Soft (Fabric)ations

IGOR SIDDIQUI
University of Texas at Austin

The paper examines soft materials in relation to digital design and fabrication techniques. Textiles play an increasingly significant role in linking the digital and the material in contemporary architecture, in particular for their tendency to resist formal predetermination. As such, of central interest are practices that explore, rather than repress, the gap between the digital and the material and that acknowledge material agency as a central factor not only in the outcome, but also as an active participant in the process of architectural formation. Manuel DeLanda's essay "Material Complexity" is among key texts that provide a framework for defining the role of materials in design. He states:

> We may now be in a position to think about the origin of form and structure, not as something imposed from the outside on an inert matter, not as a hierarchical command from above as in an assembly line, but as something that may come from within the materials, a form that we tease out of those materials as we allow them to have their say in the structures we create.[1]

Recent works by three California-based practices - Atelier Manferdini, Matsys and Hirsuta - are considered as case studies that provide a critical context for an ongoing series of soft constructions explored by our design studio in Austin, Texas. Three full-scale prototypes, fabricated from rip-stop nylon, wool felt, and cast urethane rubber, are discussed in relation to textiles' potential to reveal and inform emerging relationships between computational and material processes in contemporary design.

INTRODUCTION

Increased convergence of CAD (computer-aided design) and CAM (computer-aided manufacturing) technologies has reprioritized the role of materials in architecture. Interrogating materiality, it has been argued, has reemerged as a reinvigorated and increasingly fundamental aspect of achieving design intent.[2] Bridging the distance between design studios and manufacturing facilities, digital technologies are facilitating the kinds of connections across industries that allow for, as Toshiko Mori has noted, the production of materials to occur simultaneously with the fabrication of building components.[3] In addition, as associative technologies such as Building Information Modeling (BIM) are progressively incorporated into professional conventions, design industries are seeking to eliminate discrepancies between documentation and construction and thus between the digital and the material. In this way the margins of difference between computational calibration and material manifestation are narrowed, increasing the predictability in performance, aesthetics, and economy of building. The design process is as such rendered efficient, controllable, and precise.

Parallel to, and at times intersecting, such ambitions are contemporary practices that, rather than repressing the difference between the digital and the material, exploit, amplify and activate the gap between the two. Instead of disciplining the material through digital means and fully predetermining its behavior, works that result from such practices employ digital techniques as frameworks for exploiting material self-determination. In reference to such works and their authors, Michael Weinstock writes:

> Recent several younger architects have incorporated material processes into their design methodology, suggesting a paradigm shift in the discipline. These

> architects are at the forefront of a reconfiguration of the field, through which 'emergent' design techniques produce an architecture irreducible to prescribed forms and spaces.[4]

What emerges through such processes of materialization is an array of design techniques whose physical outcomes exceed that which can be prescribed through computation alone. In this way materials have the agency to thicken, spatialize, and differentiate architectural space, and their inevitable interaction with gravity and time informs and transforms the digital frameworks with which they interface. Soft materials, textiles and fabrics among them, present perhaps the greatest challenge to predetermined top-down architectural geometry, defying and reshaping its abstract form both spatially and temporally. Materials like felt, latex, nylon, rubber, neoprene, and vinyl have the ability to embody the complexity of the continuous digital surface, while at the same time resisting static formation through draping, pleating, wrinkling, creasing and stretching. When not in tension, textile surfaces exhibit the kind of volatility that complicates the computer's ability to capture their form through static models. While digital simulation of the dynamic draping behavior in fabrics has been the subject of extensive research in the field of industrial textiles,[5] in architectural experiments such materials serve as hyperbolic reminders of the tenuous nature of the synchronization between digital and material data that generally occurs in design. Regardless of how continuous the procedural workflow is from design to construction, issues of tolerance, margin, and discrepancy provide opportunities for creative intervention and critical insight. In "Diminishing Difficulty: Mass Customization and the Digital Production of Architecture" Dan Willis and Todd Woodward write that the closure of the technological gap between design and construction "reduces opportunities for taking advantage of serendipitous occurrences during construction, eliminating the sorts of chance happenings that artists, and many architects, often find enliven their works."[6] Echoing the notion of translation from drawing to building defined decades ago by Robin Evans, the authors astutely point to the productivity of uncertainty in design, and the potential discoveries to be made within the interstitial spaces of the continuum between design and construction. In the following projects, soft and pliable materials, including textiles, participate in the process of design as much as they are in themselves the media for the manifestation of design intent.

