Craft Works: on How to Get Medieval

> 'Craftsmanship' may suggest a way of life that waned with the advent of industrial society—but this is misleading. Craftsmanship names an enduring human impulse, the desire to do a job well for its own sake.
>
> —Richard Sennett, *The Craftsman*, Yale University Press, 2008

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It may sound anachronistic to bring up the word *craft* today, especially within the context of contemporary technology and its related modes of production, but there are striking parallels between this medieval concept and digitally driven architectural practice. *Digital craft* is in the air today as levels of expertise in the manipulation of computational geometry and matter increase and the gaps between design and fabrication decrease. The word itself conjures up imagery akin to whittling, where a lone artisan sits with his knife, a raw piece of wood, and carves it into some quaint artifact. However, this is a bit superficial. Historically, the word denotes activity that lies somewhere between art (talent and technique) and science (knowledge), and its etymology is associated with the Greek word *techne*. Economically, it is applied to the small-scale production of customized goods. Socially, it is an autographic endeavor, where designer and maker are one and the same person. Technologically, it is associated with hand-related tools and methods that produce *variability* (albeit undesired at the time). Gottfried Semper defended the craft traditions in his book *The Four Elements of Architecture*, by tying it to "man's dignity." This also conjures up the specter of William Morris, the nineteenth-century English textile designer, who, after years of supporting the Ruskin philosophy of a wholesale rejection of industrial manufacturing and a return to hand-craftsmanship, found a way to tactically combine the two. But for all of the energy exerted by the defenders of *arts and crafts*, they could not contend with the sublime scale of the machinic production of *identicality* during the industrial revolution and modernism.

There seem to be two key features that serve a contemporary notion of craft in relation to digital practice. The first has to do with the production and management of *variability* and its aesthetic consequences/effects. The second has to do with an ethos based on *self-discipline* (doing a job well for its own sake). During the middle ages, variability was simply a consequence of customization and the lack of precisely repeatable production methods. Discipline was an ethos handed down from master to apprentice (or disciple). Today, variability is not only desired but increasingly easy to achieve, and control, by digital means. And since the master/apprentice model is all but gone, discipline must be cultivated by the individual. As parametricism continues its relentless pursuit of totalized variability, it still privileges geometry. A craft ethos has the potential to open up alternative, and perhaps more substantial, trajectories for the production of architecture. The digital craftsperson gets dirty with matter *and* geometry.

This essay drafts out three distinct but related dichotomies around the concept of digital craft: *Autography versus Allography, Matter versus. Geometry, Manual Operations versus Automated Simulations*. While a medieval notion of craft privileged the former end of these dichotomies, I am suggesting that *digital craft* is a toggling between each, a more topological relationship than a binary one. It is followed up with four case-study projects which provide specific examples that cut across the dichotomies laid out.

AUTOGRAPHIC VERSUS ALLOGRAPHIC: FROM BRUNELLESCHI TO ALBERTI

In a 2012 lecture at the Southern California Institute of Architecture, Peter Eisenman grumped about the lack of authorship being retained in the construction of the *Pinerba Condominium* project in Milan, Italy. The gist of the story was that the contractor made it clear that he was not going to maintain a high degree of fidelity to his design and construction drawings. One can imagine the frustration that would set in. But it raises the longstanding distinction between the autographic and allographic paradigms, or, "the transition from Brunelleschi's artisanal authorship (this building is mine because I made it) to Alberti's intellectual authorship (this building is mine because I designed it)."[1]

Clearly Eisenman sides with Alberti and expects a high level of *notational identicality* to be met. The more drift that occurs in the contractors' interpretation of the architect's designs the less authorship the latter has (or at least feels he has). A more explicit definition is provided by the philosopher Nelson Goodman. He states that "a work of art is autographic if and only if the distinction between original and forgery of it is significant; or better, if and only if even the most exact duplication of it does not thereby count as genuine."[2] The irony is that architecture, and the business of building, has, for the most part, occupied the allographic paradigm since the Renaissance, yet we continuously struggle to maintain the highest level of authorship of our works. What was striking about Eisenman's description of this experience was that, even in the face of defeat and compromise, he still exerted energy in working in some of his signature elements (i.e., frame, grid, shifting plan figures).

