Virtual Motion

Shifting Perspective as an Instrument for Geometrical Construction

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Abstract. From the invention of projection to the emergence of digital technology, there’s a clear correspondence among the transformations of visual representation paradigm in art, the developments of design instrument in architecture, and the human perception of time/space. Based on the examination of this particular historical trajectory, this paper focuses the working mechanism of shifting perspective as an alternative design instrument to explore the possibility of embedding time and motion into static form in digital age. Firstly, the paper reviews how the shifting perspective was introduced to represent space in modern western painting and photography. Then based on the research on shifting perspective, the paper develops a design tool, which would be able to translate motion into the particular geometrical feature of a generated 3D object. In the end, the paper brings further discussions about the formal and spatial effects brought by this new tool, and its potential to incorporate the perceptive image of human being into design process.

Keywords. Shape Study; Projective Geometry; Shifting Perspective; Motion; Time Dimension.

1. Introduction

In the tradition of architectural practice, form was strongly influenced and limited by the instruments of spatial representation, which were usually plan, section, elevation, perspective, and so on (Evans 2000). In design process, these instruments were usually operated by a series of geometrical projections between different dimensions to notate and represent the designed building. And the way of notating and representing building at that time was also closely related to the way of depicting object in other art forms like painting, especially in the representation of space by using perspective projection (Lotz 1977). Furthermore, the representation instrument in both art and architecture reflected how human being was perceiving and interpreting space/time during that period. As the
perspective projection indicating the static relation between subject and object, time was perceived as abstraction passing through the external space of measure, management and mastery (Kwinter 2001).

In contemporary architecture, digital technology transforms architectural design into a practice based on process rather than representation. Unlike the traditional mathematics of architectural form were usually understood as the instrument of geometrical construction, in which time has been eliminated; now, not only the design environment is interpreted as dynamic, but also form itself could be generated through motion (Lynn 1999). The traditional design instruments, like orthogonal or perspective projection, are being challenged or even replaced by animation and coding process, such as the utilization of genetic algorithms to search the formal result in a topological space of full possibilities (Delanda 2002). The similar shift of production could be also recognized in contemporary art practice, especially those based on digital media or interactive technology. Furthermore, on one hand, the form produced by a dynamic process in both art and architecture could generate virtual motion effect in human perception (Lynn 1999), which allows us to interpret the world beyond its actualized or materialized presence and challenges the biological foundation of our perception. On the other hand, the digital media as culture device has an influence on our contemporary life, which leads architecture towards a new materiality (Picon 2004). So we could also find mutual influences between the human perception of time/space and the new production paradigm in the art and architecture of digital era.

Therefore, from classical time to digital age, we could find clear correspondences among the transformations of visual representation paradigm in art, the developments of design instrument in architecture, and the human perception of time/space. However, tracing the history from classical time to contemporary, is the coding based generative process the only way to respond the new perception of time/space? Is there any alternative ways of producing form in between the two eras, which could be utilized by us to establish new ways of designing form with digital technology to reflect time and motion? The question becomes the initial driving force of this research. With these particular enquiries, the approach in the research was subdivided into three steps. The first part was a series of historical studies on other art techniques involving the concept of time, process and dynamic, besides of coding form and interactive design. To be specific, it was mainly addressing the techniques utilized in modern painting and photograph (the reason will be further elaborated in the background session), and trying to reveal their internal mechanism for further development. The second part was trying to transform the generative power from modern painting/photograph technique into a form-finding instrument for architectural design by combining the revealed mechanism with digital modeling technologies. Eventually, in the third part, we will conduct an experiment by using the developed instrument to generate a series of formal results under different parameters, and then make a discussion on the potential of the tool to connect form, motion type and human perception.
2. Background

2.1. NEW WAY OF PERCEIVING TIME AND SPACE IN MODERN ERA

The “dynamic” visual relation between human and the environment was not only revealed in digital age. Since the dawn of western modernity, the concept of time has already escaped from its classical situation, and expressed itself by drawing matter into the wild process of becoming-ever-different towards novelty (Kwinter 2001). So with the modern interpretation of time/space, form has already been perceived as being constructed through its own history and at same time evolving towards novelty. Modern artists recognized the dynamic condition of the world, and tried to reflect it with their works. And because the cinematic and interactive technology hasn’t been applied to the field of painting, sculpture or photography at that time, the artists had to invent certain form techniques to express virtual motion with the static material reality of the media. It’s a similar situation that the contemporary architect is facing now, because not every building can have actual motions or be merged with virtual reality. Therefore, by learning the representation techniques from modern art, we could create new tools to generate formal possibilities.

