Stereotomic Robotics

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Marc Jarzombek suggested recently that one could determine the well being of a society by its ability to carve stone precisely. So much of the discussion around digital design and fabrication has focused on the surface. Whether it is because we have inherited thin sheet materials from the industrial era, or because of contemporary isomorphic tendencies, or because of the assumed inefficiency of manual labor to carve stone, we have certainly lost the ability and knowledge to work with volume. The purpose of the following research is not intended to revert to an antiquated mode of construction, but to mine the lost knowledge of stereotomy as a way to inform contemporary methods of making with the dimension of volume.①

A number of volumetric materials have the potential to fulfill this research agenda: AAC (Autoclaved Aerated Concrete), Reconstituted Stone, EPS (expanded polystyrene) foam. We selected EPS foam as an initial volumetric and inexpensive case study material, that is 100% recyclable. The material properties of EPS foam in conjunction with advanced fabrication methods provide a solid platform to inform digital fabrication with stereotomic construction logic.

① 切石法是将实体切割成特定形状和尺寸的技术。
Stereotomy is the technique of cutting solids to specific forms and dimensions.
CNC milling a custom profile is no longer an innovative proposal, and yet milling a solid figure out of a block at an architectural scale is cost (and time) prohibitive, and casting produces volumetric, but regular components. In order to appropriately address the issue of volumetric fabrication, one is required to research methods practiced when working with volume was common practice. We have translated the developed surface technique into a digitized process as a way of embracing the almost forgotten practice of stereotomy. The developed surface (while ironically re-appropriated to the more widely known 'developable surface' that holds its roots in surface thin materials) was a method for customizing stone carving through the minimal means of a sweeping line that can be flattened or from a three-dimensional geometry into a two-dimensional drawing otherwise known as a trait. By extracting this principle, it is possible to conceive of this hypothetical line as a physical and CNC (computer numerically controlled) device – a custom built, seven-axis robot-controlled hotwire cutter at the University of Michigan’s Taubman College of Architecture and Urban Planning. This converging of past techniques with contemporary materials and methods informed the reciprocity between drawing and making in the following two projects.

Periscope: Foam Tower

Periscope is the winning entry in the 10Up! National Architecture

footnote:
① For the stone mason, this line was not a physical object, but rather a geometric principle allowing 2d traits to describe a 3d form.
Competition, whose brief called for entries that could be constructed by a two-person team, working within a $5,000 budget. The team would be given a month to design an installation for a ten foot square plot, which could be installed in less than twenty-four hours. Mounted in only six hours, Periscope is not only a beacon for the Modern Atlanta Event, but is also a product of contemporary digital fabrication culture in that the means and methods of fabrication were developed in parallel to the design, namely custom robotic fabrication tools. The regulations did not stipulate a height restriction and most entries assumed the ten-foot cube volume. Periscope, at fifty feet tall, was more ambitious.

From a distance, the observer confronts the sheer magnitude of the figure. The tower appears as tensile fabric stretched vertically by impossibly thin compression rods. This initial confusion is productive: it pulls the observer in for closer inspection to reveal Periscope’s logic of rough stereotomic construction. Two portholes at ground level invite the spectator to peer up the “skirt” and through the body of the tower. This isolated view crops a view of the sky and reveals a new internal figure that is not coincident with the exterior surface. Rather, it is a figure created by the intersection of two conical views, a result of a solid Boolean offset. Periscope resists an initial reading of its form as a surface membrane. Where the eye once read tensile fabric there is now solid compressive foam. The compressive rods are actually tensile cables.

This rhetorical inversion is both a commentary on the contemporary practice of surface operation (as opposed to volume) as well as a vehicle to pull spectators in to the Modern Atlanta Event. Over 500 custom foam units are carved from stock blocks of EPS (expanded polystyrene) foam. These blocks are then stacked in a running bond and assembled into three-foot tall sub-assemblies. At the top...