Digital craft seeks to quell this dilemma by circumnavigating the need for notational representation and thus eliminating the potential drift of translation. Theoretically, a fully crafted digital model can thus be transferred from designer to builder as is. But this demands that the architect highly resolve all logistical demands and economic constraints, which is now possible through BIM software and the algorithm, and that the builder acquires the skills to navigate sophisticated 3D software.

A short-term (and unsustainable) way around this problem has been tested through installation and pavilion architecture. This type has provided a venue for material and tectonic experimentation of digitally produced forms.

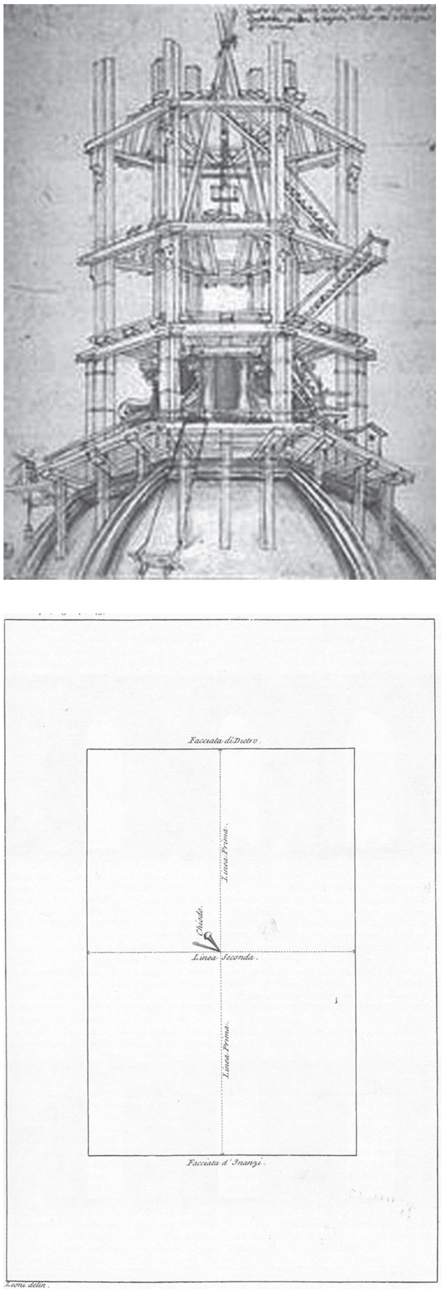

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Figure 1: *above*: Fillipo Brunelleschi's drawing for the construction of the scaffolding around Il Duomo's lantern. It was drawn by him and for him. *below*: Leon Battista Alberti's drawing of a template for a building site plan. It was drawn by him but for someone else, and potentially somewhere else.

But because of the economic constraints and intensive labor demands, it has resulted in privileging the Brunelleschi model. Designers, and a small army of unpaid enthusiasts, are forced to construct their own designs. Craft becomes quite a literal endeavor, and designers often resort to mixing advanced fabrication with traditional techniques of material assembly due to cost limitations. This actually has its benefits, as it introduces a sense of pragmatism to the problem and allows the designer to develop a sensual intelligence that can be folded back into the design process in the future.

Those who carve a niche in this genre don’t have to worry about scaling up and can evolve their craft techniques but are ultimately faced with the pressure of the new. As this type is temporary by nature and so ubiquitous, its aesthetic and cultural effects wane quickly. It is a cultural practice that demands the rate of change of fashion and music but is still tied to that of architecture, which is closer to the pace of geology. Those who use it as a stepping stone toward larger (perhaps more legitimate) projects face the problem of scale. With scale comes a host of problems related to building conventions, budget, and legal (code) restrictions. And as neither of these is loosening, the gap continues to widen.