In the modern movement of western art, there was a shift of interest from depicting a static space to expressing the motion of an object in a dynamic environment. For example, derived from the projection mechanism of traditional painting, the techniques of spatial construction started to involve the geometrical information of the forth dimension-time. In Cubist and Futurist painting, like Nude Descending a Staircase by Marcel Duchamp, by superimposing a sequence of projected lady figures, which belongs to different time frames, into a single two-dimensional space, her walking motion could be fully captured and expressed within the static media of the painting (Lynn 1999).

Comparing to painting, modern photography adopted a different approach in the representation of time and motion. For example, instead of overlapping the projected images from different time frames into a single picture, the chronophotography of Etienne-Jules Marey juxtaposed a series of successive images to trace out the trajectory of the moving object (Braun 1992). As the production of form techniques, both the superimposition of modern painting and the juxtaposition of chronophotography produce the formal results containing a series of discrete elements. However, there’s another particular kind of photography, which is different from both form techniques elaborated above. It not only represented motion effect within the static picture, but also kept the clarity and continuity of depicted object without ending up with a series of phantoms. The most representative work of this photography is called Automobile Delage (see Figure 1), and its projection mechanism is named as shifting perspective.
2.2. AUTOMOBILE DELAGE AND THE MECHANISM OF SHIFTING PERSPECTIVE

Shifting perspective could be interpreted as the combination of superimposition and juxtaposition. Its projection result is constructed in a way of superimposing different time frame into a two-dimensional image and juxtaposing the image pixels, which all belong to different time frames. And the motion effect in the photograph of Automobile Delage could be perfectly explained by the working mechanism of shifting perspective.

Automobile Delage was taken by the famous photographer Jacques Henri Lartigue trying to record a racing car at the French Grand Prix in 1912. In the photograph, the motion of the racing car was successfully captured by the camera and represented by the leaning effect of people and wheel. And James E. Cutting explained the shifting projection mechanism of the leaning effect in his research “Representing motion in a static image: constraints and parallels in art, science, and popular culture”,

“The film is exposed sequentially through a narrow slit in the shutter as two curtains move laterally across the back plane, one revealing and one re-covering the film. Here, Lartigue turned the camera on its side. The bottom part of the picture was exposed first and the upper part later; hence the forward lean of the car. Notice, however, that the people are leaning backwards by about the same degree. This was accomplished by panning the camera horizontally, left to right as the car passed, but at a rate about half as fast as the car. Time, as ones move up the image, left the stationary objects behind, and hence they lean to the left” (Cutting 2002).

Based on this explanation, the research translated the scene of the photo into a diagram to explore how the leaning geometry was constructed by shifting projection mechanism (see Figure 2). As Cutting explained, the photo was actually taken through a short time period, so the diagram was constructed in a Cartesian coordinates system, which contains three axes-X, Y and Time. Axes X and Y together represent the plane of the photo, and the axis Time represents the duration the shooting process. During the shooting process, the people standing in the background didn’t have any motion along the axis X and Y, so his 2D figure in time dimension would be constructed as a simple extruded box, which is perpendicular to the plan XY. Following the same logic, because the wheel of the car was moving
along axis X at a speed of 2V during the shooting, it would be constructed as an oblique extruded cylinder in the diagram. The narrow slit of the shutter could be represented as a horizontal line in plane XY. As Cutting explained, during the shooting, the narrow slit was moving upward, and the whole camera was moving from left to right at a speed about half of the car’s. In the diagram, when the horizontal line of the narrow slit is moving along the axis Time, it’s also moving toward up along axis Y at certain speed, and moving toward right along axis X as a speed of V. Therefore, it would be constructed as an oblique extruded plane. According to the working mechanism of a camera, when the narrow slit of the shutter overlaps with the certain part of the scene in the projected plane, the corresponding part of the picture would be exposed to record that part of the scene. So in the diagram, the final geometry of the photo could be constructed through two steps: first, the extruded plane (the slit of the shutter) would intersect with the extruded box (the people) and cylinder (the wheel); second, the intersection result would be projected back to visual plane XY to generate 2D figure.

