A Parametric Recreation of Traditional Chinese Architecture

A case study on the floor plan

Di Li¹, Michael Knight², Andre Brown³
University of Liverpool, UK
¹di.li2@liv.ac.uk, ²mknight@liv.ac.uk, ³andygpb@liv.ac.uk

Abstract. This paper presents the current state of progress investigating the possibility of modelling traditional Chinese architecture using parametrics based on the two rule books. This builds on the work of producing systematic analysis on both rule books and contributing knowledge from extant buildings. The case study target is the floor plan described in Ying Zao Fa Shi. Discussion and future works are suggested at the end.

Keywords. Parametric modelling, traditional Chinese architecture, Ying Zao Fa Shi, Kung-ch’eng tso-fa tse-le, floor plan.

INTRODUCTION

When studying traditional Chinese architecture, two references are essential—literary records and extant buildings. China, a country with over 5000 years of history boasts remarkable architecture from all dynasties and periods. Unfortunately, almost none of the buildings before Tang Dynasty (618-907) remain and many buildings from Song Dynasty (960-1279) to Ching Dynasty (1616-1912) have been badly damaged or destroyed.

However, two important texts survive: Ying Zao Fa Shi (Building Standards) from Song Dynasty and Ching Dynasty: Kung-ch’eng tso-fa tse-le (Structural Regulations) from Ching Dynasty, which are known as the “two text books of Chinese ancient architecture” (Liang, 1985). They are the only remaining classical Chinese literature which deals with architecture and are, in essence, rule books that govern most aspects of the design. As a starting point, the analysis on the two rule books is a key factor in understanding architecture of this period. This paper looks at generation of the floor plan using the Ying Zao Fa Shi. A series of rules and hypotheses are reviewed before the generation of the floor plan models using Grasshopper and Rhino. The models are discussed and evaluated and additionally, the comparison with parallel research of the Shape Grammar approach to the floor plan is discussed.

THE TWO RULE BOOKS

Figure 1 illustrates the chronological diagram indicating a brief history of China and the two dynasties (in the square boxes) in which the two rule books were compiled.

Ying Zao Fa Shi (Li, 1103) was the official building standard as a guidance of design and construction in Song Dynasty. During the period of the Song Dynasty, an increasing number of different levels and types of buildings were constructed which led to an urgent requirement of an official instruction. There were three original purposes of this book. First, to set the design guidelines to articulate the social status of feudalism. Second, to establish a unified architectural form and style to guarantee a consistent level of detail and artistic effects. Third, to define
the material choices and quantities as well as the
work load to avoid corruption and embezzlement.
The first edition was published in 1091 and with ex-
tended second edition compiled by Li Jie, the court
architect of the Hui Zong Emperor in 1103.

This book consists of thirty-four volumes. Vol-
umes one and two are the overall introduction to
different types and components of the architecture.
Volume three is about the foundations, masonry
structures and carving of handrails. Volumes four
and five introduce the structural carpentry system.
Volumes six to eleven introduce the finished car-
pentry. Volume twelve includes three timber precast
methods and bamboo weave method. Volume thir-
ten explains tile and cement processing. Volume
fourteen focuses on the composition and colour
matching of decorative painting. Volume fifteen de-
scribes the precast of bricks and ceramic materials.
Volumes sixteen to twenty-five presents the work
load required in the previous volumes. Volumes
twenty-six to twenty-eight outlines the material
consumption of the components mentioned above.
Volumes twenty-nine to thirty-four are the selected
diagrams.

The significance of Ying Zao Fa Shi is not “simply
for its existing” (Li, 2001). The book is, in general, well
organised, logical, systematic and rigorous which
is quite rare in ancient literature. Although some
aspects such as the floor plan are relatively lacking
in systematic description, the whole book provides
readers with a “rule-based and parametric” system
(Li, 2001) for the ancient style buildings. Liang (1983)
even points out that the Hui Zong Emperor was a
naive politician, but was an excellent artist. Mean-
while Li Jie was also good at drawing and music. This
might be one reason why occasionally Li Jie omitted
some important descriptive rules but paid more at-
tention to the architectural style and decoration.
Together with Li’s research (Li, 2001; 2003) and the
on-going research in the case study on the ting tang
section by the authors, it has been shown that Chi-
nese traditional architecture has some parametric
characteristics.

As shown in Figure 2, Ying Zao Fa Shi was writ-
ten in an ancient form of the Chinese language
which has no punctuation. The characters, vo-
cabulary, grammar and text direction were all dif-
ferent from contemporary written Chinese which
presents a big problem to modern researchers. In
relative terms, Ching Dynasty: Kung-ch’eng tso-fa
tse-le (1734) is linguistically more acceptable since
it is compiled in 1734, more than six hundred years
closer to us. Meanwhile, more extant buildings from
Ching Dynasty can be studied as practical evidence.
In this book, twenty-seven types of buildings with
accurate size and dimensions are given as examples,
making it useful for reconstruction of buildings of
the period.

