Title:
Analyzing the Geometric Distortions in a Chinese Scholar Garden in the Lin Family Mansion and Garden Using Computer-Simulated Projections

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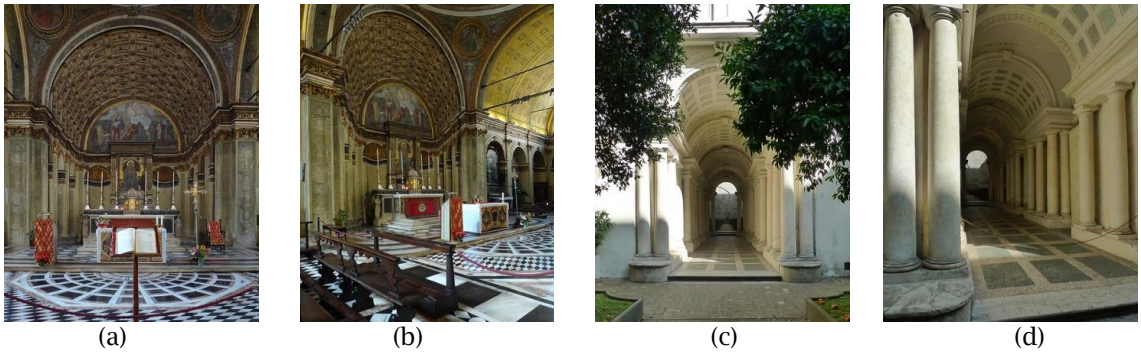
Introduction:
Architecture in the Renaissance sometimes exhibited unusual geometric distortions. These distortions were often related to a forced perspective, used to create a specific perceptual effect for particular viewpoints. As illustrated in Figs. 1(a) and 1(b), the apse of the Church of San Satiro at Milan, Italy, was constructed with distorted geometries to create an exaggerated perception of depth for the view looking straight ahead, upon entering [6].

In Colonnade Spada, located in Rome, Italy, as illustrated in Figs. 1(c) and 1(d), a similar approach was employed. Not only were the architectural elements, e.g., columns, deliberately deformed, but each pair was constructed shorter and shorter, the farther it was from the entrance. The arrangements of these deformed architectural elements were also manipulated. The floor slopes upward and is shaped like a trapezoid. The spacing between each pair of columns is also gradually reduced, based on the desired perspective, looking toward the statue at the end of the colonnade. Together, these deliberate manipulations create a forced perspective that expands twofold the illusory spatial depth of this colonnade [1].



(a) (b) (c) (d)

Fig. 1: Examples of geometric distortions based on forced perspective: (a) Apse of the Church of San Satiro, viewed from the front; (b) Apse of the Church of San Satiro, viewed from the side; (c) Colonnade Spada, viewed from the front; and (d) Colonnade Spada, viewed from the side.

Similar architectural geometric distortions can also be observed in Chinese scholar gardens. Chinese scholar gardens refer to small-scale private gardens primarily located in the Suzhou area of China,

built during the Ming Dynasty (1368–1644) and the Qing Dynasty (1616–1911). The gardens are so named because of the involvement of scholars who were both poet and painter in the garden-making process, in an effort to enrich the spatial experience within the limited physical settings [2],[5].

The Lin Family Mansion and Garden, located in Banqiao, Taiwan, is a classic example of a Chinese scholar garden preserved today. In this architectural complex, architectural constructions exhibit uncommon geometric distortions. Fig. 2 illustrates different view angles of a pavilion located in Fangjian Study, a place in the garden where scholars gathered. As illustrated, the pavilion presents uncommon distortions in perspectives viewed from the corridor, which is not perpendicular to its façade (Figs. 2(a), 2(b), and 2(d)). This is because, instead of the expected rectangular form, the pavilion is constructed in the shape of a parallelogram. However, when viewed perpendicularly, as in Fig. 2(c), the pavilion is presented in a perspective view that resembles an elevation oblique view.

An elevation oblique is a conceptual representation resulting from a parallel projection that displays a three-dimensional object in its true elevation, with a parallel line projecting backward at an angle to create the third dimension [7]. This is the most employed pictorial form of three-dimensional objects in Chinese scholar paintings. Consequently, the pavilion, along with the rock mountain, reduced bridge size, and landscaping, forms a horizontal scroll painting from its expected viewpoint.

How people from a particular culture and time paint their three-dimensional worlds as two-dimensional art can influence how they construct their three-dimensional architectures to compose two-dimensional architectural scenes. This is evident in the geometric distortions, based on a forced linear perspective, observed in Renaissance architecture. Linear perspective refers to a mathematical method that can transform the geometries in orthographic plan and elevation views into a perspective view. It is believed that the linear-perspective system was collectively established by many scholars who were both painters and architects through their two-dimensional art, three-dimensional architecture, and published text [3]. As painters were involved in the architectural design, it is not surprising that the special visual effect created by the geometric distortions has a causal relationship with the theories and techniques employed in two-dimensional art.