In a prophetic paragraph in 1989, William Mitchell posited:

> We have not quite reached the end of this story. Usually, in practice today, the end product of a computer-aided design process is a set of drawings plotted from a database. Indeed many architects shortsidedly [sic] think of computer-aided design as essentially a technique for fast drawing production. But there is little reason to doubt that architects will soon adopt the practice that is now commonplace in manufacturing industry and deliver, instead, databases in machine readable format. The contractor can then process this to produce plots and images as required, use it for input to cost estimation and construction planning and management software, and even use it directly to program CAD/CAM systems and construction robots. When this eventuates, the eclipse of the drawing will be complete.[3]

MATTER VERSUS GEOMETRY: FROM INTENSIVE TO EXTENSIVE

The relationship between matter and geometry in architecture has been far from contingent since the Renaissance. Until recently, geometry has had the upper hand, disciplining matter in its own image. With the allographic paradigm mentioned above, geometry and its related notations necessarily become the primary means to deliver the principles of identicality. Furthermore it (Euclidean and pre-topological geometry) abstracts the material world in order to gain control over it and operates within a *conceptual* framework. For example, the nine-square grid problem initiated by John Hedjuk and the Texas Rangers was a classic exercise that privileged Euclidean geometry in a Cartesian coordinate system. As points become columns and lines become walls, it is still geometry (and proportion) that determines thickness and overall organization. Matter waits for geometry’s instructions. Points, lines, planes, and volumes occupy *static* and *extensive* positions in space (as void). Manuel DeLanda convincingly makes the case for the active role of matter in the production of architectural form and the value of the craftsman for contemporary discourse.[4] This inversion is not merely a reaction to the previous paradigm but one that aligns itself with the advent of computation and developments in allied fields such as science, technology, philosophy, mathematics, and art.

The introduction of topology, calculus, and simulated physics to architectural form has completely unnerved the disciplines' sense of control over geometric organizations. In this model, points, lines, planes, and volumes are exchanged for vectors, curves, surfaces, and mass. The *extensive* differences of the former are confronted by the *intensive* ones of the latter.[5] Rather than the disciplining of matter through geometry in a top-down hierarchy, intensive differences are managed, and form is coaxed into resolute expressions. An analogy might be useful. The famous *Vitruvian Man* drawing by Leonardo Da Vinci is a clear depiction of *extensive* control over a body. A geometric system is projected onto the body, producing an essential figure. Geometry reorganizes the body into an ideal image of beauty, proportion, and harmony. Butchery diagrams, on the other hand, coax geometry from matter, in this case flesh. In locating and drawing the prime cuts of an animal, the butcher identifies the general boundary of meat according to *intensive* properties such as fat content (leanness), flavor profile, density, and muscle fiber qualities. The resultant diagram is different for each species and serves as a loose cartoon for the more visceral complexities of matter. This is only possible with and directly tied to the level of craftsmanship of the butcher. The geometric complexity of the diagram is dependent on the level of the butchers' knowledge of his animal (material), and his skill with his knives (tools).

For more than five thousand years man has been engaged in the basic crafts (agriculture, medicine, metal-working, weaving, dyeing, perfumery, and glass-making being among the oldest). Traditionally, the practical craftsman has occupied a natural opposition to his scientific counterpart. If we understand geometry as a scientific and theoretical endeavor, then "science has again and again been in the position of debtor, drawing on the craft tradition and profiting from its experience rather than teaching craftsmen anything new. It has been said that 'science owes more to the steam-engine than the steam-engine owes to science,' and the same thing is true more generally. In its early stages, especially, the craft tradition was—so far as we can tell—devoid of anything which we would recognize as scientific speculation."[6] Digital craft posits that matter obtains at least equal status to geometry and that computational geometry is "live," laden with heterogeneous material behaviors that require the coaxing of form rather than its imposition. Working exclusively with default geometries in digital space (like the voronoi) has resulted in homogeneity across the discipline and produces clichés quickly. A return to matter through digital production is really about putting sensual (physical) intelligence on the same plateau as rational intelligence. It cannot simply be an inversion of the dominant paradigm nor a wholesale return to medieval practices. The potential feedback loops within a matter/geometry complex requires craftsman-like dexterity with scientific precision and projection (of geometry, force, and thought).

