

**A Computer Model for Chinese
Traditional Timber Structure:
the Foguang Temple**

Cao, Dapeng

Submitted in total fulfilment of the requirements of the
degree of Master of Architecture

June 2005

School of Architecture, Landscape Architecture and Urban Design

The University of Adelaide

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Signature:

Acknowledgement

This research has been a rare and incredibly fruitful experience. I am appreciative to the School of Architecture, Landscape Architecture and Urban Design, the University of Adelaide for making these investigations possible.

I would like to express my deepest gratitude to professor Antony Radford for the guidance, criticism, support and time.

I am also indebted to Dr. Dean Bruton who has helped to clarify many ideas and technical difficulties, and to Mr. Verdy Kwee (PhD candidate of the University of Adelaide) for editing of my writing.

Gratitude is expressed to Mr. Luke Li (PhD candidate of the TsingHua University) for providing me valuable source of information. Many other colleagues have also provided assistance. These include Dr. Veronica Soebarto and Dr. Peter Scriver, who have been the postgraduate coordinator of my school in the past years..

Finally, I would like to acknowledge the many individuals who have offered their invaluable support throughout my research. I apologise to those whose contributions, inadvertently, have not been acknowledged.

TABLE OF CONTENTS

TABLE OF FIGURES.....	5
ABSTRACT	10
CHAPTER 1 INTRODUCTION.....	12
1.1 RESEARCH ON HISTORIC ARCHITECTURE	12
1.2 COMPUTERISED MODEL: AN INTELLIGENT MODEL	13
1.3 A BRIEF BACKGROUND ON CHINESE ARCHITECTURAL HISTORY DEVELOPMENT AND RESEARCH	14
1.3.1 <i>The development of ancient Chinese architectural history.....</i>	<i>14</i>
1.3.2 <i>The background of ancient Chinese architecture research</i>	<i>17</i>
1.4 NEW SITUATIONS FOR ANCIENT CHINESE ARCHITECTURE RESEARCH	20
1.4.1 <i>Digital techniques for ancient Chinese architectural research.....</i>	<i>21</i>
1.4.2 <i>An intelligent model for ancient Chinese architecture</i>	<i>21</i>
1.4.3 <i>Application possibilities of computerised model for ancient Chinese architecture</i>	<i>22</i>
1.5 THE FOGUANG TEMPLE	23
1.6 RESEARCH SCOPE & APPROACH	24
CHAPTER 2 A BRIEF REVIEW ON COMPUTER-AIDED HISTORIC ARCHITECTURE RESEARCH: CASES & THEORIES.....	26
2.1 THE RECONSTRUCTION OF HISTORIC SITE	26
2.2 KINDS OF MODEL	27
2.2.1 <i>Models of archaeological excavations.....</i>	<i>27</i>
2.2.2 <i>Model for architectural visualization.....</i>	<i>28</i>
2.2.3 <i>Model for detailed historic architecture research and teaching</i>	<i>30</i>

2.3 METHOD USED FOR DIGITAL MODELING AND REPRESENTATION OF HISTORIC SITE	33
.....	33
2.3.1 <i>strategies and structures of modelling</i>	33
2.3.2 <i>Representations associated with computer database</i>	38
2.4 DIGITAL MODEL FOR CHINESE HISTORIC SITES	39
2.4.1 <i>The limitation of current works of Ancient Chinese architecture</i>	39
2.4.2 <i>Appropriate situation for the modeling in this study</i>	41
CHAPTER 3 RESEARCH METHODOLOGY	42
3.1 INTERPRETIVE HISTORIC RESEARCH AND A CASE STUDY APPROACH	42
3.2 A THEORETICAL BASIS FOR DIGITAL MODELLING OF HISTORIC ARCHITECTURE ...	43
3.2.1 <i>The development of shape grammar theory</i>	43
3.2.2 <i>Shape grammar theory as an approach to study Chinese traditional</i>	
<i>structural</i>	46
3.3 METHODOLOGY FOR RECONSTRUCTING A DIGITAL MODEL OF THE FOGUANG	
TEMPLE (MAIN HALL).....	49
3.3.1 <i>Data collection and validation</i>	49
3.3.2 <i>A grammatical understanding of the Foguang temple</i>	52
3.3.3 <i>Build a database for the representation of the wooden structure of the</i>	
<i>Foguang temple</i>	54
3.3.4 <i>The methodology framework for the practical process of modelling</i>	60
3.4 METHODOLOGY FOR DEALING WITH CONTINGENCIES AND INSUFFICIENT	
INFORMATION	62
3.4.1 <i>The concept of an “ideal model”</i>	62
3.4.2 <i>The concept of minimal adaptation</i>	63
3.5 METHODOLOGIES FOR REPRESENTATION	65

