Digital Strategies / / Fabrication Tactics: Objects / Patterns / Spatial Systems

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With few exceptions, there is a wide gulf between a design and its execution. Architects terial quality of critical aspects of their projects. The advent of CNC (computer-numerically-controlled) fabrication techniques suggest a common ground; a locus of cognitive and material activity with a singular outcome – a solution for a new common ground of experimentation. But it is not without an understanding of the dialogue between strategy (design, conception) and tactic (execution) that the singular outcome of CNC technology can find its ultimate potential

Computer simulation has become the means by which virtual space becomes more than just a mirror of reality. It becomes the space within which different potential realities can be tested and evaluated in advance of material implementation. In architecture, information from material constraints to site conditions can be constantly fed into computer models to provide an accurate parametric update, which in turn introduces feedback into the overall design. Simulation then becomes a way of assessing the performance of the project and limits of a spatial system through a direct engagement with the underlying geometry of the design. In this regard virtual space becomes fluid and dialogical within the design process.

There is no longer a reliance upon incremental scalar increase in order to arrive at greater degrees of fabrication accuracy, but rather a more dynamic and non-linear "cause and effect" methodology is now possible. A game are historically at odds with contractors in defining the execution and ma of design strategies and fabrication tactics is set in motion.

The objective of this game is not to rely on the digital model for the final assessment of aesthetic and tectonic fitness of a design. Rather it is understood that manual intervention and improvisation in conjunction with architectural strategy is required. Authorship of the design is not exclusively parametric but is understood as performative. Performance criteria, while quantifiable within the digital environment can still be assessed and responded qualitatively in the physical environment. The degree to which this interplay between analysis and interpretation fluctuates with the scale and complexity of the project must be constantly gauged against material and functional realities.

It is through this performative process that different methodologies for implementing and evaluating simulation give rise to emerging digital tectonic applications. The physical realizations of these tectonic exercises are pursued in the architectural installations of our digital fabrication seminar.

LiteBEAM suspended ceiling installation

The first large scale project we initiated, LiteBEAM, was a function of available local fabrication resources, as well as a basic desire to modify and expand the parameters of the typical "suspended ceiling system". The

components of this system were derivative of the fabrication tactics and local resources uncovered in the first half of that semester. Primary elements – beams – were conceived as sculpted solid forms, complex shapes that are simple catenary expressions of a uniform load over a simple span. These beams, 15 feet long and 30 inches wide, are sculpted in 2 axes by a CNC controlled hotwire which is typically used to make architectural cornice shapes.

Between each beam is a series of vertical lenses, CNC router-cut from ½" thick clear plexi-glass. These are embedded with colored cold-cathode lighting, and support a series of fluorescent single tube fixtures that provided indirect lighting between each of the 4 beams. The lenses were provided by a signage company that typically uses this material for letter forms in exterior signage.

Below the lenses and in between each beam are a series of three shells – concave space frames that serve to capture and diffuse the light emitted from the fluorescent tubes and the edges of the lenses. The shells are made of a series of 19 transverse profiles along a central spine with secondary longitudinal elements at the perimeter. This was wrapped with white stretch nylon, and sewn at the edge. Each element was CNC laser cut from 1/8" steel plate, and will fit together with coordinated notches derived from the intersections in the digital model. A weld was placed at each intersection to form a semi-rigid frame, ready for the application of the translucent diaphragm skin.

The completed assembly hangs from a shop fabricated, welded and bolted connection up to an existing cable suspension system. While this iteration of the LiteBEAM System extends for 4 modules, it is understood as a repetitive system that could extend indefinitely.

DRINKTANK Space

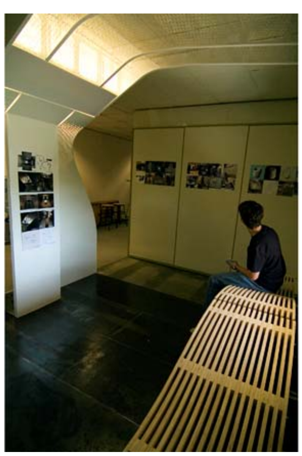
The latest project, DRINKTANK, is the continuation of the research initiated in the LiteBeam project and expanded into creating a unique and useful social space in the College. It seeks to answer a series of questions about how to provide free water, vessels for drinking, seating, lighting, and graphic signage within an integrated spatial system. The exploration that began on the ceiling datum like the LiteBEAM, but now folds down to become a wall with a double-curvature geometry. The form of the wall is determined by taking the width of the adjacent corridor at the base that transforms in section to the dimension of the existing modular ceiling grid and lighting system. The wall is self supporting while retaining a translucency to transmit natural and artificial light through fiber-optic effects demonstrated in the *luminaire* projects.