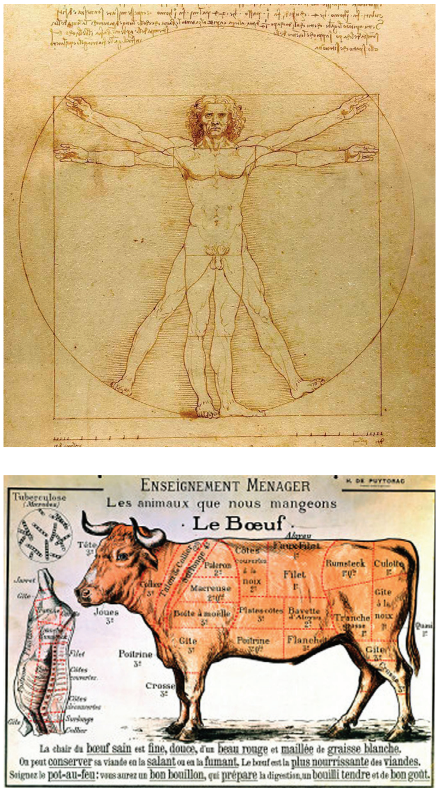

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Figure 2: *above*: Leonardo Da Vinci's Vitruvian Man; Geometry imposed onto the body as a trope for control and expression of ideality. *below*: A Butcher's approach. Diagram showing the geometric outcome on a cow derived from a material understanding of flesh.

MANUAL OPERATIONS VERSUS AUTOMATED SIMULATION: FROM DIRECT TO MEDIATED CONTROL

The rise of scripting and parametric software in architectural design and production has certainly provided unprecedented power over the control of vast amounts of geometric and tectonic information. To be clear, architecture has always been parametric (the establishing of limits or boundaries in relation to one another), but the seductive power of its computational form allows local variations to be tracked and managed globally in an automated instant. This is where a set of rules is *respected*. It clearly has its benefits in the optimization sectors, where all of a project's geometric, tectonic, and performative systems are linked to each other as well as to cost-control spread sheets through BIM software packages. But this is perhaps more useful for the back end of production. For the front end, during the earlier stages of the design process, scripting is perhaps more generative. This is where a set of rules is *written*. These models provide for mediated control through simulation. Parametric modeling simulates the physical behaviors of *change* while scripting simulates the physical behaviors of *growth*. Both are useful and productive but have their shortcomings.

One of the draws of scripting is that it is "an efficient way to produce differentiated repetition in digital modeling that would otherwise require a great deal of time and effort. At its essence it is a method for reducing the number of keystrokes required to model, alter, and then repeat a particular form."[7] This is also its danger. In being able to generate large amounts of geometry quite easily, scripted organizations tend to quickly dominate a scheme and become legible as such. It produces a totalizing and hegemonic effect where the overall imagery appears complex but where local conditions are often simplistic at best. While it is possible to write multiple scripts for all scales and systems of a project, it would require an extraordinary amount of time and possibly impede on the non-linear flow of the design process. Scripting seems best when applied selectively in a hierarchical design chain.

Manual operations, on the other hand, are a more sculptural approach, where direct transformations on control geometries take place. A simple example is in connecting two different geometric systems by moving, one at a time, the control vertices of one surface over to another. Working initially this way requires the set-up of some parameters or constraints and a loosely defined target that is being moved toward. While this method provides for local control, things can get quite messy without a good (mouse) hand. To work primarily this way one needs to be a virtuoso. The problem is that the interfaces of 3D modeling software are becoming smoother, requiring less discipline and rigor in generating superficially complex form. With a few tricks, the software can make anyone feel like a virtuoso, when in fact they are quite rare.

