting a 4-rafter beam, with 3 columns. *6-jia chuan wu, rufu dui 4-chuan fu, yong 4 zhu.*

A 6-rafter building, a 2-rafter beam in front and back, with 4 columns. *6-jia chuan wu, qian hou rufu, yong 4 zhu.*

Left [description assumed]. A 4-rafter building, a 1-rafter beam abutting a 3-rafter beam, with 3 columns. *4-jia chuan wu, zhaqian dui 3-chuan fu, yong 3 zhu.*

Right. A 4-rafter building, centrally divided, with 3 columns. *4-jia chuan wu, fen xin, yong 3 zhu.*

Left [description assumed]. A 4-rafter building, clear span, with 2 columns. *4-jia chuan wu, tongyan, yong 2 zhu.*

Right. A 4-rafter building, centrally divided, a 1-rafter beam, with 4 columns. *4-jia chuan wu, fen xin, zhaqian, yong 4 zhu.* [The description is wrong. For centrally divided, fen xin, read in front and back, qian hou.]

Figure 6c. The corpus of section diagrams consists of drawings with descriptions, of 18 ting halls from 4 to 10 rafters deep. Of the 18, three are of 6-rafter buildings, and four are of 4-rafter buildings. These are shown here. From Liang (1983, 319–321).
Figure 7. Schemata for preparing section diagrams (stage B).
<table>
<thead>
<tr>
<th>$b_0$</th>
<th>tong yan</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_1$</td>
<td>clear span</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$b_0$</th>
<th>fen xin</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_1$</td>
<td>yong $c+1$ zhu</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$b_0$</th>
<th>centrally divided</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_1$</td>
<td>with $c+1$ columns</td>
</tr>
</tbody>
</table>

Figure 8a. Schemata for instantiating beams in section diagrams (stage B).
<table>
<thead>
<tr>
<th>Stage</th>
<th>Beams</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>B16</td>
<td>B17</td>
<td>B18</td>
</tr>
<tr>
<td>$b_2 \leftarrow b_2$, qian zhaqian</td>
<td>$b_2 \leftarrow b_2$, qian rufu</td>
<td>$b_2 \leftarrow b_2$, qian 3-chuan fu</td>
</tr>
<tr>
<td>$b_3 \leftarrow b_3$, yong c + 1 zhu</td>
<td>$b_3 \leftarrow b_3$, yong c + 1 zhu</td>
<td>$b_3 \leftarrow b_3$, yong c + 1 zhu</td>
</tr>
<tr>
<td>$b_3 \leftarrow b_3$, 1-rafter beam in front</td>
<td>$b_3 \leftarrow b_3$, 2-rafter beam in front</td>
<td>$b_3 \leftarrow b_3$, 3-rafter beam in front</td>
</tr>
<tr>
<td>$b_3 \leftarrow b_3$, with c + 1 columns</td>
<td>$b_3 \leftarrow b_3$, with c + 1 columns</td>
<td>$b_3 \leftarrow b_3$, with c + 1 columns</td>
</tr>
</tbody>
</table>

Figure 8b. Schemata for instantiating beams in section diagrams (stage B).
Figure 9a. Schemata for completing section diagrams (stage B).
<table>
<thead>
<tr>
<th>B44</th>
<th>qian a1 hou a2 qian a3 hou a4</th>
<th>B46</th>
<th>qian a1 hou a3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>qian a1 hou a1</td>
<td></td>
<td>qian hou a1</td>
</tr>
<tr>
<td></td>
<td>← qian a1 hou a1</td>
<td></td>
<td>← qian hou a1</td>
</tr>
<tr>
<td>a1</td>
<td>in front, a2 in back</td>
<td>a1</td>
<td>in front, a1 in back</td>
</tr>
<tr>
<td></td>
<td>← a1a2 in front, a1a2 in back</td>
<td>a1</td>
<td>← a1 in front and back</td>
</tr>
</tbody>
</table>

For $a_1 + a_2 = c$:

<table>
<thead>
<tr>
<th>B45</th>
<th>qian a1 hou a2 ← a1 dui a2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$b_2$ ← with $c - 1$ columns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B47</th>
<th>qian hou a1a2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>← qian hou bing a1</td>
</tr>
<tr>
<td>a1a2</td>
<td>in front and back</td>
</tr>
<tr>
<td></td>
<td>← double a1 in front and back</td>
</tr>
</tbody>
</table>

For $a_1 + a_2 = c$:

<table>
<thead>
<tr>
<th>B48</th>
<th>qian hou a1a2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>← qian hou ge a1a2</td>
</tr>
<tr>
<td>a1a2</td>
<td>in front and back</td>
</tr>
<tr>
<td></td>
<td>← a1a2 in both front and back</td>
</tr>
</tbody>
</table>