![Figure 2. The technological mechanism behind “Automobile Delage” as an instrument of geometrical construction. Drawing by the author.](image)

As the diagram explained, the leaning posture of the projected figure is actually the representation of the history of its movement. Through the mechanism of shifting perspective projection, both time and the history of the motion of the depicted object could be translated to particular geometrical features to be embedded into the final picture, which provided a dynamic formal effect for modern visual art. So this diagram reveals a possibility of using the mechanism of shifting perspective as a geometrical construction tool to generate virtual motion effect for architectural form.
3. Methods

3.1. TIME AXIS IN 3D GEOMETRICAL CONSTRUCTION

In the photograph Automobile Delage, the projected 2D form was constructed by a series of horizontal lines intersecting with the extruded geometry from the original 2D figure. In that sense, the formal result is actually in a 2D coordinate system consisting of axis X and axis Time. Axis Time notates the time frames, within which the image was projected. Axis X notates the geometrical information of the depicted object in each time frame. So the projected result is actually representing the construction history of itself.

In order to use the same mechanism to generate 3D geometry rather than 2D photograph, the horizontal lines (One-Dimensional) would be replaced by a series of invisible plane (Two-Dimensional), and the extrusion (Three-Dimensional) of the original 2D figure would be replaced by a depicted 3D object with particular motions (Four-Dimensional). And finally, the 3D result would be constructed through a sequence of operations: first, in each time frame, both the depicted object and the invisible plane would be in certain positions and orientations according to their motion path; second, in each time frame, the invisible plane would intersect with the depicted object to produce a 2D figure; third, as the process finished, all the 2D figures produced by the intersection in each time frame would be juxtaposed together to generate the final 3D object.

For example, a rotating cube should be interpreted as a four-dimensional object, which is in a coordinate system consisting of X, Y, Z and Time axes (see Figure 3). Normally, if we want project it into 3D space to produce a formal result, the operation would be to “pause” its rotating motion at a single time frame. In another word, the cube would be projected into a space, in which the Time axis is diminished. And this is also the common situation happening in most of animation-based generative design process—it has to be paused at certain point to “solidify” the final result. However, in shifting projection, the Time axis would be kept to record the motions of the rotating cube and the invisible plane. And the final result would become a series of 2D figures, each of which is produced by the intersection between the cube and the plane at one time frame. As the cube rotating, the invisible plane will be moving along the time axis and passing through cube. By intersecting the invisible plane with cube at each time frame, a series of unique sectional figures of the cube would be produced. And in the end as the sectional figures being juxtaposed one to another according to their positions along the Time axis, the form of the final result would be revealed.
3.2. SYSTEM DEVELOPMENTS

As described above, this system will be set up with four basic elements: a 3D rigid object, a 2D invisible plan, time, and 2D figure from intersection (Figure 4). Here, the original 3D rigid object is a cube, and letter A to G indicated the vertex of it. Time passes by each single frame, and “P” indicates the 2D invisible plan. This plane could only have uniform motion in a straight line because it is actually a time indicator, and it will be able to intersect with the cube and generate a series of 2D figures. With time passed frame by frame, the frozen 2D figures will accumulate and start to construct a virtual 3D geometry within multiple time-frames. In the diagram, the outlines from i(0) to i(n) are the frozen 2D figures from intersection. In the right image of Figure 4, although the final geometry constructed by the outlines i0-100 looks like the original cube, it is actually not the cube which was constructed by its vertex. Rather it’s a new geometry constructed by the accumulation of 2D figures from the Time Axis i(0) to i(n).

