Displaced Matter Aesthetics: Constructing Effectors for Non-Extractive Ceramic Ornament

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The discipline of architecture and its prevailing ornament construction aesthetics has become overly reliant on the subtractive digital fabrication process, wherein desired geometry is excavated from a procured material block. Notably, subtraction is not deletion, in procedures such as CNC milling - the 'subtracted' matter, is neither 'destroyed' nor 'deleted;' it is transferred from a contiguous piece to a particulate dust, as in the cases of foam or MDF, later to be deposed to a landfill. As our society, profession, and discipline pays closer attention to its impact on global supply chains, and the larger environment, we must find new aesthetics that optimize our material usage. This research borrows from the historical tools and processes of sculpting clay to inform an automated robotic process for the preparation and design of architectural panels wherein material is displaced or shifted rather than extracted. The resulting process requires the consideration of the displaced matter as a part of the finished aesthetic requiring both an active prototyping process to understand how the wet clay shifts by the automated forces as well as an engagement in design of the effectors that engage the material. As a byproduct, the research which was run within the confines of a design seminar, demonstrates pedagogical methods of introducing students to automated design processes.

DISPLACEMENT BEFORE SUBTRACTION

The past twenty years of digital fabrication within the architectural discipline has seen a considerable emphasis on the dichotomy between additive and subtractive fabrication processes. In its original conception, additive may have been defined as the process of adding parts to build up to a larger known geometry, while subtractive would-be removal of material from a larger block to excavate a desired geometric part or the production of a negative mold. Notably, subtraction is not deletion, though for a novice designer, who is simulating a CNC end-milling processing in a CAM software, the critical question of, 'Where did this material go?' is often not confronted. Consider the production of a mockup for the purposes of creating a concrete mold as milled from MDF [1]. A large piece of stacked MDF is placed on a pedestal adjacent to a multi-axis robot outfitted with a rotating tool effector, the matter that is 'subtracted' is neither 'destroyed' nor 'deleted.' Rather it is transferred from a contiguous piece of MDF to a particulate dust, which is whisked away by overhead dust collectors into bins later to be deposed to a landfill. Similarly, within the terracotta ornamental industry, panels and architectural ornamental pieces, such as gargoyles, are mass produced requiring the production of a foam molds, within which elements are either slip cast, hand-pressed or ram pressed[2]. As our society, profession, and discipline pays closer attention to its economical use of material, impact on global supply chains, and the larger environment, an aesthetic of displacement rather than 'extraction' should become an aesthetic and procedural principle.

Arguably, one reason displacement as an aesthetic has not been explored is the discipline's previous tendency to work with static materials, or those that have clearly defined geometric states The geometric process of removing matter from static material such as wood, stone, and various polystyrene foams, are easy to simulate by a designer in the computer before their CNC end mill process. Clay by contrast in its wet and semi wet state, though registering as a solid state in the physics sense, maintains a level of plasticity and malleability that defies the previously studied processes of removal utilizing a spiral end-mill, as these would only twist and gum the blade. Further, this plasticity makes the material difficult to simulate due to the complexities of programming elastic particle engines. An examination of the tools historically used in clay carving and indentation, make readily clear that a different tradition is at work (Figure 1). A loop or ribbon tool, that resembles a wire loop extending from a hand, when grazing wet clay, produces strands that fall back on the surface as one moves. Whereas a dental tool, resembling elements found in the horrors of the dentist office, are used to push material along the length of the surface of the clay, producing mounds and ravines accordingly as the material is displaced. In both cases, the process of removing clay, is more akin to the processes of unearthing ground in the topographical landscape and civil engineering

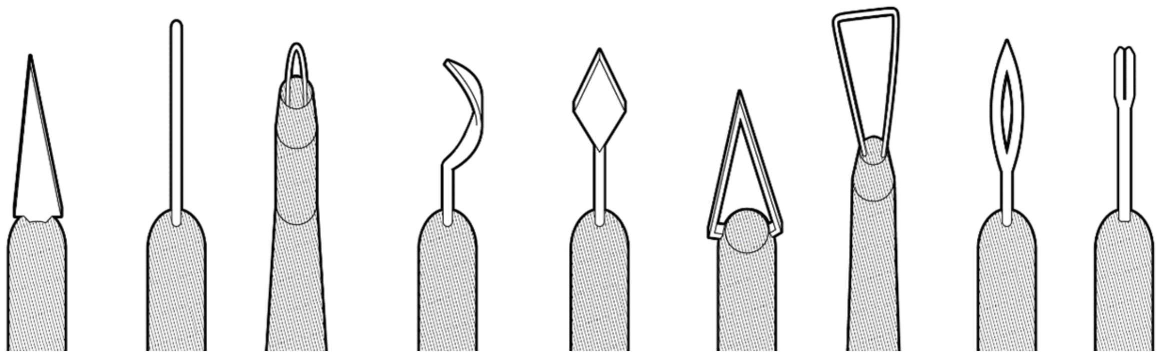

Figure 1. Traditional Clay Sculpting Tools, Drawn by the author.

