Conference Paper

Geometry Method: An Architectural Education Experiment of Crossing Boundaries of Chinese and Western

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Abstract

Western architecture has a clear system and context. One important reason is that geometry is the foundation and core of Western classical architecture. Looking back at the traditional Chinese architecture, the mentoring method of oral communication is the only way of passing on knowledge. It is almost impossible to learn from a systematic model. One of my experiments in architectural education is to re-recognize the connotation of Chinese native architecture with the method of geometry as a core, to explore the potential geometric and mathematical prototypes of Chinese traditional architectural space and aesthetics, and to translate abstract concepts and intentions into visual image and digital relationships. While discussing the spatial formal logically, it sorts out the context and classification structure of traditional Chinese space to help understand the essence of architectural design and its significance. This pedagogy is unfolded as a "trilogy" system: (1) Research and analysis of traditional Chinese classical architecture, and establishing an analytical model; (2) Build relationships between geometric analysis and space; (3) Design/ Model making.

Keywords: Geometry, Chinese Traditional Architecture, Architecture Education

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1. Geometry in Western Architecture and Its Role in Architectural Education

Geometry plays a significant role in the development of Western architecture. As a tool, geometry has constantly changed the way humans understand and describe space.

1.1. Understanding and Representing Space Through Geometry

The recorded beginning of the geometry can be traced back to ancient Egypt, ancient India and Babylon. The earliest geometry is the empirical principle of length, angle, area and volume, used in surveying, construction, astronomy and craftsmanship. Geometry is almost accompanied by the production of the earliest buildings. For instance, the ancient Egyptian pyramid is a square cone; the plan of the ancient Greek Parthenon is

rectangular, etc. They are both basic Euclidean Geometry. The Euclidean Geometry in mathematics is about the precise description of physical and material space, while the geometry in architectural form expresses the deep connection of architecture with belief, culture and historical concept in a certain mathematical way. Geometry in architecture is not only an auxiliary tool for design, but also an expression of space concept. Geometry is not only a concept of measurement, but also a concept of culture and philosophy. [1]

During the Renaissance, people believed that architecture was a science. Every part of architecture, both internal and external, should be integrated into the same mathematical proportional system.

Proportion is synonymous with geometry in the Renaissance architecture. The rise of

rationalism initiated by the 18th century European Enlightenment, once again pay attention to the sublime spiritual significance of simple geometry. The most representative works was Newton Memorial designed by Etienne-Louis Boullee, as such. In the 20th century, the modernist movement emerged, and the spatial view of Euclidean Geometry was carried forward in the modernist

architecture advocated by Le Corbusier. In the book "Towards New Architecture", Le Corbusier called the simple geometric form "the most beautiful form". [2] The geometry in the context of contemporary architecture is not limited to Euclidean Geometry. Architecture works that designed and processed in terms of topology and fractal geometry are also emerging.

1.2. Geometry in Architectural Education

In one of the most old and influential architectural treatise in the West, "Ten Books on Architecture," Vitruvius has a special discussion on the architectural composition principle and the proportional relationship. It is the basis for rediscovering the ancient Greek and Roman architecture. In the early Renaissance, Masaccio's invention of Foreshortening and Brunelleschi's invention of perspective, depicting the observation of three-dimensional objects in two dimensions. The Monge's descriptive geometry and projection drawing made geometry begin to become a pure mathematical concept in architecture.

In the 19th century, Louis Durand's "Precis of Lectures on Architecture" divided all architecture information into three parts: architectural elements, composition, and type analysis [3]. This type of diagramming practice would eventually lead to the Beaux-Arts notion of "parti". [4] Parti is a special term referring to the abstract illustration of the volume or layout of the building type. In its concept composition, a set of design

principles for how to deal with the relationship between the volume, plane and elevation of a building is the essence of the design method of the Beaux-Arts. The composition contains the integration, which is to be partially integrated into a whole. [5] Although the Beaux-Arts system has been criticized by modern architects, parti still exists in a concealed way in the discipline of architecture, which pays special attention to functions and form.
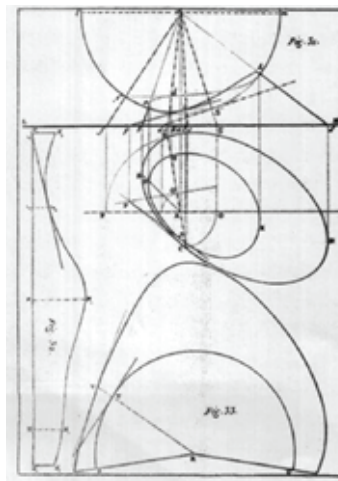

