CONSTRUCTING ATMOSPHERES

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Abstract. This paper documents and critically reflects upon the design, development, fabrication, and implementation of three pavilion projects developed during 2013-14. The core investigation of this work is the production of architectural spaces characterized by a quality of enveloping, diffuse, visual and spatial atmospheres. The principal activity of the research is aimed at refining methods for software-based exploration of formal complexities and the subsequent need to control variability and efficiency in fabrication output, using Grasshopper for Rhino to develop customized definitions particular to each specific project scenario. Linking the projects together are issues of scale, resolution of effect, and intent to move from disparate assemblies of structure and skin toward composite, manifold construction techniques that address multiple concerns (gravity, bracing, affect, etc) with a minimum of assembly. A material palette common to the current vernacular of CNC-based projects such as plywood, plastics, and other sheet materials is utilised. This work is invested in extending the possibilities of the architect and architecture as a discipline, extrapolating the workflow from these successive projects to the speculative impact of the work upon emerging possibilities of architectural construction and craft.

Keywords. 3d modelling; Digital fabrication; Rhinoceros; Grasshopper; Tessellation.

1. Introduction

Architects today work in an age where advanced technological tools are closing the gap between the virtual and the real, characterised by the widespread availability of sophisticated software applications and tools for digital fabrication and assembly. Yet within this environment of the true digital age,
which has continued to mature since its practical popular adoption in the early 1990s, a struggle still exists to define and capture the opportunity of this confluence of technologically enhanced tools with architectural ambitions. As noted by Marcus (2012), we now find ourselves facing a choice between two poles of technological determinism: a detached formalism versus a hyper-functionalism that pursue formal complexity at one pole and efficient performance on the other. Marcus further notes that it is in the organization of information supported by digital tools which can satisfy both qualitative and quantitative goals. While this is indeed true, it is important to consider two other primary issues. Firstly, the material consequences and apprehension of craftsmanship in the digitally enhanced construct, and second, the issue of authorship as a question of architectural expression.

Considering the question of expression, one can view the way in which the formalism and efficiency possible with digital tools manifest as technique, and as a form of architectural style – the result of applying technological solutions to design motivations. Rather than technology for its own sake, one must have a cultural or disciplinary thesis beyond the tools, such that those very tools can be manipulated to serve expression.

Reiser (2012) states that "technique is thus a way of combatting technological inertia: it forms the essence of style. The mark of a mature project in architecture is characterised by the systematic flouting of its founding principles. Youthful reliance on the rigour of the exact disciplines (ie mathematics, engineering, computation) matures into the ability to craft precise forms of fiction; it is what separates an architect’s use of geometry from that of a mathematician. Maturity thus is a process of becoming undisciplined. " The work contained herein exemplifies this attitude toward technique, underpinned by a concern for craft, an exploration of procedural tools, and formal experimentation.

2. Project Overview

The research undertaken involves three sequential projects designed for international urban lighting festivals, acting as a vehicle for study of architectural questions as a primary concern, with the technicalities of light pursued secondarily. These include, in chronological order, the Wellington, New Zealand 2013 WGTN Lux Festival, entitled "Atmospheric Tessellation; " the 2014 ilight Marina Bay Festival, Singapore, entitled "Critical Mass; " and the 2014 Vivid Festival, Sydney, Australia, dubbed "Cellular Tessellation" (refer to Figure 1). In each case, the festival brief is the development of a small-scale pavilion to emit light and enhance audience experience in the civic realm. This work is a collaborative effort undertaken by three research-
ers with a background in both professional architectural practice and academia, with the work being facilitated through an academic architectural fabrication lab at the Bond University Abedian School of Architecture, Gold Coast, Australia.

Figure 1. Projects left to right, WGTN Lux Pavilion, Atmospheric Tessellation; iLight Marina Bay Festival, Singapore, Critical Mass; Vivid Festival Sydney, Cellular Tessellation.

3. Process Overview

Each of the three pavilion-scale projects investigated here use Grasshopper for Rhino to develop customized definitions particular to each specific project scenario. Linking the projects together are issues of scale, resolution of effect, and intent to move from disparate assemblies of structure and skin toward composite, manifold construction techniques that address multiple concerns (gravity, bracing, affect, etc) with a minimum of materials. A material palette common to the current vernacular of CNC-based projects such as plywood, plastics, and other sheet materials are utilised. Concerns of information management, form generation, digital craft, and construction viability are also studied through the working process.

