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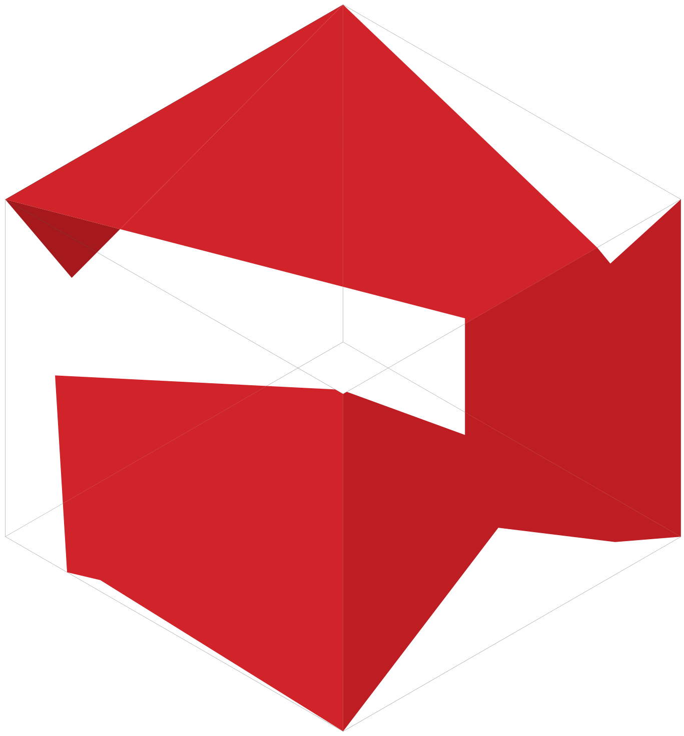

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Textiles: Alternative Forms of Malleability

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Abstract: The simulation of textile behaviour remains a difficult computational problem, often eliminating the nuanced and nonlinear behaviour that contributes to the character of a given textile and its response to deformation through buckling, creasing, and wrinkling. Historically these types of behaviours have been extricated from the discipline of architectural form, because of their unpredictability and lack of control in the design process. The reverse is true of craft and textiles, where material variability is a vital form of expression and identity. This paper will examine how digital tools, in conjunction with textiles, are posing new alternatives for form, structure and expression. It will survey the authors' research using analog textile models in the development of ceramic furniture prototypes. Digital tools are used in parallel with textiles as a means to examine form finding, geometric variation, and plasticity, in the development of structural volumes and surfaces. Methods for reinserting the textile models into the digital workflow, their management in the digital environment using subdivision surface software, and prototyping are discussed.

Keywords: Analog, ceramic, computation, digital, nonlinear, form finding, malleability, membrane, model, plasticity, prototyping, subdivision surface software, textile, craft

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Textiles:
Alternative Forms of Malleability

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Introduction

Materials and textiles can exhibit computational behaviour. Simply, for any given degree of input - such as a force - an output will be generated. This output may differ in kind and degree, such as a wrinkle. During the first half of the 20th century, analog computing involved 'machines using continuous physical phenomena instead of digits to model the problems to solve' and this approach eventually gave way to digital computing (Picon, 2010). There are a wide range of behaviours, effects and topologies that can be produced using textiles. In some instances these phenomena, such as curvature degree, can only be produced at a particular scale and are therefore referred to as being 'scale specific.' In architecture, the analogous use of textiles belongs to three distinct conceptualisations of surface. Firstly, as it relates to structural behaviour - through the use of form finding models to study statics, for example in the work of Frei Otto & Antonio Gaudi. Secondly, as it relates to ornamentation and the geometric development of relief on architectural surfaces, for example in the work of Frank Lloyd Wright and Louis Sullivan. Thirdly, through effect and the transference of material properties such as a material's transparency, plasticity or texture to a larger architectural system, or surface, consisting of many parts or components. These characteristics also persist at the scale of industrial design objects albeit at smaller scales than their architectural counterparts. All of the work referenced here has been investigated at the scale of furniture, with a focus on maximising its performance and size.