RULES FOR THE FLOOR PLAN AND PARA-
METRIC APPROACH
In order to understand and recreate floor plans, a
description of the ancient floor plan system is neces-
sary. In Ying Zao Fa Shi, the following factors or pa-
Parameters can be used to describe a building:

- The building type (such as dian tang or ting tang, here tang means hall).
- The overall dimension (measured in modular unit):
  - Building width (and bay width)
  - Building depth (and rafters)
- The grade (which is used to calculate the absolute value of the modular unit)

In the most common and formal cases, the floor plan of a single house is rectangular and consists of two major factors: building width and building depth, which determines the dimension and scale of the house. The building width and building depth form the area of a building. This area can be divided into small units (small rectangles) i.e. bays (usually, each bay has four columns at the four corners, although not in every case). Each bay is determined by the bay width and bay depth, as shown in Figure 3. The sum of the bay width or bay depth gives the building width or depth. But in reality, the bay depth is not described in the set of parameters above. Instead, the horizontally projected rafter is used to measure the depth. There are three reasons. First, Ying Zao Fa Shi mentions for ting tang type building, one bay depth equals to two rafters deep but it does not mention the relationship for the dian tang type building. Therefore in order to unify the parameters...
in the later parametric modelling, the rafter is selected as the depth measurement for both building types. Second, to be consistent with the research of case study on the section, the rafter is a key parameter in defining the section. The rafter is closely related to the disposition of the columns and beams and the total number of columns. Third, from the workers’ experiences, they tend to use rafters rather than bay depth. Apart from the rectangular forms, there are also several non-rectangular floor plans, known as non-formal architecture, which includes the use of the triangle, circle, sector, octagon, polygon, and the superposition of polygons and Wan shape. They are widely used in pavilions and gardens which typically appear in Southern China. But these irregular shape floor plans are not discussed in this paper.

At this point, it is worth describing the measurement units used. Depending on the eight grades of the buildings, a fen can have eight different absolute values (Liang, 1983), measured in cun (a Chinese length unit), as shown in Table 1. Given that 1 cun = 32mm approximately in Song Dynasty, the final absolute values of width and depth can be obtained. For example, if the building is ting tang type and in Grade Three, 1 fen = 0.5 cun \times 32\text{mm}/\text{cun}=16\text{mm}.

In order to build up the parametric logic, there are four more details which need to be clarified: the value of bay width and rafter, and number of both (which constitutes the building width and building depth). Unfortunately, at this stage, Ying Zao Fa Shi does not provide a systematic definition. Instead, it gives information partially by defining and partially by enumerating. Despite this, the parametric model could still be built up by first making hypothesis based on the information in hand and then evaluating with the diagrams in the rule book and extant building measurement data. The assumptions here are based on the investigation of historian Chen (1993). As shown in Table 2, the four parameters are summarised. In particular, the bay width is not given directly. The calculation is as follows: a bay has two sets of dou gong (the bracket joint) that sit on each side of the columns (the black dots in Figure 3) and either one or two sets between the columns (intercolumnar dou gong). The centre-to-centre distance of dou gong is 125 fen ± 25 fen. Thus the bay width with one intercolumnar dou gong is 250 fen ± 50 fen, and with two intercolumnar dou gong is 375 fen ± 75 fen. Therefore the total range of bay width is 200-450 fen. In addition, the centre bay is often wider and in most extant examples the two outer bays are often slightly narrower than the others [3]. In the table, the modular unit fen is used rather than the absolute values.

After all the parameters are clarified, the parametric model now can be built. Figure 4 shows the logic diagram for the parametric modelling. In this logic diagram, ting tang and dian tang types are integrated together since Liu (1984) points out that “although Ying Zao Fa Shi distinct the two types strictly, buildings are slickly dealt with in practice”. The rectangular floor plan grid is set first by defining the x-y plane as the base plane. The next step is to define the size and number of bays. In order to achieve this, the four parameters described above are outlined here. As the primary parameters, the

<table>
<thead>
<tr>
<th>Size of fen (in cun)</th>
<th>0.60</th>
<th>0.55</th>
<th>0.50</th>
<th>0.48</th>
<th>0.44</th>
<th>0.40</th>
<th>0.35</th>
<th>0.30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grades of dian tang</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grades of ting tang</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grades of other types</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 1
Absolute values of fen for different grades.

<table>
<thead>
<tr>
<th>Building width (number of bays)</th>
<th>ting tang</th>
<th>dian tang</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,5,7,9 bays</td>
<td>3,5,7,9,11 bays</td>
</tr>
<tr>
<td>Building depth (number of rafters)</td>
<td>4,6,8,10 rafters</td>
<td>2,4,6,8,10,12 rafters</td>
</tr>
<tr>
<td>Bay width</td>
<td>200-450 fen</td>
<td></td>
</tr>
<tr>
<td>rafter</td>
<td>≤ 150 fen</td>
<td></td>
</tr>
</tbody>
</table>

Table 2
Definition of the four parameters.
rafter, number of bays and number of rafters can be directly controlled by the corresponding number range listed in Table 2. The bay width is a multiplication of two factors: centre-to-centre distance of dou gong and number of intervals between dou gong. Additionally, the number of intervals between dou gong is equal to the number of intercolumnar dou gong plus one. Since the number of intercolumnar dou gong is known directly, this is the fourth parameter. Thus, overall, there are only four simple parameters that can be controlled depending on the building type and grade. In addition, there is one judgment in this logic diagram: the building width should always be larger than the building depth. And if so, the conclusion will appear true. Under this one set of logic diagrams the floor plan of both ting tang and dian tang types, all eight grades of building with different bays and rafters are involved. Figure 5 shows two examples of the model.

Comparing the examples with the diagrams in Ying Zao Fa Shi (Figure 2 right), they are highly consistent in form. And there is one extant building example—Fuoguang Temple Wenshu Dian (Figure 6), which built at 1137, located at Shanxi Province. It is a Grade Two dian tang type building with seven bays. From the parametric model, the minimum building width is given as 7x200x0.55x32=24640mm=24.64m while the maximum is 7x450x0.55x32=55440mm=55.44m. Similarly, the building depth spans from 15.84m to 21.12m. Wang (2011) provides its measurement data of 31.56m in width and 17.60m in depth. As Liu (1984) argues that “there is not such an extant building completed follows Ying Zao Fa Shi found so far”, if the measurement data is within the range of the parametric model, then the two are consistent.

**DISCUSSION**

Parametric design differs from the conventional design mode of adding and removing marks in that
the relationships between the parameters are the essence of parametrics. In this case study, the relationships are not based on one specific example, but a systematic description and summary of all the buildings in a typical period—which are the rules. The logic diagram of the formal rectangular floor plan is then built up based on the rules. Following this, different outcomes can be generated to indicate the advantages of parametric method which can result in different final products without a new set of logic diagrams or the removal/addition individual components. In particular, all the floor plan formats are included in this set of logic diagram, including both the building types (dian tang and ting tang), any dimensions and all the grades.

There is parallel research in the Shape Grammar approach to the floor plan (Li, 2001). In the research, Li derives the process with initial symbols and a set of rules, and then the design rules act on the initial symbols repeatedly, resulting in a final design. Following each typical set of rules will result in one corresponding final design. Thus Shape Grammar generates a language of design. How and in what sequence do the rules applied makes up the so called grammar? Compared with Li’s research (Li, 2001), the advantage of the parametric method is the ease with which the process can be extended into three dimensional modelling. For instance, the intersectant points could be the column locations when combining with the case study on the section. Then, the two dimensional representation of architecture through the plan and section will form the three dimensional parametric model. And indeed, according to Wang (2011), more special proportions (relationships) exist in the elevations, as well as many other building factors. On the other hand,
if all the attempts are limited in two dimensional planes, it may omit rules and relationships that exist between the section and the floor plan.

CONCLUSION
Accordingly, three major similarities between Shape Grammar and parametrics can be drawn. Both of them are derived systematically and logically; both of them are generative and productive; both of them can be symbolically and graphically illustrated. In contrast, three key differences can be identified as well. The parameters in parametric method can be any variables, abstract or concrete, without the limitation of just geometrical entities. The rules used in parametrics can be any logic relationships, not only repetitions and the final outcome could involve many different variations.

When combined with parallel work in the parametric generation of the ting tang section, it is found that the characters summarized from deriving the floor plans are consistent with those from generating sections. Taking Li’s work (Li, 2001) of shape grammar approach to the floor plan and ting tang section into consideration, it can be concluded that Chinese traditional architecture has parametric characteristics. Since the whole structure of traditional buildings constructed using the rule books is complex and closely interrelated, a parametric method has the advantage of illustrating and generating the principles from the rule books to complex digital reconstructions. The application is not limited to the restoration of ancient building, but could also be used as inspiration in the generation of new designs. Apart from individual buildings, based on the floor plan logic diagram, a similar parametric method can be used in recreation of many city plans, since several Chinese ancient cities also show parametric characteristics.

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