3.5.1 <i>Representing the database</i>	65
3.5.2 <i>Representing the building</i>	65
CHAPTER 4 BUILDING THE DIGITAL MODEL FOR THE FOGUANG TEMPLE	67
4.1 INFORMATION MANAGEMENT PRIOR TO MODELING	67
4.1.1 <i>Graphic information collection</i>	68
4.1.2 <i>Graphic information validation</i>	69
4.2 A BASIC STUDY OF THE CONSTRUCTION RULES.....	70
4.2.1 <i>The “Grammar book” as modelling reference</i>	70
4.2.2 <i>Possible construction rules</i>	72
4.2.3 <i>Adoption of rules and grammars in Computer drawing of the temple</i>	75
4.3 COMPUTATIONAL MODELING.....	76
4.4 MODELLING THE “UNKNOWN” PART	79
4.4.1 <i>A Theoretical Model</i>	81
4.4.2 <i>Structural functions of the unknown section</i>	83
4.4.3 <i>Segment organization</i>	85
4.4.4 <i>Elements dimensions and details</i>	86
4.4.5 <i>Modelling the unknown part – a step by step record</i>	87
4.4.6 <i>An unresolved issue: the connectivity of Nidaogong and Lan’e</i>	103
4.4.7 <i>Final effect and representation of the digital structure</i>	104
4.5 CREATING THE DATABASE	106
4.6 REVIEW AND REVISE THE MODEL.....	110
CHAPTER 5 DISCUSSION.....	111
5.1 AN ASSESSMENT OF THE MODEL AND MODELING PROCESS	111
5.1.1 <i>Evaluation of the model</i>	111
5.1.2 <i>A review of the computer modelling process: strengths and limitations</i> ...	114
<i>The strengths of the study include:</i>	114

5.1.3 3D modelling based database	114
5.2 SOME ISSUES GENERATED DURING THE MODELING PROCESS	115
5.2.1 The naming system of the building.....	115
5.2.2 Ambiguity in drawings	117
CHAPTER 6 CONCLUSION.....	119
6.1 A REVIEW OF THE STUDY PROCESS	119
6.1.1 Research framework.....	119
6.1.2 Standards of judging	119
6.2 SOME CONTRIBUTIONS FROM THIS STUDY.....	120
6.2.1 A computer model for ancient Chinese building.....	120
6.2.2 Digital techniques and historic Chinese architecture studies.....	121
6.2.3 Digital techniques & historic architecture studies	121
6.3 FURTHER RESEARCH.....	122
BIBLIOGRAPHY	123
APPENDIX A: CD OF VISUALIZATION EFFECTS	127

Table of figures

(FIGURE 1-1, FIGURE 1-2, FIGURE 1-3: PHOTOS OF THE MAIN HALL OF THE FOGUANG TEMPLE)	23
(FIGURE 2-1, FIGURE 2-2: THE SHAPE-TYPE LIST AND THE WHOLE FEATURES OF THE STRUCTURE, “THE WOODEN CONSTRUCTION DATA MODELING OF KOREAN TRADITIONAL ARCHITECTURE, CAADRIA CONFERENCE”).....	32
(FIGURE 2-3: CITY LEVEL, “DIGITAL RECONSTRUCTION OF MEDIEVAL CHINESE CITIES, THE GLOBAL DESIGN STUDIO, CADA”).....	34
(FIGURE 2-4: COMPOUND LEVEL, “DIGITAL RECONSTRUCTION OF MEDIEVAL CHINESE CITIES, THE GLOBAL DESIGN STUDIO, CADA”).....	35
(FIGURE 2-5, FIGURE 2-6: WARD LEVEL, “DIGITAL RECONSTRUCTION OF MEDIEVAL CHINESE CITIES, THE GLOBAL DESIGN STUDIO, CADA”).....	35
(FIGURE 2-7: DIGITAL MODEL OF ARTIST’S HOLIDAY HOUSE ON THE LAKE, GALLI & MUHLHOFF, 2000)	36
(FIGURE 2-8: DIGITAL MODEL OF HORTICULTURIST’S HOUSE, GALLI & MUHLHOFF, 2000)	36
(FIGURE 2-9: COMPUTER SIMULATION OF THE MONGOLIAN PALACE COMPARING WITH THE PHOTO OF ANCIENT CHINESE BUILDING).....	40
(FIGURE 3-1: METHODOLOGIES FOR DATA VALIDATION).....	51
(FIGURE 3-2: DISASSEMBLING TO STRUCTURE TO THREE SEGMENTS, “GUO, 1999, THE STRUCTURE OF CHINESE TIMBER ARCHITECTURE”).....	53
(FIGURE 3-3: A BASIC DATABASE STRUCTURE)	55
(FIGURE 3-4: TABULAR FORMAT DATABASE)	56
(FIGURE 3-5: A DATABASE STRUCTURE FOR ANCIENT CHINESE BUILDINGS)	58
(FIGURE 3-6: THE IMPLEMENTATION FRAMEWORK).....	60

(FIGURE 3-7: IDEA OF THE MODELLING PROCESS)	63
(FIGURE 3-8: THE COMPUTER LAYOUT OF THE DATABASE ON SINGLE ELEMENT)	65
(FIGURE 4-1: PREVIOUS MANUAL DRAWING INPUT COMPUTER)	69
(FIGURE 4-2: PHOTOS OF PHYSICAL REALITY INPUT COMPUTER).....	70
(FIGURE 4-3: THE LINK BETWEEN MANUAL DRAWING - PHOTOS).....	70
(FIGURE 4-4: A DIGITAL DRAWING BASED ON THE MANUAL DRAWING)	70
(FIGURE 4-5: THE STANDARD MODULE OF ELEMENTS).....	73
(FIGURE 4-6: STRUCTURAL RELATIONS)	74
(FIGURE 4-7, PREVIOUS DRAWING OF THE PLAN OF THE COLUMN NETWORK)	74
(FIGURE 4-8, COMPUTER DRAFTING OF THE NETWORK OF THE COLUMNS OF THE STRUCTURE).....	75
(FIGURE 4-9: SAMPLES OF STANDARD TIMBER UNITS)	75
(FIGURE 4-10: MANUAL AND DIGITALISED DRAWINGS OF THE ELEVATION TO CONFORM TO UNIT).....	76
(FIGURE 4-11: AN EXAMPLE OF SECTION DRAWING WITH COMPLETED ELEVATION AS REFERENCE)	76
(FIGURE 4-12: STRUCTURE COMPONENTS DE-CONSTRUCTED)	78
(FIGURE 4-13,FIGURE 4-14: MODELLING OF DIFFERENT ELEMENTS).....	78
(FIGURE 4-15: FROM ELEMENTS TO SEGMENT).....	79
(FIGURE 4-16: FROM COMPONENTS TO THE WHOLE STRUCTURE).....	79
(FIGURE 4-17: PHOTOS OF THE DETAIL)	79
(FIGURE 4-18: PREVIOUS DRAFTS OF THE DETAIL).....	80
(FIGURE 4-19: THE MODELLING PROCESS DIAGRAM)	82
(FIGURE 4-20: A FRAMEWORK OF THE “HYPOTHESIS-REVIEW” MODELLING SYSTEM) ..	83

(FIGURE 4-21,FIGURE 4-22: THE MODEL BEFORE THE SIMULATION OF THE CORNER STRUCTURE).....	84
(FIGURE 4-23,FIGURE 4-24: HYPOTHESIS OF THE TIE-BEAMS).....	84
(FIGURE 4-25,FIGURE 4-26: THE BRACKET SYSTEM FROM THE X AND Y DIRECTION)...	85
(FIGURE 4-27: FINAL EFFECTS)	86
(FIGURE 4-28: DIFFERENT DIMENSIONS ACCORDING TO DIRECTIONS)	86
(FIGURE 4-29,FIGURE 4-30: THE ELEMENTS CHANGING)	87
(FIGURE 4-31,FIGURE 4-32).....	88
(FIGURE 4-33,FIGURE 4-34).....	88
(FIGURE 4-35,FIGURE 4-36).....	88
(FIGURE 4-37,FIGURE 4-38).....	89
(FIGURE 4-39,FIGURE 4-40).....	89
(FIGURE 4-41,FIGURE 4-42).....	90
(FIGURE 4-43).....	90
(FIGURE 4-44,FIGURE 4-45).....	90
(FIGURE 4-46,FIGURE 4-47).....	91
(FIGURE 4-48,FIGURE 4-49).....	91
(FIGURE 4-50,FIGURE 4-51).....	91
(FIGURE 4-52, FIGURE 4-53).....	92
(FIGURE 4-54, FIGURE 4-55).....	92
(FIGURE 4-56, FIGURE 4-57).....	93
(FIGURE 4-58, FIGURE 4-59).....	93
(FIGURE 4-60, FIGURE 4-61).....	93
(FIGURE 4-62, FIGURE 4-63).....	94
(FIGURE 4-64, FIGURE 4-65).....	94

(FIGURE 4-66, FIGURE 4-67).....	95
(FIGURE 4-68, FIGURE 4-69).....	95
(FIGURE 4-70, FIGURE 4-71).....	96
(FIGURE 4-72, FIGURE 4-73).....	96
(FIGURE 4-74, FIGURE 4-75).....	96
(FIGURE 4-76: STRUCTURAL DETAILS OF THE CAPITAL-BLOCK).....	97
(FIGURE 4-77: THREE TYPES OF JOINT OF THE BRACKET SYSTEM OF THE INTERIOR CORNER COLUMN)	97
(FIGURE 4-78, FIGURE 4-79, FIGURE 4-80: STRUCTURAL DETAILS OF THESE JOINTS) ...	98
(FIGURE 4-81, FIGURE 4-82: STRUCTURAL DETAILS OF THE JOINT BETWEEN GUA ZI GONG AND XIA ANG ON THE EAVE CORNER COLUMN).....	99
(FIGURE 4-83, FIGURE 4-84: STRUCTURAL DETAILS OF THE JOINT BETWEEN MAN GONG AND XIA ANG ON THE EAVE CORNER COLUMN)	100
(FIGURE 4-85: STRUCTURAL DETAILS OF THE JOINT BETWEEN CAO RO FU AND YA CAO FANG ON THE EAVE CORNER COLUMN).....	101
(FIGURE 4-86: STRUCTURAL DETAILS OF THE JOINT BETWEEN JIAO BEI ON THE INTERIOR CORNER COLUMN)	101
(FIGURE 4-87: STRUCTURAL DETAILS OF THE JOINT BETWEEN CAO RO FU ON THE INTERIOR CORNER COLUMN).....	102
(FIGURE 4-88: STRUCTURAL DETAILS OF THE JOINT BETWEEN JIAO BEI ON THE INTERIOR CORNER COLUMN)	102
(FIGURE 4-89: UNRESOLVED CONNECTIVITY)	103
(FIGURE 4-90: THE “UNKNOWN PART” (SHOWN IN RED COLOR) AND THE WHOLE STRUCTURE)	104
(FIGURE 4-91: MORE DETAILS OF THE “UNKNOWN PART” (SHOWN IN RED COLOR).....	105

(FIGURE 4-92, FIGURE 4-93: THE FINAL VISUALISATION EFFECTS OF THE WHOLE STRUCTURE).....	105
(FIGURE 4-94: LIST OF STRUCTURAL COMPONENTS)	107
(FIGURE 4-95).....	108
(FIGURE 4-96).....	108
(FIGURE 4-97).....	109
(FIGURE 4-98).....	109
(FIGURE 4-99).....	110
(FIGURE 5-1: THE ELEMENTS IN WHITE COLOR WERE NOT NAMED IN PREVIOUS STUDIES)	116
(FIGURE 5-2: THE IMPORTANT PART, THE CORNER WAS NOT DETAILED).....	117
(FIGURE 5-3: THE COMPLEX ELEMENT CONNECTIONS).....	118

Abstract

This thesis presents a study of an ancient Chinese timber structure- the main hall of the Foguang temple built in China in the Tang Dynasty (857), which is regarded as one of the most important temples in that period. The research represents a detailed digital model of the structural timber components and their connectivity.

The research questions are:

- Firstly, how to identify and represent the structural components, and the ways they are assembled. This is not covered in the few previous studies of the temple, which just offered brief introductions and general descriptions of the construction of the timber structure.
- Secondly, how to create a digital model for such a structure where there is insufficient or incompatible information. These are common issues that arise in the simulation and representation of historic architecture.

The outcome of the research is the presentation of a digital model that is much more detailed than previously existing representations.

During the process, two concepts were developed and adopted:

- Firstly, the concept of “building an ideal model”. Rather than seeking the representation of the timber structure as built, the notion outlined in this thesis is to create an ideal digital model according to the vocabulary of structural components and the predefined spatial relations of their assembly connectivity.
- Secondly, the concept of “simplest adaptation”. When choosing from a number of reasonable hypotheses about a component or assembly detail, it is assumed to be the simplest possible adaptation of an already accepted component or assembly detail.

The thesis is organized as followings:

Chapter 1: an introduction to the research on ancient Chinese architecture

Chapter 2: a review of the computer simulation and representation of historic architecture

Chapter 3: a discussion about the methodology on the concept of “building an ideal model”, and the methodology for modelling when there is a lack of information

Chapter 4: a record of the digital modelling process

Chapter 5: discussions on and conclusions of the research.

The thesis has an accompanying CD which contains the representation information, including:

- A 2D ‘Flash’ presentation that shows the brief contents of the research
- 3D animations that represent in detail the timber structure and the assembly process
- A database that represents the structural components and their relations.