Erratic

The Material Simulacra of Pliable Surfaces

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This paper examines how designers can invigorate designs with a sense of liveliness and indeterminacy through manipulation of pliable materials. Two approaches to material manipulation are defined and juxtaposed in the paper: The control associated with Frei Otto's elegantly tensioned membranes and the noise associated with Sigurd Lewerentz's intensely material brick walls. These historical approaches become pertinent in relation to current opportunities offered by material simulation software in architecture. Simulation may be used to increase control over the materialization of design, but is at the same time a way to introduce the noise of real-time, real-world experiments into digital design. The paper presents this discussion in parallel with documentation of the research project 'Erratic', a recent installation carried out by the authors' practice Norell/Rodhe. Constructed from polyurethane cold foam, the project combines analogue experiments with digital simulations to target architectural qualities like mass, figuration and relief.

Keywords: *Control, Material manipulation, Material simulation, Noise, Pliable surfaces*

INTRODUCTION

The dynamic nature of materials can provide a starting point for architectural design. Current approaches to material manipulation in architecture seem to fall squarely into two distinct categories. Materials are either considered useful in the design process because they can exhibit computational behaviour, or, alternatively, because their nonlinear behaviour and materiality can challenge the formal control and smoothness associated with digital design practice at large (Carpo 2012). In addition, digital material simulation increasingly offers the designer the opportunity to manipulate dynamic materials "live" within the computer (Carpo 2014). Simulations present new disciplinary challenges as certain aspects of real-world experiments with materials may cross the border between analogue and digital design mediums. This paper presents a research enquiry into the nature of these issues in digital design through the installation *Erratic*, a project carried out by our practice Norell/Rodhe. The project playfully explores the tension between geometrical control and materials that behave erratically (Figure 1). It positions the material simulacra - the images of materiality - that digital simulation can produce as a "real" materiality with architectural implications beyond structural engineering.

Figure 1
Erratic installation at the Aalto University Digital Design Laboratory, Helsinki, 2013.

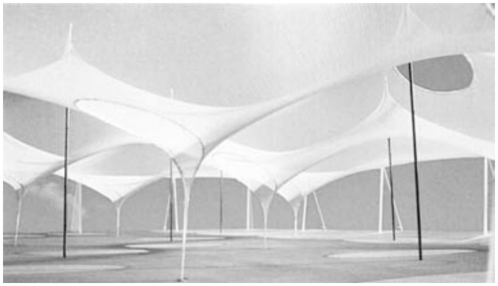


Figure 2
Form-finding study for the German Pavilion at Expo 1967 in Montreal (1965) by Atelier Frei Otto with Larry Medlin. Photograph by Atelier Frei Otto.

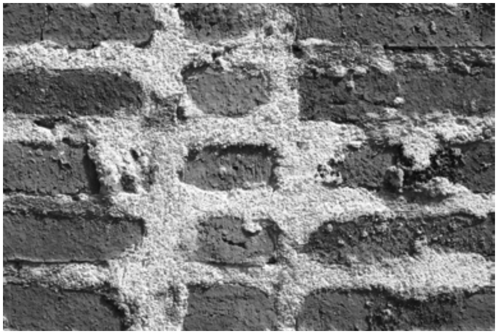


Figure 3
Brick wall detail, St Mark's Church (1960) by Sigurd Lewerentz. Photograph by authors.

MATERIAL MANIPULATION: CONTROL VS. NOISE

Two distinct approaches to material manipulation are of particular importance to this paper. The first approach is best exemplified by the form-finding techniques used by Frei Otto. Otto conceived of several projects such as the German Pavilion at the 1967 Montreal World Fair by using models in which stretched membranes created elegant forms that were in pure tension (Figure 2). The resulting geometry could subsequently be accurately translated into a cable net construction (Otto & Rasch 2006, p. 93-99). In this approach, the architect effectively gains geometrical control of form by manipulating a material surface informed by forces or other external influences. The second approach is no less common, but perhaps less talked about. It typically involves custom designed manufacturing processes that intentionally let go of geometrical control. By amplifying and partially controlling by-products that may arise in real-time interaction between materials, machines, environments and craftsmen, the architect can produce new material sensibilities. Sigurd Lewerentz, in his design for St. Mark's church in Stockholm, Sweden, devised a predecessor to such contemporary processes (Figure 3). The bricklayers on the building site were instructed to only use whole, uncut bricks and unusually thick mortar joints to absorb any variations in the construction. This inevitably created a lot of excess mortar that was smeared over the brickwork instead of being removed, creating an ambiguous conglomerate of bricks and mortar with an intense materiality (eds Flora, Giardello & Postiglione 2002, p. 310-331).

Although different in many respects, what these two examples have in common is their reliance on manipulation of materials. In the first approach, the aim is geometrical exactitude and translatability. The opposite is true for the second approach, where the aim is to add noise by introducing something that cannot be reduced to exact geometries. While Lewerentz did represent each individual brick in drawings, he did not attempt to draw the smeared mortar, something that would have been difficult and redundant. Instead, he designed the material process behind it.

The idea that material processes may add a sense of indeterminacy to conventional digital design processes has recently been under some debate. In an essay titled "Digital Darwinism: Mass Collaboration, Form-Finding, and The Dissolution of Authorship", Mario Carpo notes that many of today's digital designers are keen to let go of control as long as it can be attributed to nature itself (Carpo 2012, p. 99). In his reading, the devolution of agency to a material may simply be a revival of old ideas of emergence and vitalism. Our interest in control and noise does however not lie in authorship, but in the translation from representation to materialized design. Noise, in this context, might be defined as anything that distorts an exact translation. Lewerentz's brick wall is arguably no less intentionally designed than a regular brick wall - in fact the opposite is probably true. Rather, it is an example of how architects may deal with noise and inexactitude as an approach to design.

As this research deals with manipulation of materials rather than pure forms, it is important to distinguish between forms that can be reduced to exact geometries and those that cannot. Exact forms, as described by Greg Lynn, are those that can be reduced eidetically (Lynn 1993). A sphere, for instance, is exact because it is ideal - it is exact in measure and contour, visually fixed, and identically repeatable. Inexact forms, on the other hand, are those that cannot be reduced because their contours cannot be described. They are non-ideal, impure, vague and amorphous. Anexact forms, finally, are those that can be locally described geometrically, but cannot be wholly reduced to an exact form. A traditional way of dealing with inexact forms in architecture is to describe the material process in a set of instructions - push, pull, smear, pour, mix, brush, etc. - rather than to provide a geometrical description. This is what Lewerentz did, and it is what many architects still do as most standard digital fabrication processes can materialize anexact forms, but are unable to handle inexact forms.

THE DYNAMICS OF EXCESS MATERIAL

Since its inception in 2012, our practice has investigated material processes that negotiate between noise and control throughout a number of works. Beyond process and translation, this interest of ours is simultaneously a pursuit of formal and material sensibilities. Dynamic material processes can target qualities like figuration, relief and texture in novel ways. As in form finding, these qualities come about when materials are subjected to forces and influences, but the objective is not limited to finding optimal structural forms. In our view, materials may also be deliberately manipulated to other, more qualitative ends, such as lending character and idiosyncrasy to architecture and design.

After an invitation from ADD, The Aalto University Digital Design Laboratory in Helsinki, Finland, we decided to develop *Erratic*, an installation that would concretize some of these ideas. The research for Erratic began in 2012 with a series of analogue studies based on a sewing technique known as furrowing. In furrowing, fabric is gathered and point wise constrained to a foundation stay, creating a deep relief of swirling grooves (Wolff 1996, p. 9). Two specific aspects of furrowing seemed particularly relevant to us. Firstly, it is a technique that is based on the dynamics of excess material as opposed to the minimum of material associated with form-finding techniques like catenary curves and minimal surface membranes. Though computational in nature, it regularly produces formal features that are inconsistent with the logics of form-finding, like creases, wrinkles and buckles. Secondly, it produces an abundance of noisy materiality (the meandering surface) with a minimum of geometrical input (the precise position of each constraining point).

In Erratic we decided to constrain the surface to an underlying point grid instead of the foundation stay that is commonly used in furrowing. This means that the surface can bend inwards or outwards between each constraining point and that there is not a single optimal state for any given configuration of points (Figure 4). Consequently, the surface will not necessarily be organized the same way if an experiment is repeated. Minor asymmetries in the experiment will determine the result (Figure ref.). In order to move beyond the scale of garments, our experiments with furrowing focused on materials with a high bending stiffness, like felt and polyurethane cold foam. These materials are pliable - they are supple enough to be bent repeatedly without breaking, but they are not particularly elastic (Figure 5).

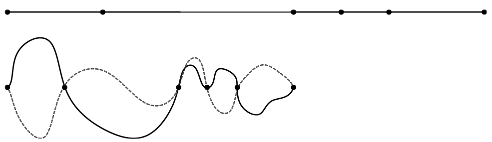


Figure 4
Diagrammatic sections showing variable results of constraining process.

Figure 5
Partial mock-up for Erratic installation using polyurethane cold foam, scale 1:1.

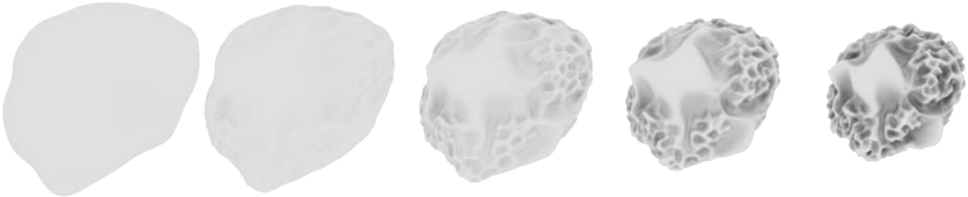
MATERIAL SIMULATION: FROM SURFACE TO CHUNK

In architecture, the use of digital geometry to model the range of curvatures associated with textile materials has often been suspended altogether in favour of analogue models. The reasons for this are plentiful. NURBS surfaces might suffice to describe geometry locally, but it is generally difficult to maintain continuity across adjacent surface patches. Subdivision surface algorithms solve this issue since they provide simultaneous control of several surface patches, but their logic of refinement is largely at odds with the logic of manipulating actual fabric. Adding a detail, like a wrinkle, to a subdivision surface essentially increases its area and resolution locally. Manipulating a piece of non-elastic fabric in a similar way is fundamentally different in that no material is ever added, it is just redistributed by means of pushing, pulling and constraining. The surface area stays constant no matter how much articulation is added to the piece.

In turning our furrowing experiments into a full-scale installation, it had increasingly become clear that scale models and mock-ups were too time consuming to work with for the purposes of designing a complete piece. Further, there was a need to quantify and describe the project to fabricators and collaborators. Knowing the pitfalls of both NURBS and subdivision surfaces, we instead looked to digital simulation of materials.

Material simulation is increasingly becoming common practice in various fields, ranging from chemistry and structural engineering to character animation. For the development of Erratic, we opted to use a particle-spring based software for simulation of textile behavior. Here, each edge in a dense mesh acts as a spring of (more or less) fixed length, much like a stitch in a piece of fabric. Points in the mesh can be moved and constrained, much like in the process of furrowing. This presents significant change in how a pliable surface can be conceptualized in the computer. To a certain extent, it makes it possible to work with digital geometry as if it was a finite chunk of material rather than an infinitely extendable surface. Design can happen "live" as the chunk can be manipulated in real-time. This meant that we could sustain a similar design process across analogue and digital design mediums, rather than relying on a simplified geometric description in the digital realm. Within current digital design practice, this

Figure 6
Snapshots from digitally simulated constraining process: A spheroid mesh constrained in 200+ points.



has been described as a shift from form defined by pure mathematical objects, to form guided by material structure (Carpo 2014).

In order to match the nature of our furrowing experiments, parameters in the simulation software like bend, stretch and compression resistance, were adjusted towards a pliable material that produced smooth, swelling curvatures as a result of the constraining process. For several reasons, we decided to work with a closed spheroid as a starting point. A closed surface reads as a solid and creates an ambiguity since it does not reveal its thickness. More importantly, when inserted into a space, a solid becomes a freestanding object rather than a semi-flat surface that works as a floor, wall or ceiling. This provides an opportunity to extend its architectural qualities from texture and relief to figural massing. Given these preferences, we devised a basic design process. An irregular topological volume - essentially a sack - was constrained in hundreds of points that were pulled towards the centre (Figure 6). Design decisions lay in which points to select on the one hand, and the precise definition of material characteristics on the other hand. Points were selected in zones based on a script that targeted surface curvature in order to expedite the process and quickly get a diversity of results. A series of design variations was developed inspired by the articulation and massing of erratic blocks. Each erratic was given its own character based on relief, hierarchy, scale and posture. In the form of 3D-printed study models for the installation, these design variations also had a quality all of their own since they reproduced the formal outcome of the constraining process, but suppressed other sensory input such as texture and color (Figure 7).

ERRATIC INSTALLATION

In science, it has become important to distinguish between real-world experiments and simulations aimed at mimicking those experiments (Winsberg 2010). In keeping with this terminology, our analogue studies of furrowing would qualify as experiments and be epistemologically distinct from the digital simulations that we undertook in parallel. Ini-

Figure 7
Elevation and section drawing of digitally simulated Erratic model (left). 3D-printed Erratic study models, created with digital material simulation, 12 x 12 x 12 cm each (right).

tially, this distinction seemed sensible as analogue mock-ups and scale models took precedent over early tests with digital simulation. However, as design work for the installation was increasingly carried out using simulation, the distinction became more ambiguous. Finally, in constructing the actual installation at ADD in Helsinki, both analogue mock-ups and digital models worked as simulations, since neither of them had targeted the exact properties of the material or scale of the piece. Given the nature of the installation, we had anticipated that it would be difficult if not impossible to match simulations to already carried out experiments with exactitude. Instead, we focused on getting a for construction purposes acceptable match by incrementally fine-tuning digital parameters and material properties in parallel. Distinctions between experiment and simulation on one hand and analogue and digital on the other thus became less important as neither took precedent over the other.

The Erratic installation is sited in a double height gallery and café space at ADD. Its roughly fits inside a 2.8 m cube, making it considerably larger than the furniture that surrounds it, but at the same time smaller than a house. The first step in the fine-tuning process was to narrow down our selection of pliable materials in relation to the sizing of the installation. Polyurethane cold foam was chosen for two reasons. It is a strong, lightweight and pliable material that, when constrained, can support itself for large distances. This was crucial, since we wanted to lend the piece a sense of hierarchy by giving its articulation sudden shifts in scale. Further, since polyurethane cold foam is a homogenous and isotropic material, thickness and density could easily be customized in dialogue with our fabricator in order to improve correspondence between digital simulations and analogue experiments.

Another important step was to fine-tune the distribution of constraining points. Based on the simulation studies we decided to gather the constraining points with a global scale factor of 0.625, meaning that a point-to-point distance of 1 on the unconstrained surface became 0.625 when constrained. Less would make the piece look flat and unarticulated, where as a more would risk turning the furrows into folds, something that would visually reveal the surface thickness and remove the ambiguity between surface and solid. A defining feature of many of the early erratic studies we had done was their hierarchy between wildly different densities of constraining points. Some areas were densely gridded and the resulting furrowing read almost as texture in relation to the mass as a whole. Other areas as large as a couple of meters across were left without points, resulting in bulbous protrusions that approached the scale of the piece as a whole. Defining the minimum and maximum distances between two constraining points as well as the thickness and density of the foam was done in relation to these characteristics. The minimum distance between two points has to be able to comfortably fit a wrinkle, i.e. two layers of material. The maximum distance has to be defined in relation to the properties of the foam so that long spans can be managed without unwanted buckling.

The positions of the constraining points had to be matched by an inner armature supporting the piece. Given that visitors would never actually see this armature, we decided to keep its manufacturing rather simple. We found that an irregularly subdivided cube with extension struts of varying length could approximate the location of most constraining points (Figure 8). The cube was constructed from regular lumber, while the extension struts and joints between strut and surface had to be metal in order to handle the violent battle of forces between the two. To emphasize the tension between the rigid armature and the turbulent furrowed surface, these constraining points were not covered or hidden. In a frontal view the observant reader can see how they align into an orthogonal grid, where as they disappear when seen obliquely (Figure 5 & 9).

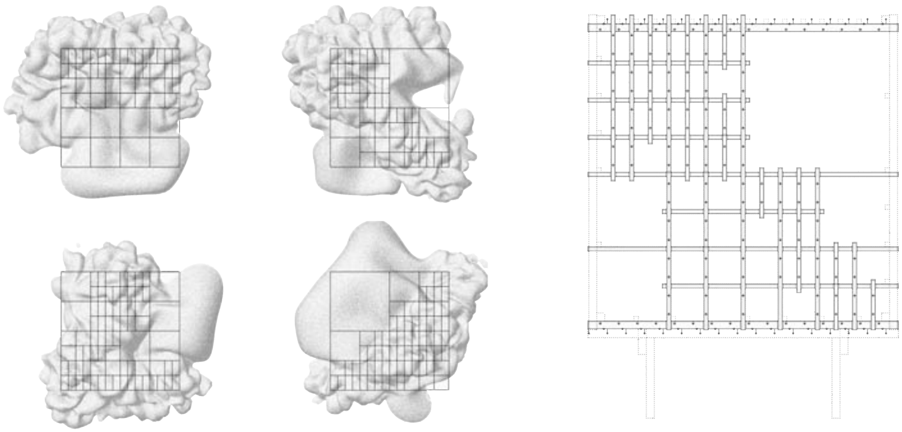


Figure 8
Erratic elevation drawings showing relationship between digitally simulated model and armature (left). Typical elevation of Erratic armature (right).

Figure 9
Close up view of Erratic installation at the Aalto University Digital Design Laboratory, Helsinki, 2013.

Overall, the installation consists of a wooden armature with 200 metal struts connected to a custom designed 50+ kilo, 50 sq m, 30 mm thick sack of expanded polyurethane cold foam. Using ADD's onsite overhead crane the sack was gradually lowered over the armature and connected step by step in order to avoid heavy point loads on singular constraining points (Figure 10). Point-wise constraining the surface to the armature was a scripted operation, where each point on the grid had a numbered counterpart on the surface in order to achieve the desired amount of furrowing. However, there was a lot of room for styling once the surface was connected to the armature. The length of individual struts was gradually fine-tuned to shape larger gestures as well as to remove unwanted concavities. Finally, the porous polyurethane surface was powdered with plaster powder, changing its materiality from yellowish foam into a lustrous white surface akin to the 3D-printed Erratics displayed in the accompanying exhibition (Figure 9).

CONCLUSION

Constraining large-scale pliable surfaces can bring supple and sensuous qualities associated with textile to an architectural scale. Digital simulation prior to construction is likely a necessity in this endeavour, since sheer size prohibits full-scale mock-ups. Pliable materials like polyurethane cold foam present new challenges to designers as they are more flexible than most building materials, but at the same time more rigid than textiles. Further, the use of material simulation software in Erratic suggests that the dynamic nature of these surfaces can be sustained across digital and analogue design mediums. The virtue of the simulated massing studies for the installation was not their local accuracy but the degree to which they

Figure 10
Polyurethane sack lowered over armature and connected to struts.

aided the design of specific characteristics, like posture, hierarchy and relief. Simulation in this context is not necessarily an attempt to increase exactitude and close the gap between digital geometry and materialized design. Instead, it presents an opportunity to introduce aspects of "live" into the digital design process in ways that are consistent with real-time manipulation of an actual chunk of material. Partially a real-time experiment and partially a representation, a simulation is difficult to position in relation to the conventional distinctions between drawing and materialization of design. As in the case of Erratic, the noise of real-world experiments may in this way find its way into architectural representations.

In science, simulations require extended and continuous use in order to gain credentials. Eric Winsberg argues that "Simulation practices have their own lives: They evolve and mature over the course of a long period of use (...)" (2010, p. 45). It is largely still to be seen how we architects can and will incorporate material simulation into our practice as well as into our discipline.

ACKNOWLEDGEMENTS

Erratic was exhibited at The Aalto University Digital Design Laboratory in Helsinki between September 19 and October 17, 2013. The project was developed with funding from the research environment Architecture in the Making at Chalmers University of Technology, Department of Architecture in Gothenburg.

Project Design: Norell/Rodhe. Team: Daniel Norell, Einar Rodhe, Hseng Tai Lintner, Stefan Svedberg, Axel Wolgers. Fabrication: Emballageteknik AB.

REFERENCES

Carpo, M 2012, 'Digital Darwinism: Mass Collaboration, Form-Finding, and The Dissolution of Authorship', *Log*, N/A(26), pp. 97-105

Carpo, M 2014, 'Breaking the Curve: Mario Carpo on Big Data and Design', *Artforum*, 52(6, Feb 2014), pp. 168-173

Flora, N, Giardiello, P and Postiglione, G (eds) 2002, *Sigurd Lewerentz 1885 1975*, Electa Architecture, Milan

Lynn, G 2004 (1993), 'Probable Geometries: The Architecture of Writing in Bodies', in Lachowsky, M and Benzakin, J (eds) 2004 (1993), *Folds, Bodies and Blobs: Collected Essays*, La Lettre Volée, Brussels, pp. 79-94

Otto, F and Rasch, B 2006, *Finding Form: Towards an Architecture of the Minimal*, Axel Menges

Winsberg, E 2010, *Science in the Age of Computer Simulation*, The University of Chicago Press, Chicago and London

Wolff, C 1996, *The Art of Manipulating Fabric*, Krause Publications