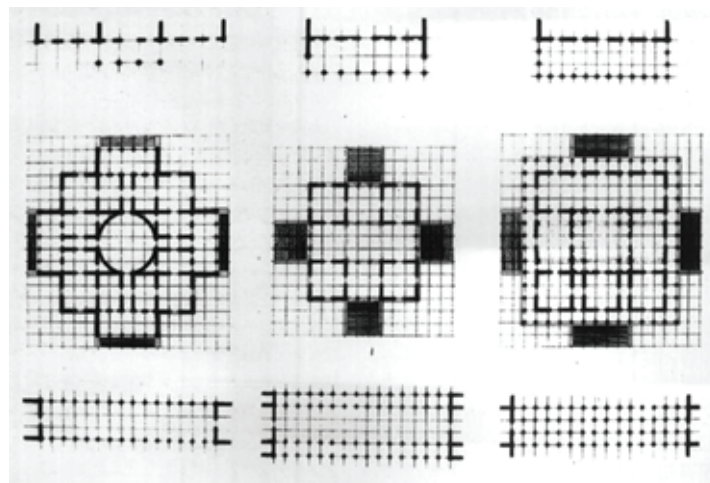**Figure** 1: Drawing of circular cone and its developed surface in Monge,s descriptive geometry.

Figure 2: Illustrations in Louis Durand's Precis of Lectures on Architecture.

At the beginning of the 20th century, the Bauhaus, which was short-lived but far-reaching, emphasized the perception of materials and structure, the subjective feelings of students, the emphasis on the intrinsic function of space, and the preference for geometric shapes.

2. The Interpretation and Educational Mode of Traditional Chinese Architecture

2.1. The system of traditional Chinese architecture is weak in inheritance, while the pass on of knowledge was mainly in the style of mentoring

In ancient China, there was always the concept of "orbicular sky and rectangular earth", which explained the universe in a simple geometric form. The ancient Chinese architectural books classic "Yingzao Fashi" also has a large number of architectural proportions and the summary of the building construction modulus. But these discussions of geometry are only at the level of observation and description. While Chinese traditional humanistic thinking is rich of endless design ideas and techniques; however, the oral and mentoring method is the only way to inherit these thinking. The master is slowly infiltrating the students with these ideas. It can only be understood, but cannot be said. For the interpretation of traditional Chinese classics, one way is the "study of classics", which introduces the classic paradigm as the tool to be used to refer to the interpretation by means of citation; another is the method of argumentation, to discuss the ideal world and connections to the basic law of nature without taking realistic restrictions into consideration. Neither of them could be easily articulated and transferred from masters to students.

In the past century, Chinese traditional knowledge has always been gradually examined, interpreted and reconstructed by different concepts with specific perspectives. For example, Liang Sicheng and Liu Dunzhen, the predecessors of Society for the Study of Chinese Architecture, re-discover Chinese traditional architectural knowledge with the method that they learned from the West, so that they can effectively integrate it into the global architectural knowledge system. However, they study the detailed structure of wood and how they are built; these practices are based on their knowledge of the formal meaning of architecture they have already accumulated. Another example is that Peng Yigang used modern "spatial perspective method" to analyze the plan of ancient Chinese gardens, trying to make it comparable and compatible with modern architecture.. [6]

2.2. Polarization: Views on Chinese Traditional Architecture from Contemporary Chinese Architecture Education

There are two opposite views towards Chinese traditional architecture in China's contemporary architecture education: either praising Chinese traditional architecture, over-emphasizing the vernacular characteristics, and thinking that Western architectural education methods are ineffective in facing Chinese problems; or fully embracing the Western architectural paradigm, and carrying out architecture training based on Western pedagogy. The cognition and inheritance of Chinese traditional architecture is becoming abandoned.