The primary expressive goal of this work is the production of architectural spaces characterized by a quality of enveloping, diffuse, visual and spatial atmospheres. In service of this goal, each of the three projects is conceived as research into the following:

1. Creating visual and spatial richness through articulation of building envelopes,
2. Panelisation of double-curved surfaces through tessellation,
3. Resolving efficiencies of skin versus structure,
4. Integration of LED light as a means of visual stimulus,
5. User-interaction via Arduino-based sensing and actuation of components, and
6. File-to-fabrication procurement strategies for remote implementation.

The approach taken here extends the concept of ‘protoarchitectures’ referred to by Bob Sheil (2012), which proposes a genre of experimental de-
sign challenging the methods and role of the design, particularly in relation to how and why the work is made. Sheil’s elaboration upon his own work posits early, pre-digital bespoke production against more contemporary endeavours using digital methods. In particular, it is noted in the digital vein, that the drawing becomes both the design and making tool both for fabrication and representation. It is within this loop that the pursuit of stated project goals herein are played out, including where physical prototypes are utilised to judge and test propositions fluidly (Figure 2).

4. Case Study: Atmospheric Tessellation

The first of the three projects is also the one presently of greatest definition and completion, having been exhibited in Wellington in June 2014. Atmospheric Tessellation was designed to incorporate different types of overlapping geometry to create a formally complex structure. It consisted of four elements: back sheeting, a notched rib structure, triangulated panels and quadrilateral frustum pyramids. The waffled rib structure was cut from 18mm plywood, and the triangular faces and back sheeting were cut from 9mm ply, and the frustum pyramids were cut from 0.8mm polypropylene sheets. The front two layers of the structure are the primary visual element of the structure and the ribs, which are braced by a sheet plywood diaphragm, are the primary structural element. In this way, the two visible layers are conceived as a skin, supported by the structural plywood monocoque shell. The visible layers were generated using three discrete surfaces: an initial surface, a tessellated surface and finally, an implied surface. The initial surface

Figure 2. Workflow diagram.
was the genesis point for the structure, and although it was rectangular, it was also doubly curved in response to the corner location within one of Wellington’s many laneways (Figure 3).

The surface went through three processes of transformation. Firstly, it was divided into regular triangles that formed a 7 x 11 triangular tessellated surface. Each of the 77 triangular faces was further subdivided into three quadrilaterals. These quadrilaterals were extruded using weighted attractors to form the final implied surface. This process created multiple levels of tessellating geometry: the triangular surfaces, which tessellate neatly on a grid, the quadrilateral tessellation, and most interestingly, the product of the quadrilateral tessellation, which produced hexagonal gaps. The clarity of the hexagonal tessellation was unexpected due to the fact the light leakage around the edges of the triangular faces resulted in the internal gap unintentionally appearing wider and darker.

One challenge of the surface implied by the outer faces of the frustum pyramids was the negotiation of doubly curved surfaces, specifically the transition from positive to negative curvature (valleys) where extrusions can commonly intersect when extruded along the base surface normal. While it was impractical to script a custom solution to unilaterally prevent this from happening, adding a branch to the definition that would check for collisions and return a Boolean value indicating their existence (or not) was employed.
Other issues include the time it took for the definition to propagate when changes were necessary - such as in the removal of collisions noted above. To combat this issue, a common CGI technique was used to introduce a branch of the definition that employed proxy objects – in this case simple cubes – that gave an overall indication of the size and distribution of the final objects but was editable in real time.

Atmospheric Tessellation was generated entirely using only the Rhino plugin Grasshopper. The form was generated in its buildable parts, which were all cut out of flat sheet material. The front surface was created first, and then the super structure was generated from that surface. To enable the creation of the structure, there were a few key accommodating design decisions that were made. Firstly, 7 columns were evenly spaced so that there would be a uniform distribution of load to the rib structure. Secondly, the rib structure and its bracing had to use as little material as possible in order to be economical, therefore there were only six vertical ribs instead of the eight required to make seven columns. In order to compensate for the two "missing" vertical ribs, all horizontal ribs butted onto the side bracing. This minimised the use of the 18mm ply and the side bracing was a more than adequate support for the two columns of triangles. The extruded quadrilaterals were unrolled and sorted, before finally being nested on polypropylene sheets. The material was chosen both for its translucent properties and its unique colour contrast. During the day, the structure appears to be plywood with metallic plastic extrusions, but at night the plastic extrusions become crystal-like and the contrast renders the plywood obscure (Figure 4).