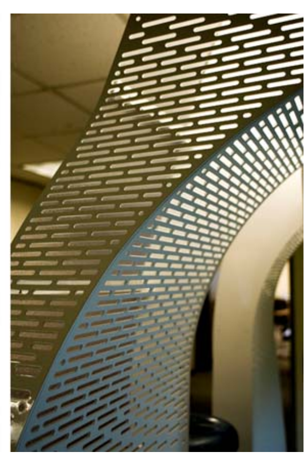
The aforementioned criteria: Water, Vessels, Seating, Lighting, Graphics, and Spatial System determine how the complexity of the project is broken down into a collaborative structure where groups of 4 students work in small teams to develop specific parts of the whole system. Architecture and Industrial Design students work together to share their own specific expertise. We are making a conscious effort to cross-pollinate the two programs in our College through this installation seminar.

Again, we engage the ability to CNC cut steel, acrylic, foam, and other polymers to form the structure and surface of the double-curvature wall that frames the water dispenser device. Digital tools allow us to flatten curved surfaces to generate templates for patterns and profiles of frame components. It also allows us accurately locate points where fasteners will be introduced within close tolerances. A strategy to introduce perforation to components and surfaces serves to lighten materials, allow for light transmission, and accommodate bending in specific areas of the surfaces.

A finer system of light modulation materials and seating surfaces is incorporated into the overall system. This gives the individual teams input about design specifics and material innovation toward the project. The design of the water dispenser and drinking vessels gives those teams latitude to explore issues specific to Industrial Design.

The project successfully applied the research we seek to expand in the College and in practice to engage ourselves with the light-manufacturing industry that is a potent resource in our city.





Fluid Form

Much of the research that is eventually applied to these architecturally scaled systems and spaces is initiated through a study of fluid form. “Wet” materials such as cast polymers, plaster, or concrete are studied to express their fluid properties. Frozen fabrics, catenary models, grid shells, porous surfaces, and flexible formwork castings all provide a means to explore the fluid nature of materials. We explore ways of harnessing these properties and controlling them.

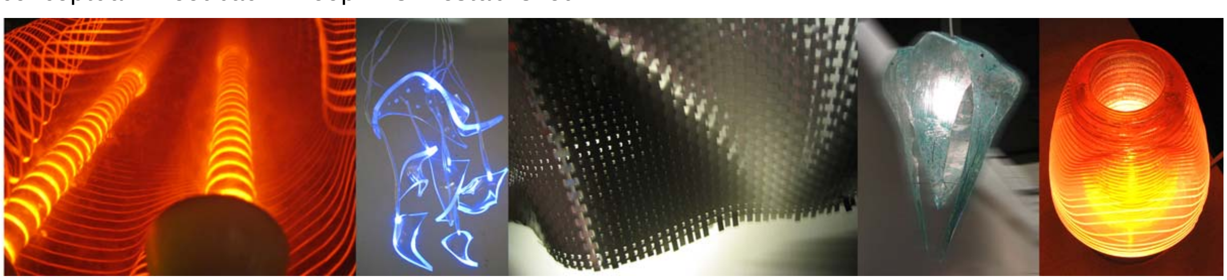
We further study these formations with 3D modeling software to visualize their application into architectural systems with respect to modularity, pattern, and variation. A conceptual feedback loop is established between the fluid material process and the virtual projection of potential spaces created with them. We see the meaning of fluidity as being a literal material property on one hand as a way to describe a working methodology that moves fluidly between virtual to actual space.

Light and Space

Before the scalar jump to the architectural interventions we test these “fluid” formations through the design of small luminaires. Lighting is the ideal middle ground between architecture and industrial design. Building luminous objects offers the opportunity to study new materials and forms in terms of how they modulate light and define space at a manageable scale. The CNC machines at our disposal limit the scale of fabrication to a small format with a narrow range of materials to use with them. We can test ideas and techniques that can be applied and expanded through professional fabricators. Basic knowledge of electrical lighting and wiring is also attained by the students. The techniques that are learned at the scale of the object, when combined on a group design/build project, are collectively productive.