There are also attempts to understand how to inherit Chinese native construction in architectural education. Wang Xin's "painting view method" is a kind of discussion about the structural consciousness and method of space creation in Chinese traditional landscape painting. With this perspective, a way is created to transform the painting language into contemporary architectural design, and to envision the poetic geometry of Chinese native architecture by inspiring by nature. [7]

One of my experiments in architectural education is to re-recognize the connotation of Chinese native architecture with the method of geometry as a core, to explore the potential geometric and mathematical prototypes of Chinese traditional architectural space and aesthetics, and to translate abstract concepts and intentions into visual image and digital relationships. While discussing the spatial formal logically, it sorts out the context and classification structure of traditional Chinese space to help understand the essence of architectural design and its significance.

3. How to Use Geometry As a Tool to Cognize Chinese Traditional Construction

My course is the thesis design studio for the fifth year undergraduate students. The course lasts two semesters. The course is unfolded through a "trilogy" stages: (1) The research and analysis of traditional classics: studying the humanistic value of traditional Chinese classic architecture, establishing analytical models by applying geometry as the core research and building relationships between the space, construction and geometry; (2) Establishing rules between geometry and space: Through geometric and spatial analysis, the quantitative relationship of spatial laws can be derived,

and spatial laws can be used to by multiple design methods, which greatly enhance the spatial diversity; (3) Design/Model making: develop spatial prototype, select a site

to design with certain program, and to experience the space by making large scale physical models.

In this process, two main geometric methods are: 1.descriptive geometry and projection drawings; 2.digital quantitative analysis. These methods are combined with the discussion of the ideas and meanings of Chinese traditional construction. For example, in the first phase "research and analysis of traditional classics", the traditional Chinese classical architecture is taken as the starting point, its spatial type is extracted and transformed. While discussing the spatial form, the relationship between architecture and nature is taken as the entry point to establish the connotation of space. Through these two main concepts, descriptive geometry and digital quantification, students can learn the classification and context of traditional Chinese spatial construction, understand the essence of traditional architectural design, and clarify its meaning and destination.

In the second stage, "Establishing rules between geometry and space", based on the analysis model achieved in the first stage, students select a certain spatial type and define the relationship with geometric elements based on the theory and paradigm analysis. By changing the domain of the geometrical variate, students study the dependent variable in the corresponding spatial morphology and explain whether it conforms to the Chinese spatial meanings. Based on these tests, a set of transformation rules for the relationship between geometric elements and spatial connotations is established.

4. Cases of Student Works

The first semester contain the first two stages. In the first stage, it often leads to unexpected consequences when students use geometrical techniques and quantitative analysis to study the traditional Chinese architecture.

In the research of Jiang Linpeng and Wei Linyue, the traditional Chinese quadrangle courtyard is used as a classical model. They mapped a preserved village with typical quadrangle courtyard settlements, illustrated and extracted the basic constituent elements, combined with the reading of historical theory, found that the quadrangle courtyard shares three common characteristics with ancient Chinese architecture and cities: self-similarity, spatial hierarchy, and units repetition in different scales.

Whether it is common people's or aristocracy's, the quadrangle dwellings only vary in size, quantities, and height of the scale, their architectural form and spatial structure remain unchanged. These three characteristics has a very close relationship with the traditional clan system, which not only creates sustainable living conditions for daily

life, but also satisfies the ethical needs of a family with hierarchy, order, and differentiation. On this basis, they quantify the characteristics of the quadrangle courtyard with illustrations to understand its characteristics.