For the original cube, there are basically three moton factors that could be manipulated–translation, rotation and scale. Figure 5 illustrates the motion of the original 3D cube by tracing it path in 170 frames. The value of the rotation factor is increased linearly from time t=0 to t=170. The accumulated outcome of the 2D
intersection figures is presented in the right image of Figure 6. In the drawing, the seams are actually the representation of all the points, which were generated by intersecting the 2D plan with the edge of the cube, and the curved surface is the imprint of intersection edges. Therefore, all the geometrical features of the new form represent both the property of the original cube and the character of its motion simultaneously. The final result can be modified not just by changing the original 3D form, but more effectively by manipulating the variations of its motion. And the form of the motion variation curve would be reflected on the feature of the final geometry (Figure 5).

Figure 5. The system with a rotating cube, and the final result records and reflects its motion history.

In Figure 6, varies geometries are generated from an animated cube with different motions, and the motion variation curves are showing how the motion was set up (Figure 6). In comparison with the form in Figure 5, the first geometry in Figure 6 has horizontal seams, which indicate the discrete acceleration of its rotating motion. The seams would happen on the inflection point of the motion variation curve. The second geometry has some dramatic position on its foot, but suddenly become smooth after certain point. This feature could also be reflected by the motion variation curve of its rotation. The last two geometries of Figure 6 have both motions of move and rotation, which give them drifting features.

Figure 6. The final result varies according to different motion variation curves.
This system also provides a possibility to integrate certain type of motion from other project, and to combine the character of a 3D geometry with the information from any kind of movement. In the case study below, the motion variation curves were extracted from the motion of a dancer. And the final result reflects her motion history on its geometrical features (Figure 7).

Figure 7. The motion variation curves of the system derive from movement of a dancer, and the generative result.

4. Results and Reflections
As the results of the series of formal studies showing, the generative system has the capability to reflect motion and time on the geometrical features of its outcome. Each of these formal results contains unique geometrical composition and surface curvature, which indicate the speed, acceleration/deceleration, and even the trajectory of the motion history of the original object. However, to allow the further development of this generative tool and to make it available to architecture practice, there are still some issues that need to be addressed. And the most important one of them would the problem of resolution. Depending the subdivision degree of the Time axis, the generated formal result would appear in different resolutions. On one hand, it could be interpreted as an issue of computational capability. As the time axis is divided into more segments, the “thickness” of the invisible plane would become smaller, and finally we would get higher degree of the continuity of the surface. On the other hand, the “roughness” of the surface could be utilized to incorporate with the tooling path of fabrication or even treated as ornamentation, as there’s no real continuity in physical world. And this strategy could take reference from Greg Lynn’s early experiment, in which the ornament was generated by the process of converting a spline mesh surface into the tool path of CNC machine (Lynn 2004).

5. Conclusion and Further Research
In contrast with the traditional way of conceiving form based on the coordinates of X, Y, Z axes, the instrument of geometrical construction derived from shifting perspective will be able to operate within a virtual space in which the coordinates is established by X, Y and Time axes. As the whole generative process becomes a dynamic animation, the instrument will offer an alternative approach of geometrical construction to readdress time and motion in space. In consequence, architecture will not be a static object standing in a single time frame anymore, but
a system of dynamic organizations reflecting its virtual motion history.

According to Brain Massumi, although building is concrete and static in most circumstance, human occupant is always moving through or passing by a building, so as a “Doppler effect”, the building could be interpreted as a moving object in perceptive reality too (Massumi 1998). In that sense, both building and human would have motions being mutually relative to each other. Therefore, the further research will address on the motion of the invisible plane, and to imagine it as the particular motion of human eyes. In doing so, the tool could offer the possibility to compute the intended perceptive image of human being, which is usually missed in contemporary digital design, and to provide the possibility of redefining the relation between human as perceivers and the space of architecture.

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