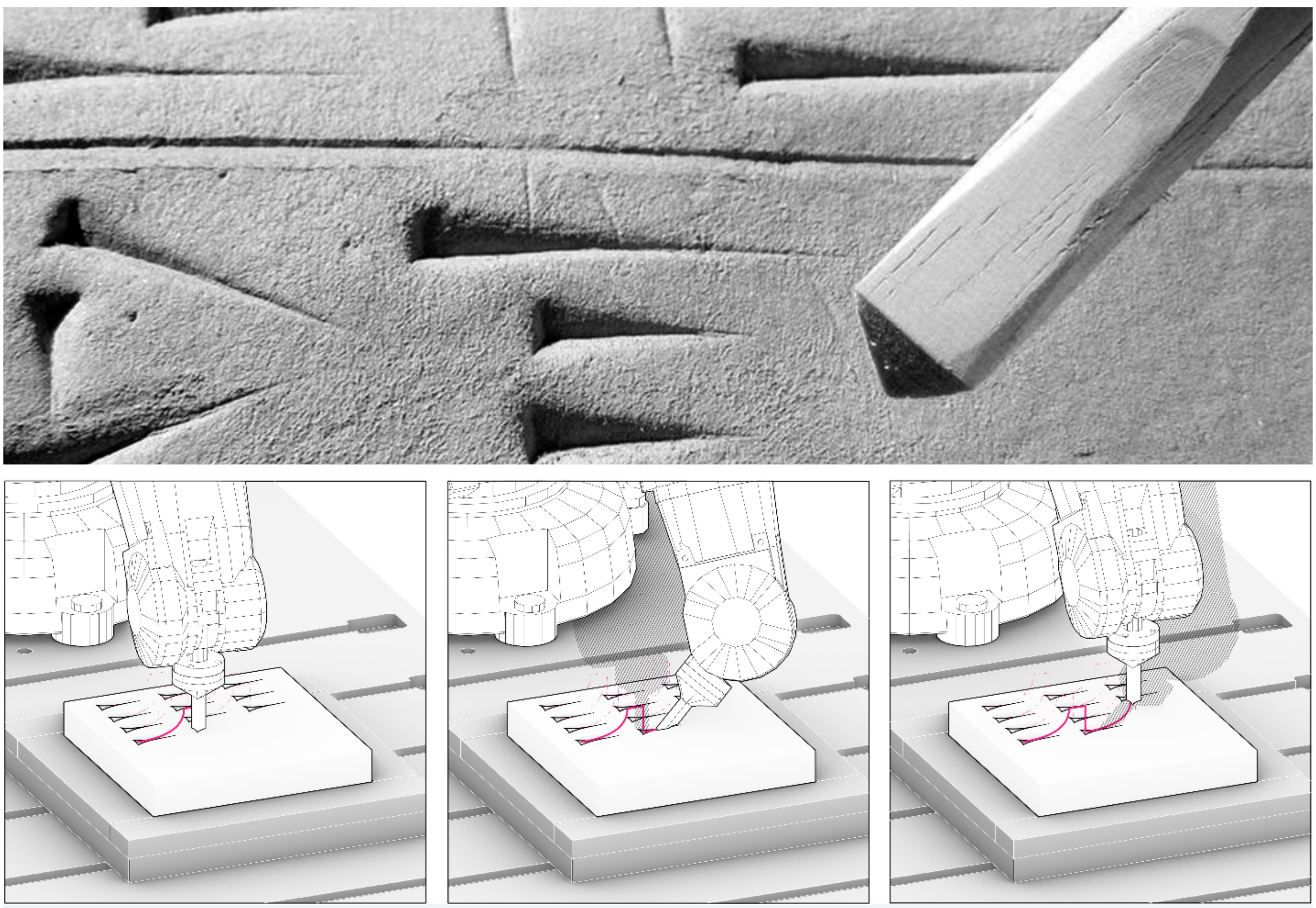

Figure 2. Cuneiform Clay Tablet and Stylus Photograph by Shelia Terry, 2013 and ABB IRB 140 demonstrating a multi axis defined path for digital cuneiform

context, wherein architects have learned to balance ‘cut and fill,’ as a sustainable non-extractive process.

DIGITAL CUNEIFORM

These effects, which have been used for millennia towards the inscription and sculpting of clay manually by artists and artisans, have found relatively little traction within the digital automation arena, perhaps in part due to the difficulty in simulating their visual effect in the computer a prior. An examination of the vernacular and historic techniques of carving and imprinting such as an Assyrian Tablet bearing Cuneiform script, draws our attention to the fact that the design of the pattern and imprint requires careful pre-design of both the tool and the

Figure 3. A series of End-Effectors for IRB 140 robot, Drawn by the author.

manual procedure for how the tool enters, transits within, and exits the medium of wet clay. Herein the triangular effector is pushed into wet clay, to a ninety-degree angle to produce an imprint, rotated within the clay and then removed on a long bias that spreads material to either side of its knife blade side condition as it exits the substrate. The resulting topology of the once flat surface of the clay exudes a puckered or pillowed affect, resulting from the displacement of the material being pushed aside by the effector in transit. The goal of this research was to create a workflow process to bring the aesthetic matter found in displacement of live clay into the automation arena as a means of informing an aesthetic of non – subtractive removal. This research was conducted in a design seminar, engaged in the teaching of robotic automation, wherein the process of 'Digital Cuneiform' was also developed to engage students in designing a robot's motion, crafting end effector geometry, and the ultimate piece of architectural ornament (Figure 2).

For this study two types of clay were used, Amaco Earthenware Terracotta 77 clay, and Amaco Stoneware 38. The clay was prepared in a nine-inch by nine-inch by three-inch high mold, in a semi-wet state. These wet clay slabs were removed from their mold and inserted into a 1" high plywood collar jig was the removed and substituted with a one-inch-high jig attached to a larger piece of plywood designed to hold the semi wet slab in place when clamped to a table under a university administered ABB IRB 140, 6 axis robots. A series of end effectors were constructed to experiment with two types of displacement, impression wherein the effector would be pushed normal to the surface of the clay slab, plowing, where a tool was designed to cut through the material displacing material to either side, and sometimes a combination of the two. Designs for effectors were cataloged based on their profile as projected in two axes to provide an understanding of the displacement movement the tool would have on the clay..

Different configurations were attempted including the introduction of springs into the effector, to allow for physics to be introduced in the activating process. Effectors were made as 3D printed using solid infill PLA, as well as by modifying existing clay tools and creating PLA fasteners to mount to the IRB's circular collet (Figure 3). Investigations began by deploying the end effectors by hand in repetitive motions, to explore the possible effects of the end effectors on the wet clay. These motions were then systematized and recorded with stop motion photography, to dissect the movement of the arm for developing an understanding of how to code the radial and translation movements of the six-axis robotic arm.

Motion patterns were designed in the Mcneel's Rhino 7 digital modeling environment as continuous curves, which allowed for the generation of Rapid Code in the procedural modeling Grasshopper application using the plugin 'Robots.' Simulations of each of the tool paths were algorithmically produced using Boolean procedures, to gain an understanding of the effect or removal, as paired against the true displacement of matter. More advanced curves were encoded with planar divisions along their length, to indicate the axial transitions required for the robot to enter and exit the substrate using different parts of the effector, as in the cuneiform tool.