![Figure 4. Atmospheric Tessellation, elements, and assembly showing un-lit polypropylene.](image-url)
5. Advancing the Project: Singapore and Sydney

In addition to the articulation of surface, the two most recent projects [Singapore and then Sydney] deal with notions of enclosure, volume, and envelope. These added parameters also bring with them the challenge of structural tectonics and the resistance of forces both internal and external, while the limited footprint and scope of the structure required maximisation of interior volume. Due to additional project limitations such as budget, projected assembly time and accessible technology, the decision was made to integrate the necessities of surface and structure as much as possible, towards establishing greater economy and potential significance for scalability of this principle. This resulted in a more conventional and efficient approach to the rationalisation of the underlying geometry of the projects: the Singapore project is based on a system of planar quadrilaterals and the Sydney project based on trivalent polygons, and both attempt to maximise positive curvature in order to avoid geometrical irregularities. The use of quadrilaterals and trivalent panels allow for the utilisation of the inherent structural rigidity of the skin materials for transference of load between panels. The geometric approaches, while well known as simpler from the aspect of fabrication and assembly, required a much more stringent monitoring and enforcement of the planarity of rationalised surfaces during the computational design phases to ensure proximity to the initial geometry.

The Sydney project in particular (Figure 5) is an exploration in balancing these issues through the development of sub-assemblies which operate as both skin and structure and have the benefit of utilising simple fasteners to connect the assemblies. The constant distance between assemblies facilitates fabrication such that the bulk of the required effort can be directed toward the assemblies themselves, of which there are over 200 unique versions. This interstitial space also allows for design of internal lighting systems which, due to the ability to inhabit the structure, must be tightly integrated into the overall system.

All three projects mentioned have similar attributes: the representation of multiple levels or layers of geometry through 2d tessellation patterns and 3d form articulation; the goal is to express both the explicit and the implicit form.

The Sydney Vivid Festival project is scheduled for full realisation in May-June, 2014 (Figure 5).
Figure 5. Vivid Sydney 2014 proposal from competition winning submission, showing sub-structure only.

6. Project Implications

This set of projects reveals an important example of the necessary relationship between the parametric model and the digitally crafted prototype, the end product of each project really serving as one version of what could be multiple, mass customised constructs. Bechthold (2013) observes that mass customisation is beginning to make an impact upon construction products, but with few if any direct connections between the product configuration software and the digitally driven manufacturing process. This arena of speculation is found in the work presented here, both in the way connections and components are considered (for example, the quadrilateral as unit construction), and also in the reproducible scale of the pavilion. The pavilions presented here are linked to master geometry, which when subjected to the contingencies of varied site conditions, could adapt readily.

As noted by Sharples (2008), the practice of architecture is returning to a pre-industrialized state. New technology is creating a method of production where there is efficiency in customization – allowing the emergence of individually crafted solutions to problems. This capacity brings us to the crux of the main issue of contemporary practice: how we manage and share information.

Parametric design relies upon considering the relationship-definition process as an integral part of the broader design process, which has not previously been considered traditionally as part of "design thinking" (Dunn, 2012). However, what has been identified here is the use of the full iterative process from formation of preliminary assumptions and relationships between geometries and their material corollaries, which when fed back to the parametric model after validation through a physical prototype, yields a more robust
Definition in subsequent versions of the work. Experimentation, craft, and refinement of the digital expression form the "protoarchitectural" workflow.

While today’s software tools allow for immense complexity of form, such outcomes can often escape both the predictive and the possible. As with Weinstock’s observations on morphogenetics (Weinstock, 2010), genetic information (the corollary to the parametric definition), does not need to fully specify the geometry of a form, as the natural forces of the environment and mathematical principles will determine the specific geometry during growth and development. Similarly, the physical prototype makes explicit the natural forces which can be rendered obscure at the level of code. The digital design process requires a feedback loop between virtual and physical models (Stacey, 2012) – each domain helping to identify the strengths and liabilities of the proposed system – and ultimately allowing one to focus upon issues of craft and of architectural expression.

7. Conclusions

Architects and designers work in an age today where achieving formal complexity and performance is readily achievable via parametric modelling processes. Further coupled with digital fabrication tools, the control of design intent, craftsmanship, and architectural expression are more potent than ever. However taking complex formal qualities into the built world within budgetary constraints and quality standards is still an experimental process requiring consideration of how to best integrate multiple concerns. Small scale projects such as the pavilions presented here allow designers to investigate, test, and learn through a continual feedback loop between the virtual, digital domain and that of the prototypical versioned construct. Pushing experimental work forward is critical for the discipline to advance (Beson, 2012). To do so, full immersion in work at the intersection of digital fabrication and modelling can provide a basis for technique which draws upon the tools now available to the architect’s repertoire. From the lessons learned at the small, bespoke scale of the pavilion, one can potentially advance to the greater scales (Figure 7) without loss of potential for mass customisation.
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References