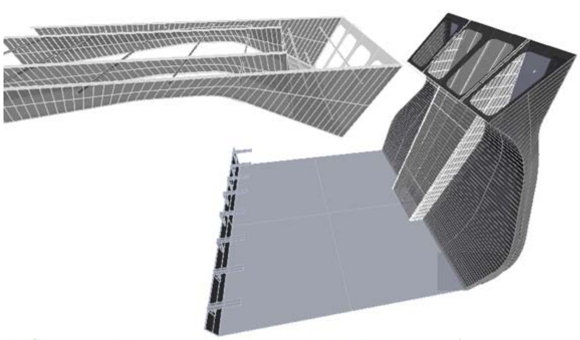
Digital Simulation

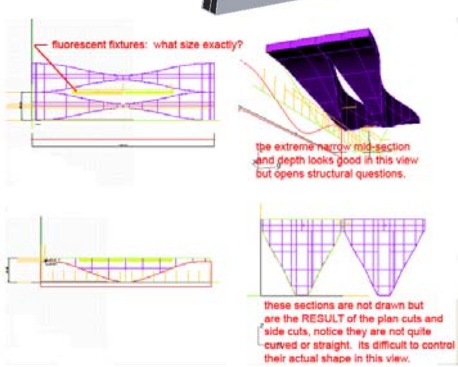
Simulations in virtual space have become real in sense that they provide highly accurate models from which we derive components to be CNC fabricated. We can anticipate constraints of context, materials, and infrastructure to control the tolerances between the parts. Materials properties of expansion and contraction still have to be accommodated but require much less adjustment in the field. The modular nature of the projects we have built take into account assembly sequences, fabrication cutting limits, material weight, and construction phasing. The digital models allow us to simulate these



procedures and evaluate the right path. The students get a scaled down experience about how different parameters affect not only the form of a project but how things come together and in what sequence.

In the case of the DRINKTANK space, we worked with laser-cut steel sections that bolted together in precise locations. The digital model afforded the opportunity to determine how the whole would be divided and fasteners could be located exactly where connections could be completed with simple fasteners. Our intuition about where stresses were greatest allowed us to simultaneously deal with structural stability. The LiteBEAM had to accommodate an existing suspension system from which it would be hung. We located the internal structural pieces with precise alignment to the lines of force. The integral lighting system was a combination of off-the-shelf fixtures and custom electronics that had to be coordinated with the rest of the ceiling pieces. The models allowed us to calibrate the components so that everything fit with negligible tolerances.





Pattern Making

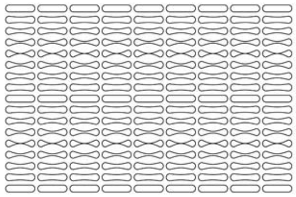
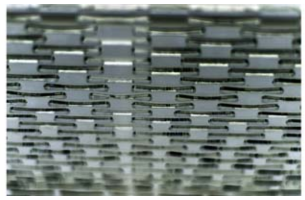
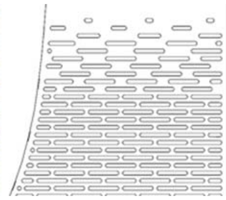
We use patterns at multiple scales to explore the potential of repeatable construction modules, component templating for fabrication, and intricate surface articulation. The patterns we employ at the largest scale take on the role of organizing structure and infrastructure within a logically coordinated system. This is not unlike standard construction technologies, but we seek to customize architecture on the level of the module itself and scale it up. The tyranny on the 4'x8 dimension of sheet-materials or specifically the 2'x2' generic suspended ceiling grid can only be overcome by a reconsideration of how to differentiate the incremental repetition of the systems that are available to the designer.

With the LiteBEAM, we sought to expand the standard ceiling module. We worked with a CNC process that cuts foam with a hotwire in 2 dimensions. We convinced the fabricators that 3D forms could be produced by rotating the initial cut forms 90-degrees. The templates that we used to form the catenary beams was woven with the photometric diagram of our lighting system to produce a repeatable pattern that could be expanded infinitely. Two beams when joined with the lighting array nested in the void between them formed a non-standard construction module that echoed the expandability a standard system while exploring the sculptural potential of EPS foam, framework, and frozen fabrics.