Digital craft requires the simultaneous distribution of manual operations and automated simulations. Which one to start with is of no import. At some point the designer must get dirty with scripted geometry by directly and manually taking control, or, inversely, must discipline a raw geometry by mediating it through automation.

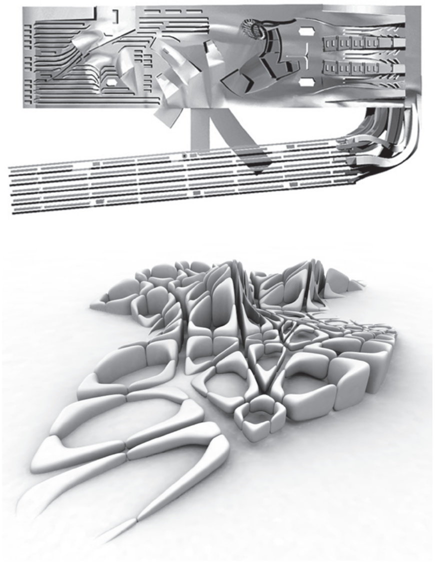

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Figure 3: *above*: Rendered plan of Reiser-Umemoto's Kansai Library entry (1996). Totality is based on the refined relationship between heterogeneous elements. This can only be achieved via manual operations, working locally to resolve conflicting adjacencies and overlap. *below*: Parametric Urbanism; a block type from Zaha Hadid's Istanbul master plan project (2006). Totality is based on the incremental variation of homogeneous elements. This can only be achieved via control of global paramters.

CASE STUDY #1: CHUB

Chub is a 19-foot diameter conference table made of stacked plywood sheet. The budget only covered the cost of materials. Other than the glass tops, which were outsourced, everything was done in house (using a school's shop resources). In this project variability plays out in two distinct ways. The overall table is subdivided into eleven wedges: six small, four medium, and one large. Each wedge is comprised of thirty-six contour layers of ¾" plywood and organized in an irregular arrangement so as to avoid hierarchy and global symmetry. This was a desired variability, planned and digitally organized during the front end of design. During the prototyping phase and fabrication of the contour parts, a minor problem was detected. The milling machine we were using was a bit old and did not have a vacuum system to secure the material. This led to excessive vibration between the tool head and material, enough so that the cut pieces were off and did not connect in a seamless way. This was an *undesirable form of variation* that turned into an opportunity for design feedback.

Rather than idealize continuity, seamlessness, and zero tolerance, we decided to reveal the joint by producing a cleft feature (basically filleting the corners of each piece). This produced a high enough tolerance that the discrepancy became imperceptible. It also required the design of several seams that ran across the body and counter to the grain of the contour. Part-to-whole relationships became even more figural and articulated. We played with the seaming morphology and produced a zipper-like effect, shifting the actual materiality of plywood sheet to a virtual one of fabric. If the fabrication were not in our hands this most likely would have been solved in a more cost-effective way. Because we were directly involved in the process of production, the vagaries and instabilities of matter were able to be rigorously converted into geometry.

The original design, prior to any feedback of material or fabrication intelligence, was more top-down driven in terms of its overall form and articulation. Geometry was directly and manually manipulated by operating on curve and surface components of a hemisphere. A large single geometric object was subdivided into its parts. Because we were more focused on it as an object and had an image in mind (like a cross-section of a pomegranate) this method served our purposes. But it also meant that each wedge, even within the same size group, was slightly and insignificantly different. This would have meant that shop drawings would have been produced for each of the eleven wedges. While it's all the same for the machine, four times as many g-codes would have needed to be written, plus the daunting task of managing thousands of unique pieces. Going into design development and absorbing all the material and fabrication parameters led us to remodel it with more precision, tactically employing automated techniques. This time around we started locally with the small wedge and generated a set of key curves that were animated to produce the other two. This way, when all the wedges were arrayed into the overall configuration, we had precise control. The outcome is a much tighter morphology, and variability was constrained to the three sizes with each copy being just that, an exact replica. This relaxed a bit the mania of part management and labeling.