(a) (b) (c) (d)

Fig. 2: Oblique Pavilion viewed from different observation points: (a) from the right at the corridor, (b) from the right at the extended pavilion of Fangjian Study, (c) looking straight from the corridor, and (d) from the left at the corridor.

Chinese scholar gardens are known for the involvement of a scholar who specialized in both painting and literature in their design and construction. A Chinese scholar garden, therefore, exhibits a pictorial idea from a scholarly landscape painting and promotes expertise in “garden making [8].” The Lin Family Mansion and Garden, built around 1890, is a typical Chinese scholar garden that embodies pictorial ideas in its spatial experience. As a result, it is reasonable to suspect that the geometric distortions of its architectural construction relate to a two-dimensional Chinese scholarly landscape painting.

In addition to the distorted pavilions in Fangjian Study, more geometrically distorted pavilions are scattered around the Banyan Shade Pond. In addition to the Octagonal and Square Pavilions, the Fishing, Oblique, and Overlapping Pavilions were constructed in parallelogram forms with three

different angles; see Fig. 3. Along with the Triangular Pavilion, they exhibit different forms of uncommon geometric distortions that can be seen in the complex. Literature reviews thus far have attributed these variations as a method of adding diversity to the complex, leaving unknown their particular visual effects from particular viewpoints.

In this study, we propose that these distortions follow the concept of presenting a two-dimensional Chinese scholarly painting with the arrangement and distorted construction of three-dimensional objects for particular expected scenes. A Chinese scholarly painting depicts three-dimensional architectural elements with a pictorial system of elevation obliques of paraline drawing based on an oblique projection system. Therefore, this study proposes a computer-simulated projection to study the interrelationship of the geometrical distortions and the resultant visual presentation of two-dimensional framed scenes from expected viewpoints.

(a) (b) (c) (d)

Fig. 3: Pavilions with geometric distortions around Banyan Shade Pond: (a) Fishing Pavilion, (b) Oblique Pavilion, (c) Overlapping Pavilion, and (d) Triangular Pavilion.

Main Ideas:

Fig. 4 illustrates the difference between parallel and perspective projection systems. Perspective projections converge to a single viewpoint, with the resulting parallel lines converging to a vanishing point, resembling an image of what we see on a picture plane. On the other hand, parallel projections allow the parallel lines to remain parallel on the picture plane, resulting in a conceptual representation of what we know [3]. There are different variations of parallel projection. For example, orthographic projections are projected perpendicularly to the picture plane to create multiview plan and elevation drawings; oblique projections intersect the picture plane at an oblique angle, revealing third-dimensional information to create a three-dimensional paraline drawing.

These different approaches to describing three-dimensional geometry result in a fundamental difference between two-dimensional artistic representations in the West and East. By abandoning the vanishing point, a Chinese painting can also be free from a single viewpoint, resulting in an unlimited pictorial space that can be expanded horizontally, as long the painter wants. A Chinese painting is thus presented in a scrolling form that is expected to be viewed section by section, instead of all at once.

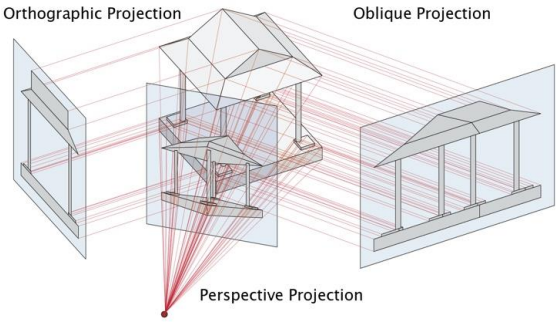


Fig. 4: Perspective projection and parallel projections of orthographic and oblique projections.

Yuan-Ye, a classical text authored by Ji Cheng, a famous garden maker and painter of the Ming Dynasty, well illustrates how the techniques of composing a Chinese scholarly painting can be applied to compose the three-dimensional scenes in a Chinese scholar garden [4]. As a result, exploring a Chinese scholar garden can invoke the viewing experience of a Chinese scholarly scroll painting.

In light of this unique relationship between two-dimensional art and three-dimensional architecture, we hypothesize that the geometric distortions in the Lin Family Mansion and Garden are particularly manipulated to allow expected viewpoints to create scenes that resemble the three-dimensional pictorial architectural forms depicted in scroll paintings. To analyze these viewpoint relationships and the geometric distortions, we utilized computer-simulated projections to determine the proper viewpoint and observe how those distortions appear.

