LEARNING, PROTOTYPING AND ADAPTING

May 17-20 2018
School of Architecture
Tsinghua University, China

This volume contains the peer reviewed short papers accepted for the 23rd International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA) 2018, held at the School of Architecture, Tsinghua University, Beijing, China.

Learning Prototyping and Adapting Short Papers Proceedings

2018 CAADRIA

The 23rd International Conference on Computer-Aided Architectural Design Research in Asia

Learning Prototyping and Adapting

Short Papers Proceedings

Edited by
Weixin Huang
Mani Williams
Dan Luo
Yi-Sin Wu
Yuming Lin

W. Huang, M. Williams, D. Luo, Y. Wu and Y. Lin (eds.), *Learning, Prototyping and Adapting, Short Paper Proceedings of the 23rd International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA) 2018*.

ARCHITECT'S FEASIBLE DESIGN SOLUTION SPACE

Case studies of non-standard façade design practice in China

SINING WANG[1] and KRISTOF CROLLA[2]
[1,2] *The Chinese University of Hong Kong, Hong Kong, China*
[1] *wangsining@link.cuhk.edu.hk*
[2]*kristof.crolla@cuhk.edu.hk*

Abstract. Facing China's challenging construction context, notorious for its high speed, poor detailing, and low budget, an ideal digital paradigm for non-standard architectural practice may be inaccessible. However, a group of Chinese avant-garde practitioners has successfully bypassed these restrictions by including regional idiosyncrasies into their computation-driven design and materialisation methods. This paper raises the argument that a critical component to those successes is that their parametrically established exploration space responds to local constraints. Here, we study two non-standard façades from architectural practice Archi-Solution Workshop and discuss the architect's strategies.

Keywords. Design solution space; parametric modelling; non-standard; challenging context; Archi-Solution Workshop.

1. Introduction

Mario Carpo's theoretical underpinnings (2011) affirm that the digital turn is stimulating a shift in the role the architect plays in practice. The medium of parametric modelling, including the model's "creation" and "use" (Davis, 2013), assists the architect to redraw the landscape for a new authorial environment. Architectural practice is a negotiation between created problems and feasible solutions (Hudson, 2010), meaning that in parametric practice the model creation defines a structured problem space where an architect uses digital models to explore design solutions.

For non-standard architectural practice in China, increased geometric complexity requires extensive development in correlated industries. When, due to time and financial restrictions, only conventional building development and implementation techniques are made available to the architect, a gap appears between the desired forms and the effective project delivery strategies. Professor Xu (2013) suggested a “third cultural attitude” to respond to the Western digital trend; a mindset which, rather than is merely synthesising China and the West, is rooted in a contemporary construction context which adaptively reacts to technological advancements. As part of this research in commonality, here, we study two non-standard façade projects from Chinese architectural practice Archi-Solution Workshop and discuss its design and materialisation strategy.

2. Feasible design solution space

Design activity creates a problem space (Newell et al., 1957) which bounds are defined by a designer’s intent, plan and actions, and are driven by related constraints. Design exploration refers to the search for feasible options inside a solution space (Woodbury and Burrow, 2003). In architectural practice, regional peculiarities from construction attribute to the setup of requirements, conditions, and boundaries of a problem space. Also, an architect’s solution space (design capacity) relies on his/her empirical knowledge and given resources. The common space of this capacity and the bounds of the problem he/she defined, therefore, generalise a range of feasible explorations.

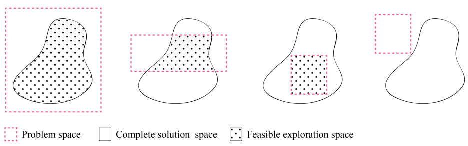

Figure 1. Four feasible exploration conditions from the intersection of the problem and complete solution space (from left to right): 1) solution space inside problem space; 2) solution space intersect problem space; 3) problem space inside solution space; and 4) solution space outside problem space.

A bound, mathematically speaking, is a constrained “domain” (Vajna et al., 2011). A bound of design problem attributes to the upper and lower limit of input variables and their relations within this problem structure. The search for a feasible design solution may encounter four conditions regarding a given problem domain (Figure 1). The interpretation of these conditions from left to right: 1) the architect’s design capacity (equals the complete solution space) is insufficient therefore restricting his/her explorations; 2) the architect’s solutions intersect a problem domain, meaning some variations may be invalid; 3) the problem domain is defined inside the architect’s design capacity, meaning a conservative design concept; and 4) no solutions are available when the problem domain is fully outside the architect's solution space.