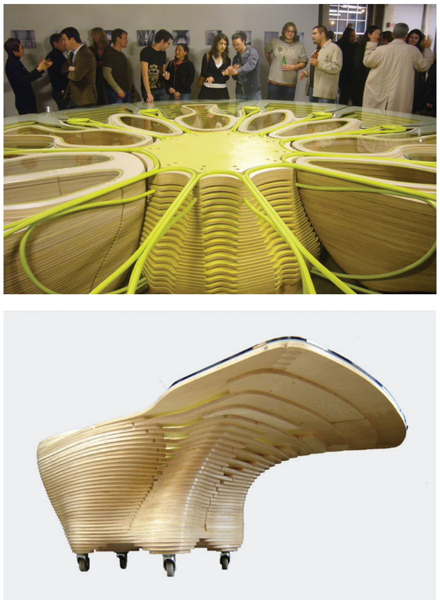

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Figure 4: *above*: *Chub:* photo with three wedges removed; *below*: underside of medium wedge.

Figure 5: *above*: *Grin Bar:* overhead view; *below*: panel layout

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Figure 6: *above: Go Figure:* photo from rear corner; *below:* photo of segment assembly

CASE STUDY # 2: GRIN BAR

This project, for a private client, is an island bar to serve as a focal object in his residence. It is composed of an open-shelf base made of plywood sheet with a black lacquer finish and is wrapped on the top and front sides with relief-formed hardwood panels. The base is straight-forward and utilitarian. The wrapping surfaces consist of two distinct formal logics: sculpted and panelized. This is similar to car bodies where the sculptural figure of the overall body is superimposed with the seams of panelized elements. Sometimes they correlate and sometimes they don't. The surface relief is based on the graphics of a distorted two-dimensional smile. Those lines are converted to surface relief features, such as cusps, valleys, ridges, swells, depressions, and channels, and coerced into performance criteria like gutters and snack bowls. The panelization logic is based on material and fabrication parameters such as size availability, depth, and weight. Rather than use the geometry of the surface to determine the seams, a logic based on normals and interruption was used. The seams are always straight cuts and are normal (perpendicular) at a point along a curve. Where the surface relief is the most intense, a seam cuts across this territory to interrupt an otherwise hyper-smooth condition. Similar to Chub, the seams are expressed and made legible, which allows for tolerances in any material deviations (such as expansion and contraction) that may occur, and provide for additional morphological articulation. But in this case the seams aren't figural but severely crisp in order to counter the strong figuration in the surface relief.

CASE STUDY # 3: GO FIGURE

Go Figure is an installation of four self-similar delineated figures that link together to fill a volume of 24'w x48'l x12'h. Similar to *Chub*, the budget covered the cost of material, fabrication, and finish. Assembly and installation were performed by the author, a coordinator, and a handful of students. Different from Chub, material, fabrication, and assembly logics were incorporated into the design early on. While the actual figure is based on extrinsic factors, all of the tectonics were guided by intrinsic factors in relation to laser-cutting, aluminum sheet, torsion, compression, tension, and powder-coating. Proto-typing at multiple scales allowed for local problems or issues to be detected and addressed in various ways.

Variability operates at two scales. The variability of segmentation and thickness is constrained to one figure and duplicated four times. Color variation works across all four, meaning that each figure is a unique color combination. Each figure is composed of twelve segments with equal length. Length is constrained by sheet size, and distribution is calibrated so that none of the joints are located at the touch-down points. The cross section is a continuously variable equilateral triangle ranging from 2.5" to 6" edge lengths. The triangular cross section provides rigidity and allows the spline-based figure to be unrolled into flat pieces. The edges of each face contain a staggered tooth articulation so that when two edges line up, the teeth get crimped over to form a connection.