In Qiu Shuping and Xiao Qiaoque's study of Tulou Architecture, they first analyzed the characteristics of the Tulou as a ring and found three characteristics: centrality, infinite loop, and maximum visible range. These characteristics are geometrical optimal solutions to the density needs of the Tulou as clan habitations in particular mountainous region and the external protective function of the building. In addition, they also found that instead of standing alone, Tulou often assembled together into settlements. Compared Tulou settlements with the layout of western traditional cities, they found that they all gradually developed around the center which were the public spaces either for villages or cities, where Tulou achieved balance between its enclosure and the settlement centrality.

Figure 3: Mapping of deep structure of quadrangle courtyard.
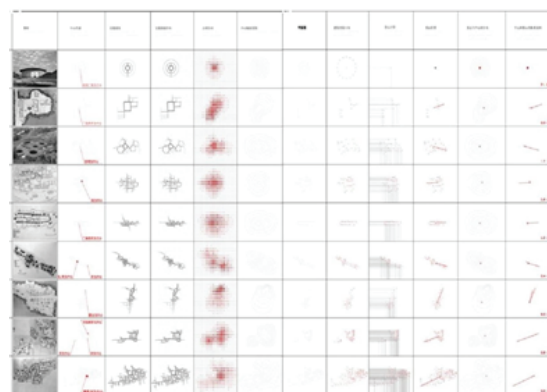

Figure 4: Diagramming of Tulou's geometry as ring and its settlements.

In the second phase, how to spatialize the geometrically quantified model under different environmental variables is the core of this phase.

In Fang Xiaoli's research on the mural paintings of Mogao Grottoes in Dunhuang, it was found that the way of viewing murals is not a static standing point view as former understood. The picture serves as a carrier, representing the sutra story and historical events. For long scrolls, single frames, series, etc., there are watching methods of one-way viewing, approaching from the both ends to the middle,

s-type trend picturesque, and collages of several narrative illustrations. These methods transfer the interpretation of the picture into temporality and narrativity. After taking this temporality into consideration, by combining the space with viewer's angel and distance between standing point and the picture, a series of visual segments and content narratives can be mapped and drew, and a geometric relationship between mural content and spatial sequence can be established.

After finding the characteristics of the Tulou, Qi Shuping and Xiao Qiaojue optimized the plan of Tulou by the geometric relationship of Tulou groups. They varied the centers of former Tulou as ring and changed its way of enclosure, through that lots of floor plans with rich variations of private space, semi-public space and public space are created, where different spatial needs can be well addressed.
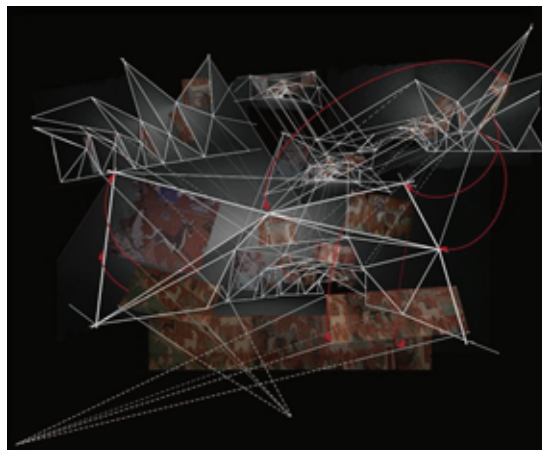

Figure 5: Narrativity of mural content and spatial sequence.

Based on the two stages' studies in the first semester, students choose a specific site and function to develop the design in the second semester. This is a process from the abstract to the concrete.

After studying the relationship between traditional Chinese roof trusses and walls, Zhu Xiaocheng applied the shell structure as a way to unify the gap between them. His design is to transform the Shui'an Mountain Residence by Wang Shu. He noticed that the integrity of the shell structure can solve the disconnection between the truss of the wood structure and the concrete bearing system beneath. The shell is much thinner while achieving the long span, which makes light and thin as the original design
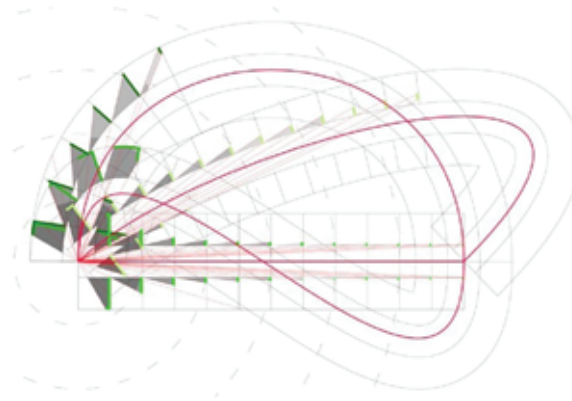
Figure 6: Variation of Tulou's plan by changing its center and enclosure.