A pavilion, in Chinese, refers to a place to stop and stay; this implies that they provide opportunities to see the garden without blocking foot traffic. We thus viewed the garden from the different pavilions to examine how they appeared from the different viewpoints. The intention of the projection simulation is to reveal whether a viewed image resulting from a perspective projection will resemble the pictorial presentation of an oblique projection.

A 3D model of a portion of the Lin Family Mansion and Garden was constructed. In addition to the physical setting of the garden and pavilions, perspective projections of different viewpoints and viewed targets were also modeled, based on the linear-perspective principle. Fig. 5 illustrates the resultant projected images on picture planes of the Fishing Pavilion from different viewpoints. The result demonstrates that viewing from the Octagonal Pavilion provides a perfect elevation oblique view from the perspective projection.

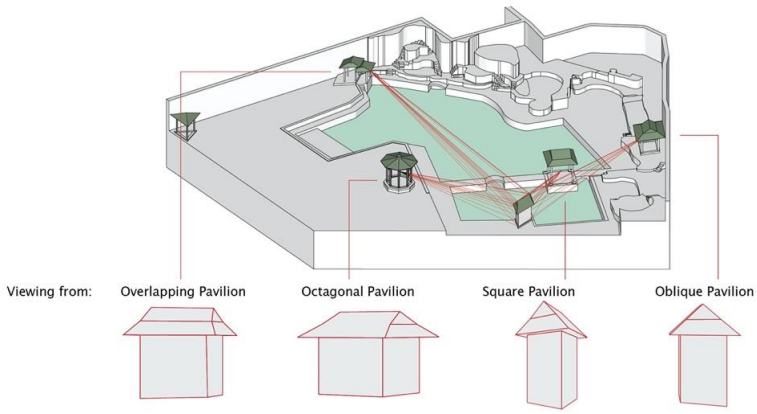


Fig. 5: Computer simulation of perspective projections of the Fishing Pavilion from viewpoints from different pavilions around the Banyan Shade Pond.

The location and form of the Octagonal Pavilion suggested that it was designed as a place to observe a panoramic view of the garden. The distorted Fishing Pavilion, Oblique Pavilion, and Overlapping Pavilion are connected with rock mountains, water, trees, and flowers to form a continuing landscape, just like a scroll painting. Fig. 6 further illustrates the perspective projected image viewed from the Octagonal Pavilion. As illustrated, the distorted pavilion is all presented in elevation or elevation oblique views. This confirms our hypothesis that the geometric distortions are particularly manipulated for a particular viewpoint. In our study, the expected viewpoints are located in the Octagonal Pavilion, where the distorted geometries are presented in a pictorial form of paraline drawing that is commonly used in Chinese scholarly paintings.

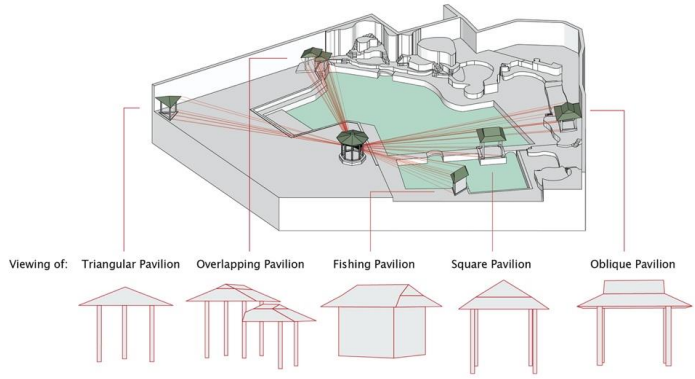


Fig. 6: Computer simulations of perspective projections of pavilions, viewed from the Octagonal Pavilion.

Conclusions:

The geometric distortions observed in Renaissance architecture were based on the theories and principles of perspective projection, which a Renaissance architect could use to plan a layout in multiview drawings and transform them into a perspective drawing to foresee how the building would appear when built. The mathematical principle of linear perspective can thus explain the cause-and-effect relationship of geometric distortion in Renaissance architecture. As the drawing system did not completely develop into a design tool in Eastern China, applications of Chinese scholarly-painting theories and techniques in their architecture design are relatively unknown.

This study utilized a computational approach to model the perspective projection of distorted geometries to investigate the cause of the architectural distortions and their expected visual effects, as observed in the Lin Family Mansion and Garden. The results revealed that the distorted geometries were designed to create a pictorial presentation of an elevation oblique view of architectural elements that blended into the landscape background to form a continuous scrolling painting, which unfolded in a panoramic view from the Octagonal Pavilion.

In summary, this study demonstrated an effective computer-aided research technique to study classic architecture and discovered an untold story of how architectural elements can be distorted, based on the oblique projection used in Chinese painting, to create a three-dimensional landscape painting.

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