CASE STUDIES

The body of design work by Atelier Manferdini demonstrates an obsession with draping and otherwise manipulating pliable sheet materials, including textiles, to construct multiple spatial layers between the surface of the body and the structure of the building. The work iteratively explores the problem of aperture within a larger continuous surface, and the methods are frequently subtractive – starting with tailored pieces of material, openings are cut into it according to parametrically differentiated digital patterns. The resulting petals, scales, and lace-like forms are as much a product of the pattern geometries as they are the result of material behavior. As projects increase in scale - such as *Merletti*, a gallery installation from 2008, and *the West Coast Pavilion* at the 2006 Architectural Biennial in Beijing[7] – the demand for a more complex seaming strategy, and thus a greater number of components, has presented Elena Manferdini, who directs the design studio, a new set of opportunities for rethinking the role that digital patterns play in relation to materials. In these projects, cutting, perforating and slashing is supplemented by the additive techniques that tessellate smaller components into larger assemblies.

For the pavilion in Beijing, the envelope is designed as a matrix in which smaller components nest within larger ones, providing scalar shifts while maintaining the consistency of the overall organization. The two-dimensional pattern modulates the surface and through its geometry associates the pavilion's structure with its cladding, while also differentiating between solid skin and see-through voids. The cladding panels, which are digitally cut, add a finer level of detail to the composite surface, further articulating and complicating the seaming pattern suggested by the elevational tessellation. Capitalizing on the suppleness of the digital line, and the efficiency with which it can be digitally translated into a cut, the articulated edges of the components produce folds, layers and overlaps that give the pavilion's surface a three-dimensional depth. Initially conveyed as a two dimensional digital pattern – both as overall elevation and as a set of individual cutting templates – the tessellation becomes thickened, layered, and spatial through the interaction of digital techniques on the one hand and material properties on the other. The surface effects are a result of that which is gained within the gap in translation between drawing and constructing, between the digital and the material, but also between fabrication and installation. The two-dimensionality of the panel templates is transformed most radically once each cut panel is reoriented from the horizontality of the cutting bed to the verticality of the building façade. Having to negotiate points of fastening, component overlaps and alignment with structure, the tiling system is transformed into a sensuous three-dimensional veil. In this project, the digital pattern is an organizer – of geometry, procedure, and program – and serves as an instructional rather than a representational tool. In other words, the pattern does not provide a simulated image of the finished product, but rather offers up a set of instructions (to the CNC-controlled machinery, to the installers…) for its construction. The pattern and the material are interdependent – one's development and articulation is impossible without the feedback from the other.

Similar in this way is *P_Wall* by Matsys,[8] both its first version from 2006 and, to an even greater degree, its ambitious reworking for the 2009 exhibit *Sensate* at the San Francisco Museum of Modern Art. The project follows a consistent thread of 20th century design research, including the work of the Spanish architect Miguel Fisac,[9] but also shares its interest in fabric formwork with contemporary research-oriented designers such as Mark West. Schematically, *P_Wall* is organized by a pair of overlaid two-dimensional tessellated patterns. Together they provide outlines – and rules – for the construction of material formwork. Hexagonal units are translated into frames over which Lycra fabric is stretched. The points from the second pattern become vertical dowels, constraining the stretched fabric from underneath and eventually, when plaster is poured into the formwork, causing the formation of the creases that reconnect the points into the triangulated mesh.[10]

The digital work in this project too is predominantly, if not entirely, two-dimensional. Three-dimensionality emerges through the introduction of materials. Once liquid plaster is poured into the constructed formwork – and each form is used multiple times based on embedded repetitions within the hexagonal pattern – material organization picks up where the digital left off. In other words, while the tessellated pattern provides the parameters and limits for the process, it is the material interaction with the formwork's constraints that gives form to each individual component. The solidified plaster - formed into 150 tiles and assembled into wall cladding 20 feet wide, 12 feet high, and 2 feet in thickness - sags, bulges, expands, and wrinkles, indexing the precise moment of each panel's execution, exceeding the digital realm's ability to predetermine and describe the resultant form. Like Manferdini's pavilion, and perhaps to a greater degree, there is procedural consistency in the process framed by digital geometry, but also a gap where what is produced materially resists prior representation and simulation.

The exterior cladding of Hirusta's *Raspberry Fields*,[11] a soon-to-be renovated vernacular structure originally built in the early 1900's in Utah, similarly examines the transformation of a flat tiled pattern into a three-dimensional surface, informed by material processes and environmental influences. The building's new skin takes as a point of departure a quintessential system, the wood shingle, and opens it up to the possibility of change by exploiting its latent material tendencies. The design utilizes two unconventional methods of construction that as a result contribute to the amplification of weathering over time. First, the direction of the wood grain in each tile is intentionally reoriented from the typical long direction to the short, encouraging accelerated warping of each shingle. Second, the bottom of each shingle is designed to remain unattached, further encouraging the material's movement away from the flat surface of the building's elevational substrate. The projected change over an extended period of time is visually amplified through the deployment of color. Rather than only considering the frontal building surface, the design actively considers the back of each component as well. While the front faces are stained a deep purple, the backs as painted in a color gradient ranging from purple to orange, a quality that will only be exposed and made visible as the process of weathering ensues. While Kudless's process is designed to register material behavior during the brief period of casting of each tile, Jason Payne takes into account the process of material change throughout the life-cycle of the building, exponentially expanding the acknowledged process of material formation. The formal transformation of the surface from flat to deep – and thus from graphic to spatial – is accounted for based on site conditions, differentiating the patterns of change not randomly, formally or purely decoratively, but rather specific to environmental factors. In this way, parts of the building surface exposed to gentler conditions will remain relatively stable over time, while others are expected to grow thicker, furrier and more geometrically relaxed.

DESIGN STUDIES

While the initial case studies included a range of soft materials, the fabrication work in our studio has been focused on soft sheets materials, including ripstop nylon, wool felt and cast urethane rubber. At the outset, the intention was to work with textiles that had self-seaming edges, so that the stitching would be utilized primarily as a means of achieving edge-to-edge connections rather than for finishing. The project, titled *Florals: Bougainvillea, Calystegia and Ferraria*, is an ongoing investigation of modular aggregations produced through the interaction of tessellated patterns and soft materials, considering in this way the transformation and insight that occurs in the translation between the digital and the physical – as well as between the graphic and the tectonic. Given the speculative nature of the prototypes, one may consider them as instruments for form-finding that is not scale-specific, though for us the full-scale aspect has been a priority and a value. Taking a cue from the blossoms after which they are named, the three prototypes examine the arrangement of subdivided flat surfaces – petals - into volumes, and their incremental aggregation into larger continuous, but differentiated, fields. Each version is based on a repetitive pattern with the aim of introducing variation within in relation to material behavior at full-scale. Variation has been primarily seen as a technique for constructing a range of apertures types and as such manipulating levels of surface opacity, porosity, and intricacy. Perhaps to a greater extent than the previous examples too, these prototypes consider the surface as two-sided– a spatial membrane, screen, or perhaps even a wall, rather than cladding.

Starting with two-dimensional tessellated patterns, the surface is modeled digitally by interpreting the pattern three-dimensionally – separating vectors into layers to create depth, developing point-to-point and edge-to-edge relationships, and constructing surfaces that in turn form repeatable variable components. The digital model is than transformed into flat cutting templates, which are used for the digital fabrication of component parts or formwork. The full components are then stitched together or cast, depending on the type, after which they are installed as per the intended aggregation. Given the softness of each material and its behavior in relation to gravity, structure, and time, each prototype has revealed a significant gap between the digital and the material. Not unlike the previous studies, the tessellated pattern is but a starting point for a series of further surface articulations facilitated by the interaction of component geometry, material properties, and environmental forces. In our evaluations, we have attempted to observe and record some of those articulations by constructing diagrammatic digital models and from them producing three-dimensional digital prints as a means of studying systemic transformations based on material behavior.

Bougainvillea (Figure 1) is based on a component that consists of three identical double-curved surfaces seamed together into an ocular form. The components aggregate point-to-point, producing a system of edges not unlike a space-frame, which under the influence of gravity produce a buoyant three-dimensional surface. The attempt to control the degree of openness of the overall surface by digitally adjusting the degree of aperture within each component was undermined by the material's tendency to drape, thus obscuring the subtlety of each parametric shift. *Calystegia* (Figure 2) addresses the issue of aperture through a six-sided component made from wool felt which is stiffer as a material than the nylon. The component geometry accounts for the possibility of full closure and total opacity of the system, but the relationship between point-to-point mechanical connections and edge-to-edge adjacencies of the component revealed an entirely different possibility for constructing apertures, one based not on the area within each component, but rather along the perimeter edges. The digital tessellated pattern is transformed as what is perceived graphically as a single vector is split open into a kind of orifice between components, inversely proportional to the size of the opening within each adjacent component – the smaller the opening within, the larger the orifice in-between. *Ferraria* (Figure 3), the final and in-progress prototype currently in the series examines the possibility of a monolithic component cast in urethane rubber and based on the tessellated formation of positive and negative times. The positive and the negative of the surface – a button and a hole – organize the surface of each component, the geometry of which is based on the number of pairs engaged to make a connection. This prototype seeks to explore the possibility of surface-to-surface connections and given the necessity for a tight mechanical fit between the buttons and the holes, we have conducted a series of trial castings to determine material shrinkage and adjust the digital pattern prior to the fabrication of formwork accordingly. Given the elasticity of the material, it is anticipated that the gap between the digital and the material will expand once a more extensive aggregation is formed.

CONCLUSION

Each project presented dismantles the binary division between design and fabrication, demonstrating that design does not simply end with digital output, and that the role of material fabrication always already exceeds the delivery of preconceived design intent. As the integration of CAD and CAM technologies have opened up the possibility of mass-customization, described by Stephen Kieran and James Timberlake in their book *Refabricating Architecture: How Manufacturing Methodologies are Poised to Transform Building Construction* as "the ability to differentiate each artifact from those fabricated before and after,"[12] it may be productive to remember that the modernist protocols of mass production too, albeit at the threshold of failure, produced variation within repetition. In that sense, the presented projects move away from the orthodoxy of mass production not just through digital means, but also by reframing material behavior as an active agent in the formation of the contemporary surface. Each example– lacy, bloated, hairy, or floral – captures, in one way or another, what one may describe as the poetics of chance, or perhaps embodies an aesthetics of the delicate marriage of control and resistance. Even more so, and in particular in relation to design pedagogy, the projects amplify the interrelatedness of digital and material processes and highlight the impossibility of reducing material behavior to static geometry. While advanced research in dynamic systems simulation is rapidly informing the commercial digital tools available to practitioners, academics and students, and while the continuous evolution of the designers' technical ability to synchronize digital form with material behavior will undoubtedly continue to inform how we practice, the presented projects suggest that while we strive for continuity in our workflow, it is in the disconnects within that we find opportunities to renegotiate in multiple ways the relationships that link the agency of the designer to those of technology and materiality. Architectural textiles - formally resistant, yet pliable - foreground the potential and challenges of incorporating material complexity in design through the simultaneous interrogation of matter and data.

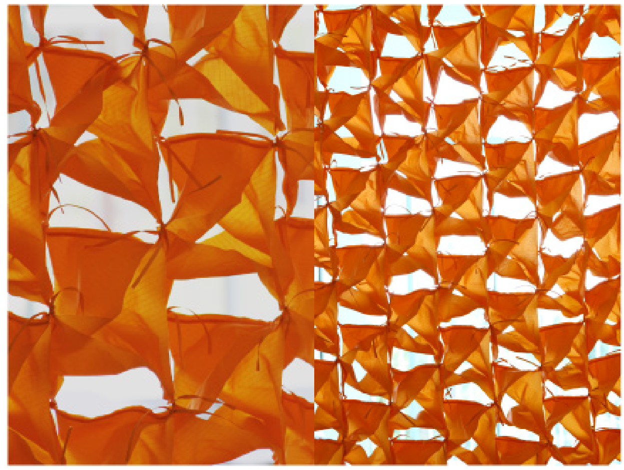

Figure 1: *Bougainvillea*, Prototype, rip-stop nylon, 2010.