外围”和塔身。这个孤立的角度产生了天空的景象，显现出一个全新的与外表面并不一致的内部轮廓。其实，这是由两个圆锥角度交叉创建出来的轮廓，也是固体布法罗逻辑运算偏移的结果。第一次看

这种带修辞色彩的倒置既是对表皮操作（与体积相对立）的当代实践，也是将观众拉入到亚特兰大竞赛中来。约500多个定制泡沫单元从EPS泡沫块中切割出来。然后用粘合剂将这些泡沫块堆积在一起，组成3英尺高的分组合件。每个分组合件的顶部和底部是一块夹板平面，既起到海运保护的作用，同时也是更重要的一种行为，可以保证通过手工集合的单元组成预期的几何图形不会慢慢散开。单元的堆积是一个手工过程。试图将不规则单元排成一列可能会导致每一项的细微变化。除了因为手法有对准之外，另外还需要能够允许承受长丝切割，因为没有凝胶可能会导致移动的误差。

每个分子结构件都设计得足够轻，使两个人就可以直接搬运。当堆到三个那么高时，每个组件都在半拖挂车内能够粘合得很好。14个分组合件堆在一起，建成50英尺高的建筑，通过拉紧的电缆将建筑固定到基础。这些固定基础重约为16500磅，从而可以抵抗设计风速范围内的翻转力量。柱体的内外表面在塔身中央至少有4英寸的接合，但是可以互相分离或扩展，从而满足用泡沫袋解决各自功能。此技术和材料性质指出了这样一个观点：当代建筑的表现与实践必须像纸一样滑的表面。

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Temporal Tenancy

Temporal Tenancy is a prototypical installation testing a proposal for rapidly deployable and customizable dwellings. This proposal responds to the problems surrounding shrinking cities and foreclosure rates by rejecting the notion of permanence in favor of a method of making that operates in direct correspondence with the ebb and flow of property fluctuations. This method of making is an extension of the research conducted in the previous project.

The tool-path geometry for the tower project was based on breaking a pre-determined geometry with horizontal slices, then extracting the top and bottom curve of each coarse and re-creating a loft operation between the two curves with a placement and direction vector for the

and bottom of each of these sub-assemblies is a plywood profile performing as both shipping protection and more importantly a jig to ensure the manual aggregation of units would not drift away from its intended geometry. The stacking of units is a manual process. Attempting to align irregular units results in subtle variations between each course. In addition to these manual misalignments, a small error tolerance is needed with such a long hot-wire cutter as the slack of the length can cause drifting.

Each sub-assembly was designed to be light enough for two people to carry. When stacked three high, each would fit snugly inside a semitrailer. Fourteen sub-assemblies stack to construct the fifty-foot tall structure held down with tension cables to the ballast base. This ballast weighs approximately 16,500 lbs to resist the overturning forces of the design wind. The interior and exterior surface of the volume touch at a minimum of four inches in the center of the tower, but are free to expand and depart from each other to serve their individual purposes resolved with a poché of foam. This technique as well as material properties questions the notion that contemporary architecture must perform in the realm of paper-thin surface.

具有讽刺意义的是，这些推动进行切石法的社会动力与迅速建造产生矛盾。在设计这些项目时，通过压力是必须的，因而研究并不仅仅局限于轻质材料。泡沫在这里只是作为石头的模拟物来使用。如今很多结构研究都侧重于源自形状生成的轻薄外壳。当想到使用这些先进技术将坚实的材料切割成不同的变化尺寸时，可以想象，制造结构并不会对结构上已确定的形态作出贡献，通过使用体积材料来改变这种局部深度时，与“找形”相对应的“找深度”方法可能会出现。
wire to move along. This process breaks a compound geometry into a series of constructible geometries. Though the top and bottom curves align, this results in a number of slipped surface discontinuities. In an attempt to resolve this issue, the Temporal Tenancy installation toolpath geometries were extracted directly from the ruling lines of the surfaces. This meant the desired surface determined the ramp and slope of the wire’s path. An infinite number of surfaces could be constructed by lofting a ruling surface between two curves. This technique simply ensured we were selecting the specific surface required to complete the continuous surface.

The Irony of Such Research

Stereotomic construction has historically been a compression-only system, as its material has been typically stone — a very heavy and permanent material. While some argue compression-only stone structures are no longer an efficient or valid system of construction, we argue that these structures outlast any partial-tension structure, making them inherently sustainable. This is certainly one of the potential results we intend this research to foster; however, in order to compete with the relatively inexpensive sheet materials, aerated materials reduce the cost for volumetric materials. This reduction in cost unfortunately produces a material with less weight and therefore incapable of performing in a compression-only system.

Ironically the impetus to engage the process of stereotomy conflicts with the prompt for a temporary installation. In designing these projects, tension is required, but the research agenda is not limited to lightweight materials. Foam operates here as an analog for stone. Today much structural research focuses on thin shells derived by form-finding techniques. When considering advanced techniques of custom carving solid blocks of material to variable-depth dimensions, one can envision compression-only structures that are not dedicated to structurally determined forms. By varying the sectional depth with volumetric materials, a method of ‘depth-finding’ as opposed to “form-finding” could emerge.

参考文献 / References: