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Research on the Construction of Component Library and Visualization of Construction Process Based on the Investigation of Ancient Buildings in Hebei Province

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Abstract

As the former territory of the Yan and Zhao states, Hebei preserves ancient buildings with a time span of thousands of years. However, the public lacks an intuitive understanding of their modular design and construction logic. Based on the existing ancient buildings in Hebei, this study systematically sorted out typical architectural cases and established a basic information database through literature research and field investigation. By applying 3D scanning and reverse modeling technologies, the architectural entities were deconstructed into a standardized digital component library, and the parametric translation of the "Cai Fen System" [3]was completed. Finally, relying on architectural animation technology, the complete dynamic construction process was simulated, and the implicit wisdom such as "camber of columns" and "rising of eaves" was visually presented. This paper explores a readable heritage interpretation method for the public[4], enabling non-professionals to deeply understand the construction wisdom of ancient Chinese architecture that combines standardized production with flexibility.

Keywords

Ancient buildings in Hebei; Field investigation; Component library; Virtual construction; Dynamic visualization.

1. Chapter 1 Introduction

1.1. Research Background

Located in the northern part of the North China Plain, Hebei has been a convergence zone of the Central Plains farming civilization and the northern nomadic civilization since ancient times, and its ancient buildings show the characteristics of multi-cultural integration. Longxing Temple was praised by Liang Sicheng as "the first famous temple outside the capital"[1][2], and the cross-shaped plane with hip-and-gable enclosed porches of the Mani Hall is unparalleled. However, the public mostly focuses on the aesthetic appearance and has a limited understanding of the internal structure. Existing digital projects focus on the replication of individual buildings, lacking the sorting out of component systems and the visualization of construction processes, which is the starting point of this study.

1.2. Research Purposes and Significance

This study aims to restore the construction process through digital means and explore an interpretation method of ancient architectural heritage for the public. The specific purposes include: making up for the public's cognitive deficiency of "seeing the form but not the principle"; exploring the transformation path from "static recording" to "dynamic interpretation"; constructing a reusable component library of ancient buildings; and providing a reference sample for the education of architectural history and public communication. In

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addition to the "result research", this study supplements the research perspective of "process research" and provides a theoretical framework focusing on the process logic for the field of architectural heritage. In terms of practical significance, the construction animation can be directly applied to museum exhibitions, scenic spot guidance, university teaching and other scenarios, improving the public's visiting experience and students' learning efficiency.

1.3. Research Content and Methods

The research is carried out around the technical chain of "Investigation of ancient buildings in Hebei - Construction of component library - Presentation of dynamic construction animation". Firstly, the basic information of ancient buildings in Hebei is systematically collected, and typical samples are selected for component-level digital acquisition. Then, the models are disassembled into standardized component units according to the structural logic to form a searchable and callable digital component library. Finally, representative buildings are selected to make dynamic construction animations in accordance with the real construction procedures. The research methods include: literature research method, field investigation method, digital modeling and animation technology method, and experimental evaluation method.

2. Chapter 2 Investigation and Research on Ancient Buildings in Hebei

2.1. Research Scope and Objects

The investigation scope of this study mainly focuses on the existing ancient architectural relics within the administrative region of Hebei Province, covering four core cultural and geographical units: the Central Hebei Plain, the Southern Hebei Region, the Northern Hebei Mountainous Area and the Eastern Coastal Area. The building types include religious buildings, ritual buildings, yamen and residential buildings, ancient pagodas, defensive buildings and mausoleum buildings.

2.2. Investigation Process and Data Collection

Before the investigation, 28 key collection objects were screened with reference to literatures such as A Comprehensive Survey of Cultural Relic Protection Units in Hebei Province. During the field investigation, laser rangefinders and tape measures were used to complete dimension measurement, SLR cameras were responsible for shooting the appearance and details of buildings, and UAVs were used to obtain roof images.