intended. By changing the sub-variables of different trajectories and section lines, he was able to achieve multiple spatial types with distinct characteristics of soft and rigidity, heavy and light, transparent and translucent, directional and non-directional, etc.
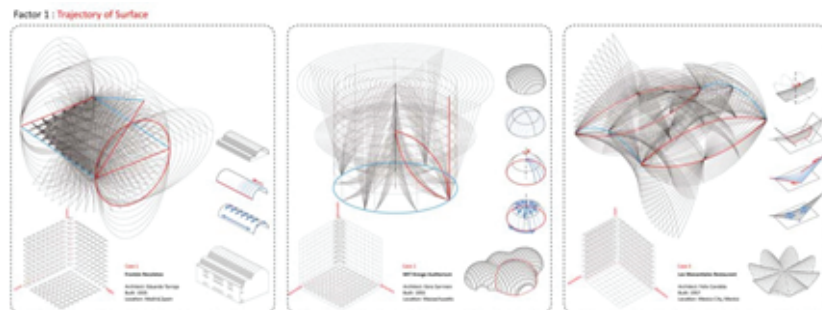

Figure 7: Studying of different trajectories and section lines of shell structure.
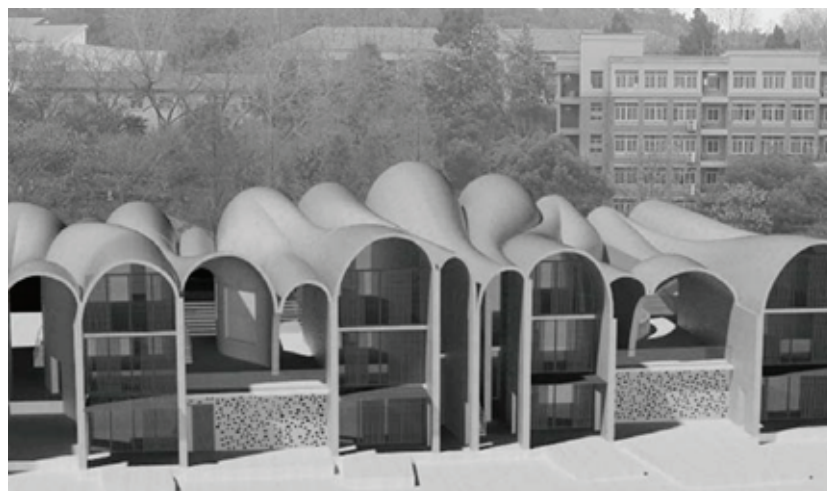

Figure 8: Design of the residence.

In Gu Anjie's research on traditional wood covered bridges and cantilevered bridges, the geometrical relationship of the corners and intersecting faces in space are found,