The robot arm's speed was variable depending on the size and make of the effector, with ranging success between 10 - 30 millimeters per second in transit time, depending on the viscosity of the clay. The final result displays a mixture of the displacement and removal, wherein wet clay was removed by the axial procedure and cleaned in between layer passes. For these cases, the clay was placed back into the stream of production towards the next panel or test, though in all configurations never was all of the material used and the wet state provided both imprints and displaced aesthetics unique to the movement of the effector. In other cases, the displacement was conducted in a manner where excavated material was still contiguous with the body of the panel informing a stranded elements that, that would dry in a manner that informing a hyper rough texture. These panels required minimal cleaning only for the purposes of removing strands which would fall away during the firing process (Figure 4).

RESULTS

The results of this research experiment produced a series of panels, of varying effects, the most notable of which displayed several aesthetic outcome that could not be reproduced

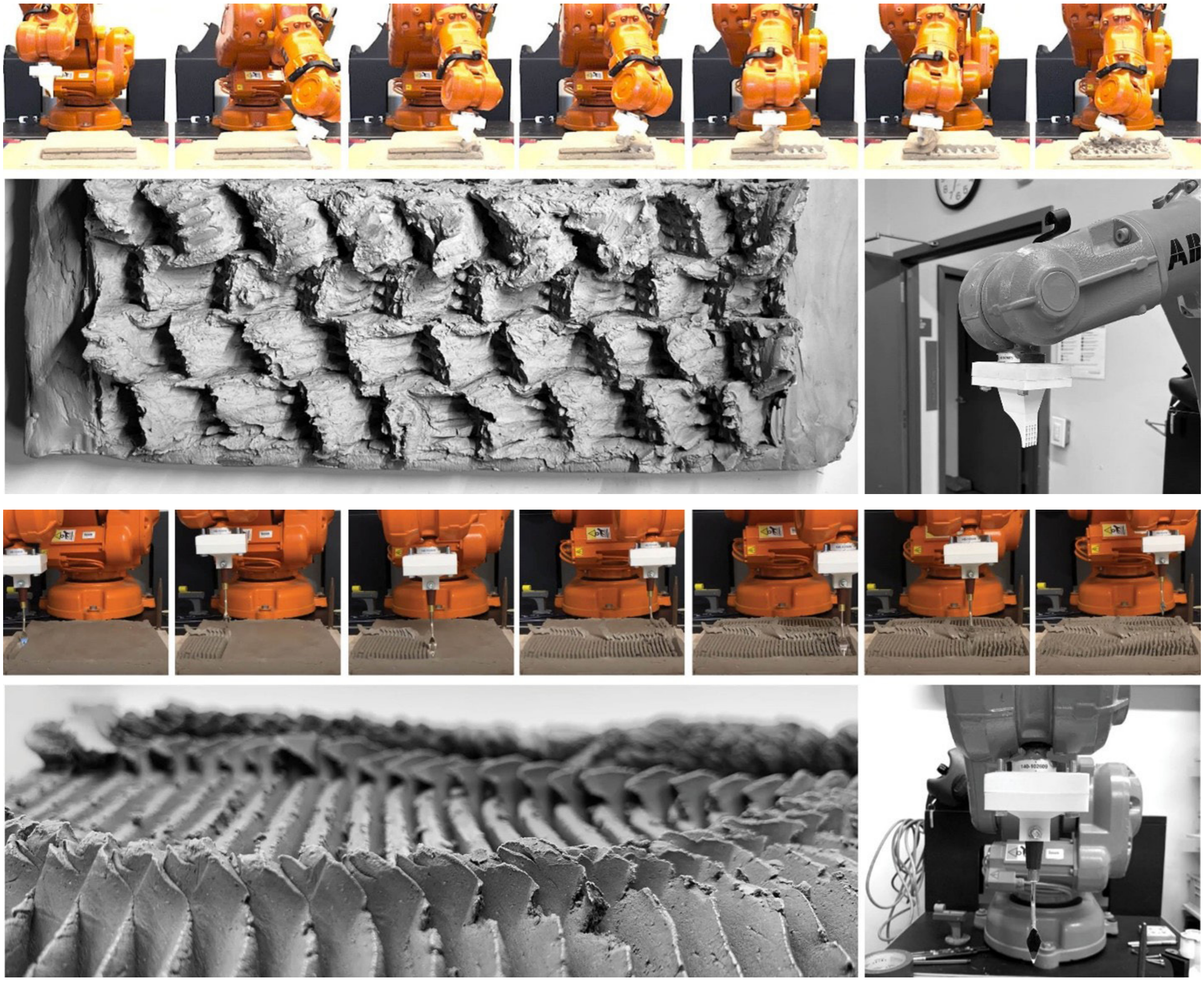

Figure 4. The above examples show two iterations, the first a Modified Cheese-Grater Plunger, with rotating axial movements on a linear path, the second a Stranded Elements Informing a Suede Texture.

with a subtractive mold or clay press process. The collection demonstrates two affects that are unique to this process that showcase themselves in the panoply of example panels. The most straight forward example would be the knobbing that would occur due to the build-up of material excavated by a dental bit along a line, the height and diameter of which would be proportionate to the length of the line. (Figure 4)

This effect, akin to plowing a street full of snow, provided the most fertile set of aesthetics to pursue, which created a rusticated textural appearance that at the architectural scale calls mind to what George Wagner observed in Paul Rudolph's architecture, a "...corduroy finish of hammered concrete[3]." In other cases, the two techniques of stamping imprints and dental pushes were intermixed, wherein one textural element would effectively erase or supersedes the other. In these studies, the clay becomes a palimpsest of procedures, telling a narrative of its own creation (Figure 8). It may be argued that this affect of clay which presents itself within its found unfinished process, could be a renaissance of the principles registered in initial Brutalist Architecture for which the concept of 'as found' was seminal. "Any discussion of brutalism will miss the point ifi it does not take into account