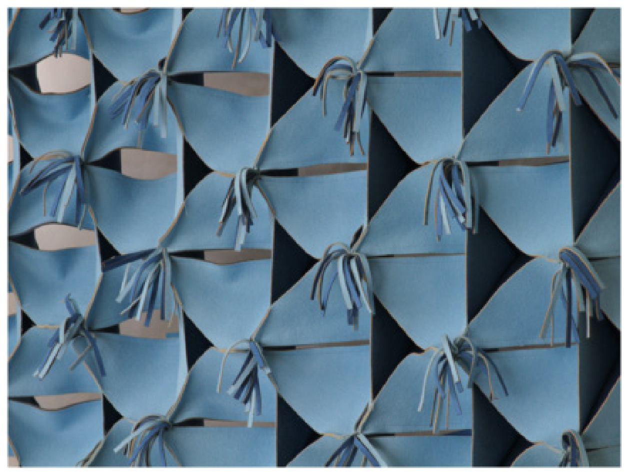

Figure 2: *Calystegia*, Prototype, wool felt, 2010.

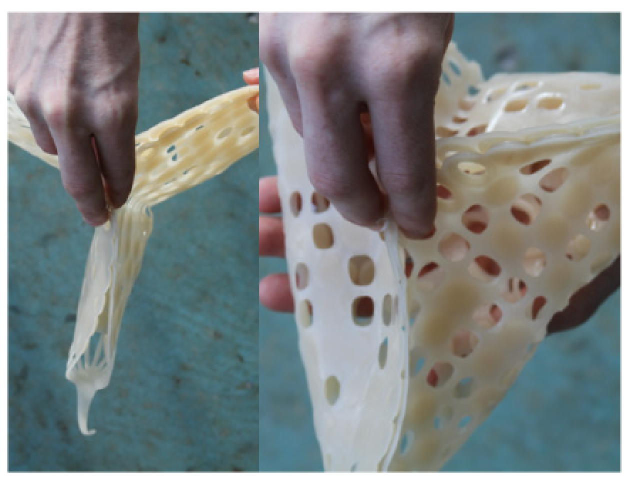

Figure 3: *Ferraria*, Prototype, cast urethane rubber, 2010.

ENDNOTES

1 Manuel DeLanda, "Material Complexity," in *Digital Tectonics*, ed. Neil Leach et al., (West Sussex: Wiley-Academy, 2004), 21.

2 Branko Kolarevic and Kevin Klinger, *Manufacturing Material Effects: Rethinking Design and Making in Architecture,* (New York: Routledge, 2008), 7.

3 Toshiko Mori, Introduction to *Immaterial/ Ultramaterial: Architecture, Design and Materials,* (New York: Braziller, Inc., 2002), xv.

4 Michael Weinstock, "Surfaces of Self-Organization: Andrew Kudless' Material Explorations," *Praxis - Journal of Writing and Building: Expanding Surface* 9, (2007): 27.

5 For examples of research in those areas, see Feng Ji, et al., "Simulate the Dynamic Draping Behavior of Knitted Fabrics," *Journal of Industrial Textiles* 35:201, (2006): 201-215; also, Bernard Eberhardt, "A Fast, Flexible, Particle-System Model for Cloth Draping," *IEEE Computer Graphics and Applications* 16:5 (1996): 52-59.

6 Dan Willis and Todd Woodward, "Diminishing Difficulty: Mass Customization and the Digital Production of Architecture," *Harvard Design Magazine* 26, (2006): 83.

7 Lisa Iwamoto, *Digital Fabrications: Architectural and Material Techniques,* (New York: Princeton Architectural Press, 2009), 42-46. Additional project information is available on the designer's website http://ateliermanferdini.com.

8 "P_Wall (2009)," Matsys, accessed November 9, 2010, http://matsysdesign.com/category/projects/p_wall2009/.

9 Julieanna Preston, "Affecting Data," *Architectural Design: Interior Atmospheres,* (New York: Wiley, 2008), 42.

10 "Form, Growth, Behavior: the Making of P_Wall" (video), San Francisco Museum of Modern Art, accessed November 9, 2010, http://www.sfmoma.org/multimedia/videos/359.

11 "Raspberry Fields," Hirsuta, accessed November 9, 2010, http://www.hirsuta.com/RASP.html; also, "Raspberry Fields," SuckerPUNCH, posted on January 18, 2010, http://www.suckerpunchdaily.com/2010/01/18/raspberry-fields/.

12 Stephen Kieran and James Timberlake, introduction to *Refabricating Architecture,* (New York: McGraw Hill, 2004), xiii.