Parametric Strategies in Civic Architecture Design

Using several NBBJ civic projects as case studies, this paper provides an overview of how NBBJ’s Los Angeles design studio is leveraging parametric and generative processes for the design of projects such as stadiums and exposition halls. A combination of ambitious intent and fast project schedules necessitates the use of advanced parametric tools to quickly solve complex problems, generate unique features, and automate parts of the design process.

Designers will utilize digital tools for a variety of purposes, which can be classified under two general categories. The first and most common application of the technology is within the category of rationalization and optimization. The tool, in this case, is limited to the role of a production device that aids the designer in efficiently solving complex design problems. In more unique projects, the advanced technology acts as a generative tool and is an integral part of a working design methodology. In this case, the design technology becomes more than just a tool at the designer’s disposal. Rather, it has the potential to act as a critical lens for identifying new possibilities in the architecture.
INTRODUCTION

In the midst of an increasingly uncertain global economy, architects are seeking new ideas and design processes to differentiate their design product and gain competitive advantages within the market. The latest advances in digital design technology are at the forefront of this conversation by fundamentally redefining how architecture can be designed, documented, and constructed. First, advanced tools offer a means to improve efficiency in the design-delivery process by allowing designers to more easily manage complex project information. Second, new design technology offers opportunities for innovation by giving the designer the ability to expand the possibilities of buildable forms through new design and fabrication processes (Shelden 2006).

For NBBJ Los Angeles, the area of practice in which advanced digital technology is becoming the most influential is within the civic market. The demand for ambitious civic design ideas from clients, city officials, and the public allows a greater degree of freedom to explore and experiment with new processes, forms, and design techniques. At the same time, the complexities associated with various practical considerations require the use of more advanced techniques to efficiently automate and manage the design challenges at large scales.

Currently, digital technology is leveraged in two ways within the design process. More commonly, advanced digital technologies are used for the purposes of rationalization and optimization. The advanced digital toolsets in these instances are used purely as a means to support the design idea, while the technology is placed in a supporting role. This is often extremely effective from a production standpoint; however, the full potential of the digital techniques to inform design thinking is rarely achieved.

In more unique cases, opportunities for utilizing the generative capabilities of advanced design software are identified, and the digital tool acts more as a critical lens for generating new architectural possibilities and for evaluating the project. When digital technology is able to operate in this mode, design ideas evolve out of a system of project rules and constraints. This process-driven approach allows for the design logic established within the early phases to be carried seamlessly into the design development and construction phases of the project. Further, this form of design process will often require the invention of new tools and techniques in the form of scripts and macros, enabling a more open-source attitude towards digital technology, accompanied by an interest in going beyond appearance and into the design of processes (Kieran 2005).

Using several case studies, this paper outlines the range of influence advanced digital tools are having within the NBBJ Los Angeles design studio. While still early in their implementation, advanced digital technology is being more readily deployed over the course of the design and delivery phases in varying degrees. The case study projects are treated as a roadmap for the continued integration of advanced tools and customized workflows within the design process in order to strike a new balance of both efficiency and innovation.

2 KINTEX EXPOSITION PHASE II

The Kintex Exposition Center Phase II is a winning NBBJ design competition entry located in South Korea (fig. 1). Programmatically, the building holds six convention halls, a multipurpose hall, and a mid-rise office tower. The building is sited as two convention wings on the east and west that flank two exterior plazas and are connected by an atrium space. Conceptually, all programmatic elements are tied together by a continuous roof form, which splits and undulates to modulate light and to conform to interior volumetric requirements (fig. 2). In terms of the digital design processes, various parametric modeling techniques became a means to quickly develop, rationalize, and detail the conceptual surface into a developed 3D model under the umbrella of the overriding design concept.

The first modeling challenge was the articulation of a long-span roof truss that conformed to both the free-form curving roof geometries and the engineer’s structural sketch (fig. 3). To accomplish this, the initial B-spline geometries that defined the roof surface sweeps were used as a starting point for structural articulation. Each B-spline was subdivided into equal point lists and then cross-connected to create the truss edges. These lines were then subdivided further to articulate truss chords and cross members. Since the geometries were associated with one another, further
The second challenge was the curtain wall design and the ability to iterate through several detailed variations of patterns that emerged from the combination of structural and glazing systems (fig. 4). The initial surface from the conceptual model was used to drive the curtain wall geometries. The surface was divided into a modular grid based on the UV parameters of the surface to allow for the propagation of standard components comprising the structure, mullions, and glazing panels (fig. 5).

While this propagation technique is now a fairly standard operation within parametric modeling software, the challenge was the precise coordination of the three different systems being driven from one surface (fig. 6). The necessary offsets, material thicknesses, structural depth, and density had to be taken into account for the successful systematization of the design.

As a benchmark project within the studio, the Kintex Expo provides an example for integrating parametric techniques in a one-directional manner within the design process. The short time frame of the competition and the late integration of the technology did not allow for any degree of feedback to occur between the design intent and the tools. The tools were, therefore, always at the service of the design but never the reverse.
3 SHELL STADIUM

The Shell Stadium is one of several design studies for an international stadium competition. The primary challenge of the competition was to create a flexible stadium design that could shrink or expand its capacity between 30,000 and 70,000 seats over the course of its life span, while still maintaining a strong iconic image. Shell Stadium is composed of two large shell-like forms that twist up from the ground to become the stadium roof (fig. 7). Conceptually, the shells would act as a self-supporting staging area under which the stadium bowl and retail functions would be free to modulate their program sizes. From the standpoint of implementing parametric tools, Shell Stadium offered several unique opportunities in the areas of formal rationalization of the roof form and in the creation of a system for generating multiple bowl prototypes.

The stadium shell concept allowed for an investigation into the potential of using rationalized mathematical geometry as a design driver. To start, the concept was loosely sketch-modeled using free-form NURBS surfaces. However, given the budgetary constraints outlined in the competition requirements, it soon became clear that there needed to be a way to develop the curvatures in a more rigorous manner. Torus geometry was chosen as a starting point because of its ability to achieve controlled doubly curved shapes while still maintaining standardized...
quadrilateral panel modules (fig. 8). The use of torus geometry as a rationalization technique has precedent in architecture design, most notably in the work of Sir Norman Foster and the Specialist Modeling Group (Peters 2008). The mathematical properties of the torus allow for more efficient manufacturing and production of architectural elements such as structure and surface materials (Shodek et. al. 2005).

Various irregular profile curves were intersected with the torus geometry in order to find an optimal torus surface section that curved from a vertical condition to a horizontal one (fig. 9). From the torus section, structural ribs and panels were generated for further study into the structural and skin systems. The use of the mathematical geometry within a parametric modeling environment also allowed the design team to efficiently coordinate 2D laser-cut files of the curving structure and panel systems (fig. 10) and quickly construct various physical study models (fig. 11).

The programming of the variable seating layouts was a unique opportunity for devising a parametric system to study bowl shapes, seating capacities, and configurations. An in-house bowl generator was scripted based on typical stadium conventions (John et. al. 2007) for the creation of two- or three-tiered bowl sections, derived from the calculation of optimal sightlines (fig. 12). The script sweeps the bowl section along a specified plan curve to create an up-to-date 3D representation (fig. 13). The user is able to adjust parameters such as the number of rows,
the distance from the playing field, and the sightline standards. Other critical
design data such as seating capacity estimates, riser angles, and 2D bowl
sections are also outputted to the user.

The Shell Stadium is an example where feedback between a design idea and the
digital tools moved the design process forward; it also set an example for how
geometry could be rationalized and fabricated. Further, the creation of the bowl
generator has proven to be a valuable tool that can be reused on multiple stadium
and arena projects.

4 HANGZHOU MAIN STADIUM

The Hangzhou Main Stadium is an 80,000-seat multipurpose stadium located in
Hangzhou, China. Originally planned as the venue for the National Games for the
People’s Republic of China, the stadium is now conceived of as a premier sports
venue for the rapidly expanding city of Hangzhou (fig. 14.). For the NBBJ LA studio,
the Hangzhou Stadium is a benchmark example where parametric thinking was
integrated into the early design stages and then advanced as the design became
articulated within a developed model. The execution of the stadium also draws from
many of the strategies outlined in the previous projects andcoordinates them into
one parametric system.
The exterior of the stadium was conceptualized as a series of unique yet repetitive truss modules (affectionately referred to as “petals”), which enclose the stadium bowl. The original geometric concept was derived from a study of 3D, symmetrical B-spline patterns, resulting from a rigorous copy-mirror process about an elliptical stadium shape (fig. 15).

Since the process followed a set of loosely defined rules, multiple iterations and variations could be generated and evaluated from the standpoint of aesthetics and proportion. After a decision was made on a visual effect, the geometry underwent an optimization process in order to conform to a series of constraints driven by structural, modular, and programmatic parameters (fig. 16). The primary challenge of the optimization process was to effectively translate the winning competition concept into a flexible parametric system that could take into account different geometric constraints, as well as have the ability to grow and adapt for future design development (fig. 17).

The original concept model was used as a starting point, and, in turn, the inner and outer limits of the geometry were defined in section. From these limits, points were mapped which would act as control points for B-spline curves. These curves are used to define the primary truss cross section (fig. 18). Multiple instances of the primary truss and the curve control points were then reoriented perpendicular to the elliptical stadium curve. This method allowed the primary trusses to maintain the same sectional dimensions around the entire stadium. The petal profiles were then described from the same set of instanced control points that have been shifted in key places within the section and elevation. The result was a customized petal geometry that was relational to the primary, regularized truss structure. The petal surfaces were modeled as a series of developable surfaces connecting two adjacent petal rail profiles. Limiting the geometry to developable surfaces is of particular importance when considering how the petal shapes would eventually be unrolled for manufacturing purposes (Shodek et. al. 2005). The curve geometry defining the trusses and petals were further subdivided to achieve the cross-bracing and lateral support centerlines (fig. 19).
Since the stadium geometry is associative, the design team is now able to efficiently study alternatives within the new geometric constraints and in keeping with the original design intent (fig. 20). As the stadium bowl geometry changes (utilizing the bowl constraints, for example), the outer form can now quickly adapt to a new plan and section. Further, feedback from consultants and engineers is able to be absorbed within the system by branching off the original geometry to add further detail and articulation (fig. 21). The advantages of this system are numerous, but the primary gains are the ability to preserve design intentions independent of any given geometric iteration and the elimination of the cost associated with generate-test-discard models of design practice (Sheperd 2006).

As an ongoing project in development, the Hangzhou Stadium acts as a benchmark for integrating parametric ideas and tools at all levels of the design process. As the design process of the main stadium moves forward, the goal is to have parametric modeling continue to be the primary means of developing the design, as well as to transmit the design intent to the local architects, engineers, and clients in China.

CONCLUSIONS AND FUTURE POSSIBILITIES

The use of parametric modeling tools in varying degrees is beginning to gain momentum within NBBJ's Los Angeles design practice. Specifically, the ambitious design criteria associated with civic projects has necessitated the use of advanced parametric modeling to effectively design with the complex constraints of programmatic, structural, and geometric concepts.

In the case of Kintex Expo, the digital tools are used as a means to efficiently build and coordinate complex design pieces, such as curtain walls and structural systems within the 3D model, using propagation and subdivision strategies. While this method of computer modeling is not a new technique, the recent implementation within the NBBJ studio has expanded the studio's design possibilities by enabling designers to more efficiently describe and visualize complex systems and relationships.

In the case of Shell Stadium, customized tools and processes have been devised within the studio to aid in solving complex and recurring design problems. The stadium bowl generator developed for the Shell Stadium has allowed for the rapid creation of stadium prototypes on various stadium projects. Rigorous rationalization techniques using mathematical geometries have allowed for explorations into the fabrication and prototyping of complex forms and structures. Developing these unique processes has spurred the creation of a digital tools library so that as new techniques are discovered and invented, they can be developed and customized for use on various projects.
The Hangzhou Stadium serves as an example of utilizing a generative approach to digital techniques by developing a rule-based methodology to drive the project from early conception into design development. Since the design was parameterized into a flexible yet precise system of constraints, the design team was able to take a comprehensive approach in solving the geometric and engineering problems, as well as efficiently study design alternatives grounded within the design intent.

Ultimately, as advanced modeling tools and techniques become more widely used within the design studio, the design of the digital process becomes just as important as the design of the projects themselves.

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