Unrolling: 3D>2D>3D

We researched the power of patterns in their ability to inform our process of making through the use of templates. We employed the techniques that tailors use to join the seams flatten patterns to form clothing as an envelope around the body. The 3D digital models have the ability to be unfolded into 2D templates that are then CNC cut out of sheet materials. These complex forms are then rebuilt by bending the materials so their seams match and are spot welded. A highly accurate translation from virtual to physical space is achieved through this operation.

With the DRINKTANK wall/ceiling sections, we were able to build at surface curving in 3-dimensions by having the 2D templates cut at a industrial CNC fabricator. A more traditional route for fabricating these types of forms would involve the construction of an elaborate system of jigs to approximate the position of the parts and trim the material until the proper shapes where achieved. This dynamic process is still present but now the parametric control


is maintained within the digital model. Changes in the design can be made and their effects on the components are manifest with different toolpaths to be sent to the CNC fabricators to cut the patterns.

Perforated Patterns

We further study the potential of patterns on the finer scale of surface articulation. The potential of CNC machines to cut or etch intricate textures into materials opens the possibility for them to take on dynamic properties. Perforation removes material without compromising the structural continuity of the surface. The degree of perforation can radically change the weight and flexibility of typically heavy pieces of sheet metal and make them easier to bend and more workable. The light modulation properties also take on interesting effects as the materials catch light in interesting ways.

With the DRINKTANK, we were able to bend steel by hand in critical locations by perforating the steel over the radius of the bend. The spacing of the slots expanded as the degree of bending dissipated relative to the other surface it would be joined with. Sheet acrylic was perforated to catch light and amplify it through edge refraction and fiber optic effects. This type of articulation introduced a series of patterns that facilitate easier on-site fabrication and non-figurative filigreed ornament onto the architectural surface.

CNC Fabrication

The current trend in schools of architecture is to install various kinds of CNC machines in their existing shop facilities. This has transformed the way information is exchanged between digital applications and the realm of physical making. These machines are often scaled-down versions of what professional fabricators are using for large-scale construction projects. Our institution is uniquely located in a city with a vast array of light-industrial fabricators dedicated to the petro-chemical sector. We find it more interesting to quickly move out of the small-scale realm of intricate model making/object design and engage this community of fabricators and builders by outsourcing our work to their large-format machines. The benefit is apparent in our ability to build 1:1 architectural systems and assemblies that are direct extractions of virtual models. Students are engaged with the real-world aspect of communicating with the projection end of the process and the fabricators gain exposure by working outside of their typical context.

This was the case in both the LiteBEAM and DRINKTANK projects. We worked vertically by scaling up the lamp ideas into models and 3D simulation of assemblies. We looked laterally at the kind of fabricators that were available and willing to work with us. This combined to create a synthesis between an academic research project and a realized application of cutting-edge technology currently used by the local professional fabrication community. It is this interface that find interesting to explore. By shifting and overlapping the context of academic projects and professional practice we open the door to a new learning environment.

Material Research

As previously indicated, the “game”, (or rather, the inter-play) between strategic thinking, and tactical execution, suggests that there is a vital feedback from the material that will necessarily alter the trajectory of the conceptualization, digital modeling, and simulation of the work. Our collective experience and local research has set a benchmark for our actions: a set of applicable processes are understood, and a range of materials is made available through local resources and budgetary constraints.

The unpredictable outcome of the game is ultimately the interface – the clash – between an academic think tank and a blue collar armature. The scale of our work in architectural installation demands that we outsource for both material acquisition and the majority of the fabrication processes. There is at once a broad range of limitations, but also an equally broad range of unpredictable new hybrids between processes and materials as we seek to fulfill the outlined conceptual potential of our designs

The co-opting of existing technologies and industries makes use of extremely potent local industry to pursue non-standard output:

- Simple Boolean subtractions in foam blocks turn the EIFS cornice industry into a supplier of lightweight and inexpensive repetitive ceiling forms.

- Repetitive perforation in 1/8” steel plate allows for hand bending of wide sheets and welding into 3-dimensional volumetric form.

- Notching and toothing of non-repetitive elements in laser cut steel allows for rapid re-construction of a skeletal 3-dimensional solid, clad in translucent fabric.

Our current research will continue to question the scales, capacities, and applications of local industry and material suppliers. We are actively pursuing industries that produce vacuum formed pieces at large scales, fiberglass and resin industries that produce environmental objects such as hot tubs and pools, spray polymer applications for large scale waterproofing and industrial coating, as well as more esoteric specialty processes in metal fabrication that will push output beyond the typical erector-set simplicity of steel construction.