3. Parametric modelling

The ratio of an architect's feasible solution space to a defined problem domain is one metric we use to measure the "flexibility" in digital practice. The parametric model is the representation of problem space, and it amplifies the architect's capacity for a thorough design search (Hudson, 2010).

3.1. THE "CREATION"

Model creation concerns appropriate geometric description, constructs hierarchy for inputted parameters, and sets-dependent relations (Cardenas, 2007). It addresses two creation ideologies regarding project materialisation: the *pre-* and *post-rationalisation* strategy. To evaluate the controllability of the two approaches, we discuss the ratio of parameter inputs to outputs and validate outputs of its fitness to defined problems.

3.2. THE "USE"

The architect uses the parametric model to explore variations and may encounter previously mentioned conditions. We judge feasibility per solution by observing how much space he/she leaves to other collaborators. Discussing either a *pre-* or *post-rationalisation* approach better fits a created problem space, and illustrating the contribution made by parametric modelling to narrow a problem space simultaneously to increase the ratio for an architect's valid design exploration.

4. Case study: Archi-Solution Workshop (ASW)

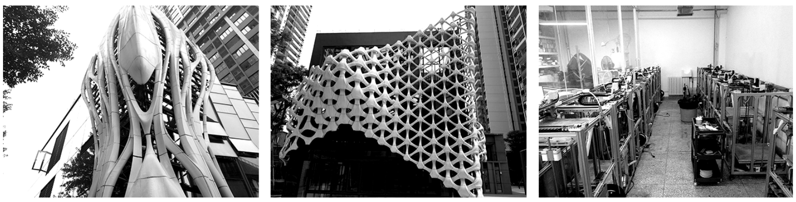

Figure 2. "Cabala" (left); "Arachne" (middle); In-house printers (right).

Beijing-based avant-garde practice ASW dedicates itself to a CAD-CAM workflow, targeting the designer's expanded authorship in project delivery. This study discusses the non-standard façades Cabala (Figure 2 left) and Arachne (Figure 2 middle) of City Box in Foshan, China. Through comparison, we measure the feasibility of the adopted strategy in each case regarding design and implementation. Moreover, by observing façade completeness to applied approaches, we conclude a rational design ideology broadens the architect's exploration flexibility.

Both cases demonstrated Fuse Deposition Modelling (FDM) technology in the large-scale practice. Digital advances are illustrated by the setup of an in-house production line which includes tailormade FDM printers (Figure 2 right) and a CAD-CAM system based on the procedural modelling plugin *Grasshopper* for the 3D NURBS modelling software platform *Rhinoceros*. The study concerns three criteria regarding the definition of the problem space: 1) geometric complexity, 2) structure strategy, and 3) façade components. The printers' capacity has maximum dimensions of 500mm (L) × 500mm (W) × 800mm (H), limiting components' size. Other contextual restrictions include that only conventional structure types are available, and that the collaborating consultants lack experience in non-standard building construction. ASW has adopted different strategies towards project deliveries.

4.1. *CABALA*: A *POST-RATIONALISATION* APPROACH

Including geometry reference curves and other inputted parameters, the *Cabala* is a free-formed design with unrestricted formal complexity. The implementation constraints came from the selected structure type: only straight elements were available for structural support. Given this, ASW has adopted a post-rationalisation modelling approach to accommodate restrictions. They used direct parametric control (all variables are algorithmically related in one script) to subdivide a pre-defined overall form horizontally and vertically. Interconnections between printed parts and the anchors, bridging to the steel frame behind it, were located afterwards (Figure 3).

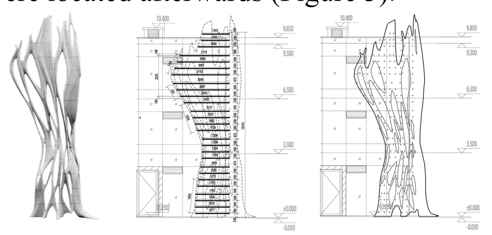

Figure 3. Freeform design (left); Structure strategy (middle); Tie rods (right) (modified from façade structural drawings © ASW).