and the spatial form of the folded plates is extracted. She built a set of spatial relationships from site to function based on the study. Her design was to transform the Beijing T3 Terminal. She found that the giant terminal building will always be covered with a relatively homogeneous roof of city-scale, which will lead to the problems of long walking distance, the detachment of program and spatial form, the lack of sense of direction brought about by the homogenization of the roof, where thousands of people will get lost in this terminal everyday as reported. Her design was intended to reconstruct spatial recognition and circulation directionality of the airport by the folded plate's structure. The design first set the scale, direction and feelings of the space by different programs. Then the rule is established of how the folded plate units' density, length and way of lighting are responding to different spatial requirements. Finally, in the section, a double-layered folded plates system is created, where the height and tone of the space can be controlled by the distance and opening between the two layers. For example, the space of boarding hall is constructed of large-scale, relatively narrow folded plates to form a high and bright space. The direction of the triangle and the light-shadow effect of the folded plates indicate the orientation of the circulation for passengers. Compare with the security check space where the scale is smaller and the speed of circulation is slow, the small scale and squared folded plates are applied.
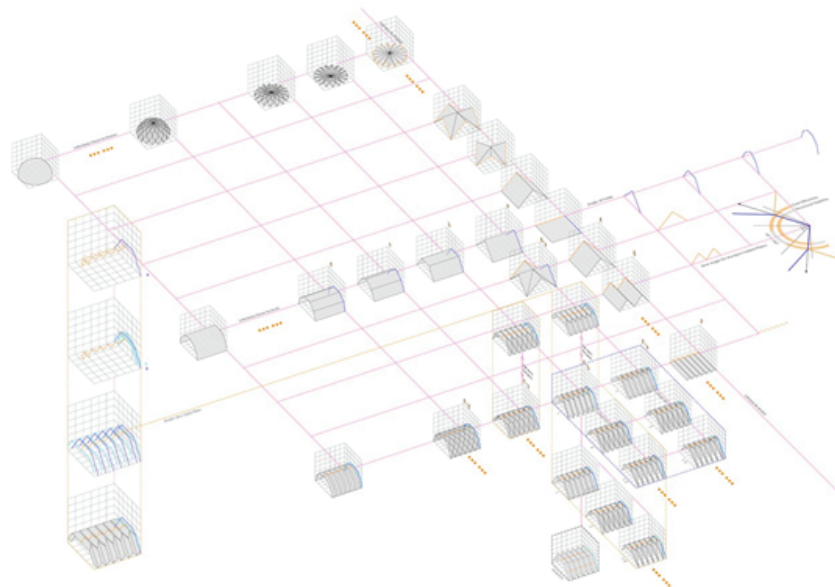

Figure 9: Studying of the geometrical relationship of the corners and intersecting faces of the traditional wood covered bridges and cantilevered bridges.
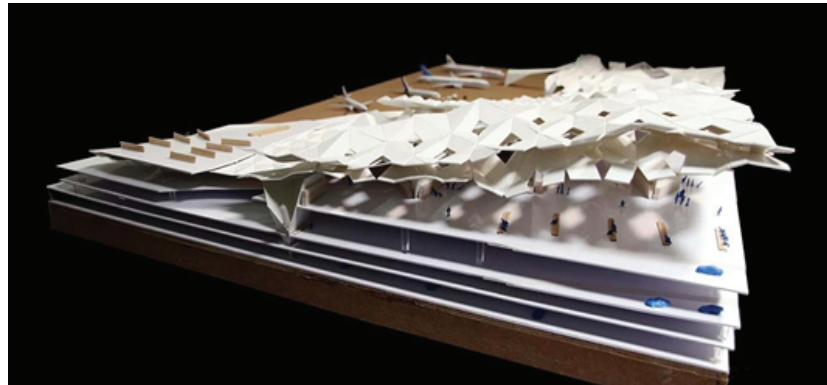
Figure 10: Design of the airport terminal.

5. Summary

Through this series of architectural education attempts, the author hopes that geometry can be used as an opportunity to understand the meanings of the Chinese traditional architecture, to convert abstract concepts and ideas into visual images and digital relations, and to provide a universal approach that is not limited to Chinese or Western architectural education.

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Conflict of Interest

The authors have no conflict of interest to declare.

Source of the Figures

Figure 1 and Figure 2, Louis Durand, *Praecis of The Lectures on Architecture*, 2000; Figure 3 was drawn by students Jiang Linpeng and Wei Linyue; Figure 4 and Figure 6 were drawn by students Qi Shuping and Xiao Qiaojue; Figure 5 was drawn by student Fang Xiaoli; Figure 7 and Figure 8 were drawn by student Zhu Xiaocheng; Figure 9 and Figure 10 were drawn by student Gu Anjie.

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