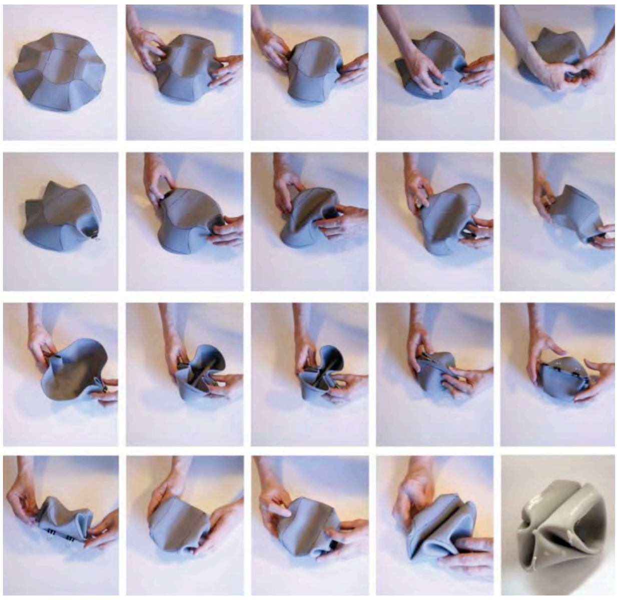
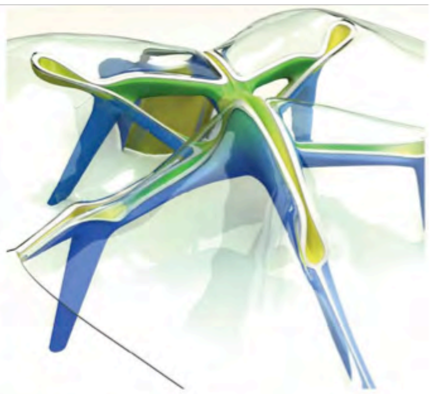


Figure 1. T-Stool, Folding sequence from a flat ellipse to an ellipsoid filled with plaster, Katrin Mueller-Russo, 2008. Photos © *Rhett Russo*

Analog Structural Models Using Folded Membranes

In 2007, we began investigating techniques to cast solids inside folded, waterproof sheets by filling the internal space with plaster[i]. This technique played an instrumental role in the design of *Flabella I*, a table prototype produced for *Project 4* gallery in Washington DC (Figure 8). The formal outcome could be altered through three parameters: the two dimensional outline of the sheet when laid flat - in this case an ellipse; the number and placement of folds in the membrane; and, the disequilibrium initiated by the introduction of the liquid plaster into the volumetric interior of the folded sheet. Initial tests were conducted using varying amounts of water and subsequently plaster (Figure 7). The results were scalar dependent. While the surface outline of the membrane could vary, the plasticity of the material and its thickness remained constant. The nonlinear relationships between these parameters were instrumental in defining the outcome, but the precise role of the membrane on the overall form remained largely indeterminate. There were added benefits with the membrane; it proved easy to modify and to remove from the surface of the cast even in the presence of highly complex curvatures and undercuts. Because the casting process initially produced solids rather than the shells we later developed, it was difficult to qualify the structural properties of the results. For this reason following studies abandoned the use of plaster and focused on the added strength of the sheet as it was folded. This process should not be confused with form finding since the working objective was not to arrive at an optimal structural form. In fact, prior to folding the membrane, we did not know what the form would look like and this resulted in numerous failures that were not stiff enough to hold the liquid. The experiments sought to expose the generative capacity of the material process and record it as a form.



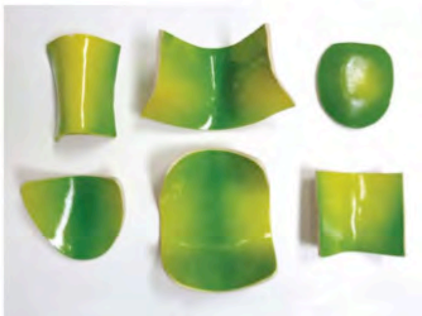


Figure 2 (left). Flabella II. Front right leg component in glazed stoneware, European Ceramic Workcentre, 2010. © *Rhett Russo* / Figure 3 (top right). Flabella II, digital rendering. © *Rhett Russo* / Figure 4 (bottom right). Flabella II, glazed stoneware samples, Rhett Russo, European Ceramic Workcentre, 2010. Photo © *Rhett Russo*