The designer created a solution space including two types of sub-component connections: 1) the Mortise & Tenon (Figure 4 left) and 2) metal plate (Figure 4 middle left). This nonetheless resulted in uneven deviations in different façade areas. The former only allows displacement along Tenon directions, whereas the latter allows resolving misalignment on all three axes. In terms of sub-components' connections to the steel frame, ASW suggested two end conditions on the tie rod, which also permitted different installing flexibility. As shown in the photos, one end consists of a ball joint (Figure 4 middle, right) permitting varying angle connections. On the other end, the rods are mounted to sliders only allowing changes in one direction (Figure 4 right). The gap between the defined problem space and ASW's proposed solutions have caused implementation difficulties due to reasons mentioned above. Eventually, the Cabala was managed to assemble by on-site contractors.

Figure 4. Mortise & Tenon (left); Metal plate (middle left); Ball joint (middle right); Rod and slider (right).

4.2. *ARACHNE*: A *PRE-RATIONALISATION* APPROACH

The second case was built one year later. Here, ASW has adjusted the mindset to a pre-rationalised approach – a constraint-based method to define problem domain. With previous experience in the *Cabala* implementation, this design follows all restrictions including production dimension, structure type, and implementing difficulties to determine a design that can be precisely materialised.

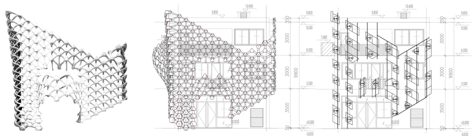

Figure 5. Mortise & Tenon (left); Metal plate (middle left); Ball joint (middle right); Rod and slider (right) (modified from façade structural drawings © ASW).

Figure 6. One joint condition (left); inflexible connection (right).

The architect matched façade components with the structure gird as only unit variations were allowed rather than an overall change (Figure 5). Also, the interconnection of printed parts was simplified to one type (metal plate) (Figure 6 left), and both sides of the tile rod adopted a similar joint condition (Figure 6 right). Deviations are evenly counteracted as a result.

4.3. DISCUSSION

In both cases, the architect established parametric representations of problem space and explored feasible solutions inside. A *post-rationalisation* mode indeed maximised the potential for geometric complexity. At the same time, the architect left more space for other parties to contribute, which may cause uncertainties resulting invalid explorations and the architect's loss of control. Comparatively, a *pre-rationalisation* mode restricted design variation but ensured more rational results. ASW, in this case, was able to predict implementing difficulties and had taken all the variables that might affect the outcome into consideration prior to form generation. With given contextual resources, the *pre-rationalisation* strategy turns out to be a better fit in non-standard local practice as the architect is able to claim a more significant role.

5. Conclusion

This study discusses the relation of an architect's feasible exploration to a defined design problem and uses a pair of case studies to emphasise that a *pre-rationalisation* approach in parametric design may be more pragmatic in China's conventional construction context. This study illustrates a higher-level knowledge that contributes to contemporary professional practice in China and further facilitates an expands digital design ideology into the local material world.

Acknowledgements

All CAD diagrams are the courtesy of Archi-solution Workshop, and the research is based on an interview with Yu Lei (founder of ASW).

References

Carpo, M.: 2011, *The alphabet and the algorithm*. MIT Press.
Cárdenas, C.A.: 2007, *Modeling Strategies: Parametric Design for Fabrication in Architectural Practice*, D.Des. Thesis, Harvard.
Davis, D.: 2013, *Modelled on software engineering: Flexible parametric models in the practice of architecture*, Ph.D. Thesis, RMIT.
Hudson, R.: 2010, *Strategies for parametric design in architecture: an application of practice led research*, Ph.D. Thesis, University of Bath.
Vajna, S., Kittel, K., & Bercsey, T.: 2011, The Autogenetic Design Theory. *In the Future of Design Methodology*, Springer, pp169-179.
Woodbury, R. F., & Burrow, A. L.: 2003, Notes on the Structure of Design Space. *International Journal of Architectural Computing*, 1(4), pp517–532.
Xu, W.G.: 2015, The Third Attitude of the Phoenix Centre, *Architectural Design Management*, 232, pp7-9.
Yao, Z., & Johnson, A. L.: 1997, On estimating the feasible solution space of design. *Computer-Aided Design*, 29(9), pp649–655.