Figure 9b. Functions for reducing descriptions of section diagrams (stage B).
Figure 10. Preparation of a 6-rafter section diagram (stage B).
Figure 11a. Derivation of a 6-rafter building, centrally divided, with a double 1-rafter beam in front and back (stage B). This section diagram is probably illegal.
Figure 11b. Derivation of a 6-rafter building, centrally divided, with a double 1-rafter beam in front and back (stage B), continued. This section diagram is probably illegal.
Figure 12. Derivation of a 6-rafter building, 1-rafter beam in front, 2-rafter beam in back, with 4 columns (stage B).
Figure 13. Derivation of a 6-rafter building, clear span, with 2 columns (stage B).
Figure 14. Derivation of a 6-rafter building, centrally divided, with 3 columns (stage B).
Figure 15. Derivation of a 6-rafter building, centrally divided, 1-rafter beam in front and back, with 5 columns (stage B).
A 6-rafter building, a 1-rafter beam in front, a 2-rafter beam in back, with 4 columns. 6-jia chuan wu, qian zhaoqian, hou rufu, yong 4 zhu.

A 6-rafter building, centrally divided, with 3 columns. 6-jia chuan wu, fen xin, yong 3 zhu.

A 6-rafter building, centrally divided, a 1-rafter beam in front and in back, with 5 columns. 6-jia chuan wu, fen xin, qian hou zhaoqian, yong 5 zhu.

A 6-rafter building, centrally divided, a double 2-rafter beam in front and back, with 7 columns. 6-jia chuan wu, fen xin, qian hou bing zhaoqian, yong 7 zhu.

A 6-rafter building, clear span, with 2 columns. 6-jia chuan wu, fen xin, yong 2 zhu.

Figure 16. New 6-rafter section diagrams with descriptions (stage B). Whether or not they are legal is for the user to determine.
Figure 17a. Schemata for generating plans (stage C).

\[ (\alpha_3, \beta_3) \times y_3 \]

\[ i \leftarrow i + 1 \]

\[ x = 0, y = 0 \]

\[ x \leftarrow x, x_2 \]

\[ l = 0 \]

\[ m \leftarrow m + 1 \]

\[ x = \frac{n}{2} \]

\[ y = y_0 \]
Figure 17b. Schemata for generating plans (stage C).
Figure 17c. Schemata for generating plans (stage C).
Figure 18. Schemata for instantiating the disposition of beams in plans (stage C).
Figure 19a. Derivation of a plan with $x = (300, 250, 200)$ and $y = 100$ (stage C).
<table>
<thead>
<tr>
<th>i</th>
<th>x</th>
<th>y</th>
<th>i</th>
<th>x</th>
<th>y</th>
<th>i</th>
<th>x</th>
<th>y</th>
<th>i</th>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>300, 250, 200</td>
<td>100</td>
<td>3</td>
<td>300, 250, 200</td>
<td>100</td>
<td>3</td>
<td>300, 250, 200</td>
<td>100</td>
<td>3</td>
<td>300, 250, 200</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 19b. Derivation of a plan with $x = (300, 250, 200)$ and $y = 100$ (stage C), continued.
Figure 20a. Derivation of the plan of a 6-rafter building, 1-rafter beam in front, 2-rafter beam in back, with 4 columns (stage C). Reduced version of figures 20b–c.
Figure 20b. Derivation of the plan of a 6-rafter building, 1-rafter beam in front, 2-rafter beam in back, with 4 columns (stage C). Enlarged version of figure 20a.
Figure 20c. Derivation of the plan of a 6-rafter building, 1-rafter beam in front, 2-rafter beam in back, with 4 columns (stage C), continued. Enlarged version of figure 20a.
Figure 21a. Derivation of the plan of a 6-rafter building, centrally divided, a1-rafter beam in front and back, with 3 columns (stage C). Reduced version of figures 21b–c.
Figure 21b. Derivation of the plan of a 6-rafter building, centrally divided, a 1-rafter beam in front and back, with 3 columns (stage C). Enlarged version of figure 21a.
Figure 21c. Derivation of the plan of a 6-rafter building, centrally divided, a1-rafter beam in front and back, with 3 columns (stage C), continued. Enlarged version of figure 21a.
Figure 22. Schemata for generating partial scale elevations (stage D).
Figure 23. Derivation of a partial elevation with $x = (300, 250, 200)$ and $z = 200$ (stage D).
For $0 \leq i < v/2 - 1$
\begin{align*}
\ell(i+1) &= h_i \\
d_i &= h_i / (v/2 - i) \\
a_i &= h_0 / (10 \times 2^i)
\end{align*}

$h_0 = vy/4$

\begin{align*}
\ell &\leftarrow \ell, \ell_i \\
h_i &= h_0 y / (\beta_{5,5}) \\
b_i &= d_i + a_i \\
h_i &= h_{i-1} - b_i
\end{align*}

$\ell \leftarrow \ell, \ell_i$

Figure 24. Schemata for generating the roof section, *juzhe* (stage E).
Figure 25. Derivation of a roof section with $v = 6$ and $y = 100$ (stage E).