bruatlism's attempt to be objective about reality[4]." In this way, one could argue that the absence of extracting the 'knobs' and letting these harden through the fireing process and perhaps fall off over time once fastened to a facade system embraces the brutal process of its own found making. In other senses of Brutalism, this process allows the clay to demonstrate what it truly is. While many applications of contemporary terracotta, utilize the material as a plasticized simulation of more historicized forms which have been translated from stone into pre-cast, the knobs celebrate the material's ability unlike concrete to be create cantilevered peaks.

Figure 5. Knobbing Aesthetic creating pronounced textural panels, as observed across collection of the Tile Invetsigations photographed on a ceramic tile courtyard.

In some cases, the process hides its own tale, wherein an unevenness is produced based on oversaturation of an effector such as a comb, an effect which may be exaggerated by the clay itself beginning with a subtle topography. In other cases, there was evidence of the potential for an examination of the process towards figurative decoration through an encoding of the combination of press and scraping to inform a floral scene that informs a pre-procedural aesthetic akin to the work of the Viennese secession due to its textural use of applied ornament (Figure 5).

CONCLUSIONS

Notably the differences between subtraction and the displaced material registers in a sensorial level in the production of the finished architectural ornament. Unlike the methods of removal and subtraction which lend themselves to graphic high contrast legibility, these procedures of displacing material broaden the architectural aesthetic interests into a haptic and tactile quality due to the visible and integral texture that is embodied in the procedure. Further studies in this process, are anticipated in relationship to investigating the full capacity of the robot's ability to work with carved and displaced wet clay. A next step of this research would investigate the pressing and displacing of material in the round, surrounding cylindrical bodies such as columns as a means of investigating how the gravity can contribute to the formation of integral strands promoting more textural elements. As a production of ornament, next phases of the work, would also consider the performance of this material for its ability to both collect and be resilient to water as a part of an integral rainscreen sequence, as well as to examine the displacement as an act of making solar shading elements for arid climates, providing visible light and aperture through the topology of the surface.

ENDNOTES

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