2.3. Construction of Component System of Ancient Buildings in Hebei

Based on the investigation results, with reference to the classification frameworks of Yingzao Fashi (Treatise on Architectural Methods)[3] and Engineering Practices, and combined with the actual characteristics of ancient buildings in Hebei, the following component classification system is established:

1.Foundation and platform layer: Platform plinth, step border stones, column base stones, and raked band stones 2.Column grid layer: Eaves columns, inner golden columns, central columns, gable columns, corner columns, and secondary columns

3.Dougong layer: Dougong blocks, brackets, ang brackets, and horizontal lintels

4.Beam frame layer: Beams, breast beams, tie beams, camber blocks, struts, and supporting brackets

5.Roof frame layer: Purlins, rafters, sheathing boards, eave fascia boards, tiles, and ridge decorations

6.Enclosure and decoration layer: Sill walls, sill windows, lattice doors, wooden plank walls, spandrel brackets, and colored paintings

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3. Chapter 3 Construction of the Component Library of Ancient Buildings

3.1. Technical Route and Precision Standards

Modeling Software

SketchUp: Used for rapid modeling of individual components with rich plug-ins, suitable for batch processing of a large number of components

Rhino: Used for precise modeling of complex curved surface components and parametric components

Component Library Management

Hierarchical folder management is adopted, combined with an Excel component list for retrieval.

Animation Production

SketchUp: It has a mature keyframe animation system and high rendering output quality.

3.2. Component Classification and Coding System

To facilitate the retrieval and call of components, the following coding rules are established:

Format: Type_Period_Serial Number_Name

Examples:

DZ_S_01_Basin-shaped column base (Column base_Song Dynasty_No.01_Basin-shaped column base)

DG_L_05_Five-step dougong (Dougong_Liao Dynasty_No.05_Five-step dougong)

LJ_S_02_Flat beam (Beam frame_Song Dynasty_No.02_Flat beam)

The design of coding rules fully takes into account the three core principles of "Functionality", "Timeliness" and "Uniqueness"[7].

3.3. Modeling Practice and Achievements

After three months of modeling work, starting from Hebei Province, we summarized and sorted out the 3D digital models of various ancient building components. The component and colored painting information were sorted and filed according to type, age and technological characteristics, recorded in atlases, and a preliminary searchable and referable digital data system was established[6]. The component library is organized in the form of folders with a hierarchical structure of "Type - Period - Individual component file", and a supporting Excel component list records component codes, names and other information for easy retrieval.

4. Chapter 4 Architectural Construction and Animation Demonstration Based on the Component Library

4.1. Sequence Design of Construction Procedures

By consulting the records of "work quota" in Yingzao Fashi and referring to the real construction procedures in the construction records of modern ancient building restoration projects, the construction procedures are determined as follows:

1.Foundation construction and column base stone placement: Level the foundation, set out the column grid, and place column base stones.

2.Column erection: Erect eaves columns and inner golden columns, and fix them with temporary supports.

3.Placement of horizontal lintels and plate lintels: Horizontal lintels and plate lintels are superimposed in a T shape to jointly support dougong and form a stable frame.

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4.Dougong layer installation: Place dougong blocks, brackets and ang brackets from bottom to top to construct the dougong layer.

5.Beam frame installation: Place beams from bottom to top to form a triangular roof truss.

6.Purlin installation: Install purlins in sequence from the ridge purlin to the eave purlin.

7.Rafter and sheathing board laying: Nail rafters from bottom to top and lay sheathing boards.

8.Tile work laying: Lay flat tiles and cylindrical tiles from the eave to the ridge.

9.Ridge decoration installation: Place the main ridge, vertical ridges and roof ornaments.

10.Enclosure structure installation: Install doors and windows, sill walls and wooden plank walls.

4.2. Timing Adjustment of the Animation

1.Column erection is demonstrated in groups (corner columns and main load-bearing columns first, then the rest of the columns).

2.Dougong is first exploded into dougong blocks, brackets and ang brackets, and then assembled and installed[5].

3.Tile work and rafter laying are simplified into piece-by-piece coverage in a "regional growth" mode.

4.3. Animation Production

1.Model import and scene setting

2.Camera path setting

3.Keyframe animation setting

4.Growth animation and transparency animation production

5.Light and material setting

6.Rendering and output

5. Chapter 5 Conclusions and Prospects

This study conducted field surveys on more than 70 ancient buildings in Hebei, established a six-layer component classification framework, completed the modeling of more than 320 components, and produced an 8-minute construction animation with the Mani Hall as a case. Practice shows that the technical route of investigation, library construction and demonstration is feasible, the component library improves construction efficiency, and animation becomes an intuitive tool for the popular science of ancient buildings. There are some limitations: the investigation depth in northern and eastern Hebei is insufficient; the component library mainly focuses on the Song, Liao and Jin dynasties with less coverage of the Ming and Qing dynasties; the modeling precision is simplified to adapt to animation display; the animation is a linear video without interactive functions; and the sample size for effect evaluation is small. The follow-up tasks include improving the component library, balancing high precision and lightweight, developing a VR/AR interactive platform, expanding the application of popular science education and connecting with the inheritance of construction techniques.

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