Initially the hubris goal was to use an all friction-fit assembly and reject any mechanical hardware, apparent or not. At the tectonics of the individual segments, the friction-fitting of the teeth was quite rigid. However, when we assembled the first figure and started to lower the scaffolding, the accumulated gravitational and eccentric forces resulted in failure. In situ we had to make adjustments and let go of the idealized 'no hardware' approach. Each tooth around the touch-down points was screwed down to make it rigid and prevent torsion. The interesting tectonic lesson learned was that if we had rigidized it prior to assembly we would not have had the tolerance needed to close the loops. So the intrinsic, yet undesirable, force variability in the 'no-hardware' method was actually necessary for assembly. The engineer had initially calculated about 6" of deflection. But this was based on the geometry of the center spline, not the material dynamics of a three-sided ruled surface. Luckily we had the walls to lean on even though it was designed not to touch them.

CASE STUDY # 4: TUMBLEWEED

This project is for a shade and canopy pavilion for outdoor venues (such as ceremonies, lectures, events), and it extends some of the figural and tectonic interests in *Go Figure*. Overall it is about ten times the scale and is outside (meaning no walls to lean on in an emergency). The general tectonic solution is rather than linking the figures, they are tangentially piled onto each other forming a structural network. Also, each figure has a secondary system, a rigid collar connected by small metal rods, forming a strange kind of tensegrity structure. The micro-repeated rods form the canopy, which becomes an intrinsic part of the morphology as opposed to a separate infill solution. The cross section of the segments is now based on an isosceles triangle. This was a crucial adjustment and allowed for parametric control of the tangential faces.

Of the four case studies, this project uses scripting the most and at multiple scales. An initial 3D voronoi framework was established and trimmed down to the approximate final form. Then figures were "drawn" over the framework with an eye toward producing strange loops as well as erasing any reference to the initial voronoi cells. Each loop is unique and was drawn manually, one at a time. This is the part where a scripting logic proved unproductive. We relied more on intuition to produce each figure and assess their accumulative effects in the larger field, basically a 'trial and error' approach. Once the lines were drawn, we went back to scripting to generate the variable thickness of the triangular cross-section and maintain facial tangency across all members.

The design examples above make a case for a sensibility driven by *ambivalence* in relation to the dichotomies presented. This implies that digital craft, as an ethos of production in relation to seriality, be simultaneously grounded in a disciplinary lineage of how things are made and projective in a discursive context of variability. While parametricism, as a style, produces a totalizing effect based on control and the indexical legibility of computation, digital craft is more of a messy endeavor, a mixture of conflicting demands and desires. Indeed, even with the hygienic interfaces of the digital, architecture has never been more a dirty business. ◆

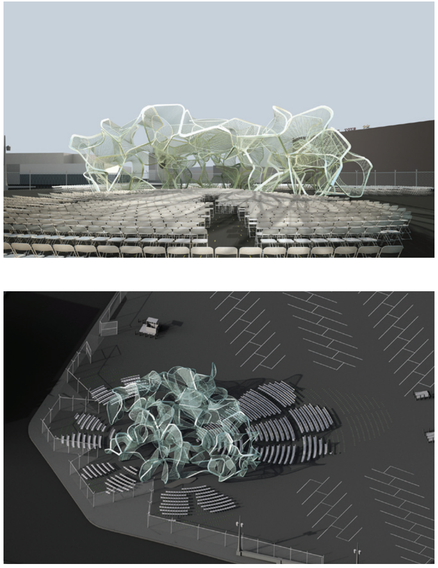
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Figure 7: *above: Tumbleweed:* Eye-level rendering; *below:* Aerial view rendering

ENDNOTES

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