Flabella II - Structural Sheets

A second table prototype, *Flabella II* was also designed using membranes, and was eventually fabricated in stoneware clay, using flexible rubber moulds, at the European Ceramic Workcentre, in 2010, (Figure 6). Unlike *Flabella I,* the plaster casting technique was not used. Because *Flabella II* is a single surface folded back upon itself, it had almost no internal volume and therefore could not contain the liquefied plaster (Figure 10). The design intent of *Flabella II* was to develop its rigidity through the redundancy of the folds introduced into the sheet. As a result, the final piece performs as a continuous structural tube and bears a closer resemblance to the topology of a knot than the folded continuity of a single surface (Figure 5 &10). During the design of *Flabella II*, the sheet model was scanned using a three dimensional scanner and further developed and refined using digital tools (Figure 8). As the design progressed, it became increasingly important to develop the continuous topology of the textile in order to digitally model the topological continuity of the form. Maintaining tangency at every edge between multiple parts was impractical. This was partially due to the introduction of the ceramic process relying on thin shell construction in order to minimise shrinkage cracks and the need to make the piece as lightweight as possible. A fundamental difference emerged between the designs of *Flabella I* and *Flabella II*. The earlier version had developed from a set of forces pushing the textile outward under the presence of the liquid while the latter versions gained stability by folding the textile inward. Each vector introduced an alternative form of malleability into the development of the textile and this played an important role in determining its formal characteristics and stability.

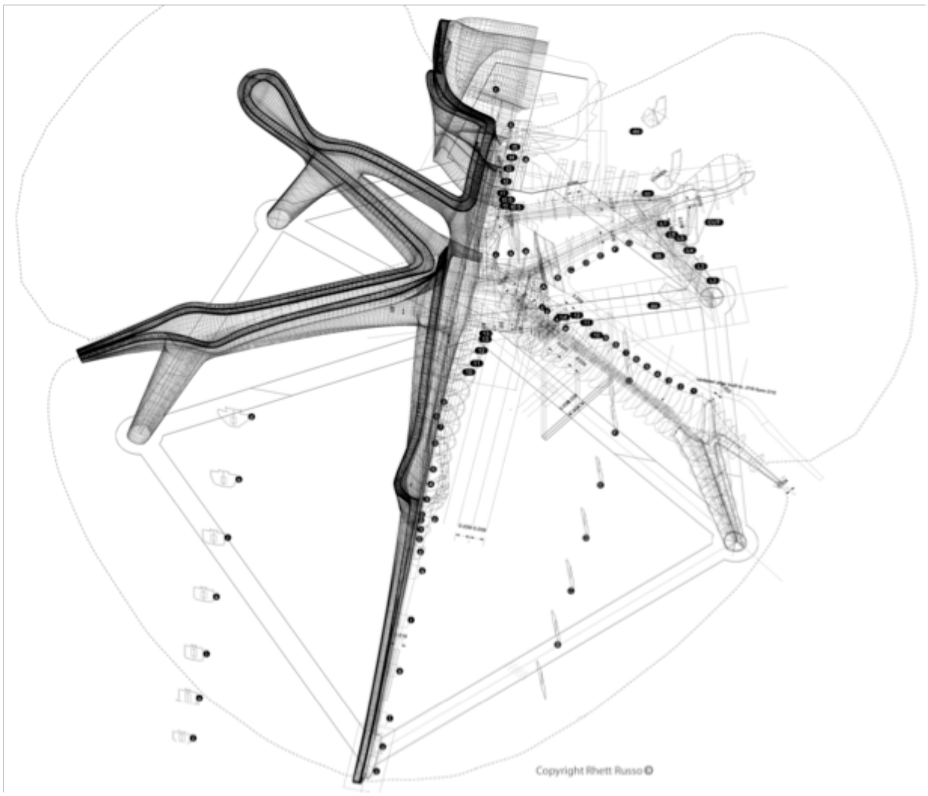


Figure 5. *Flabella II,* Digital three dimensional working model for the ceramic prototype, 2010. © *Rhett Russo*

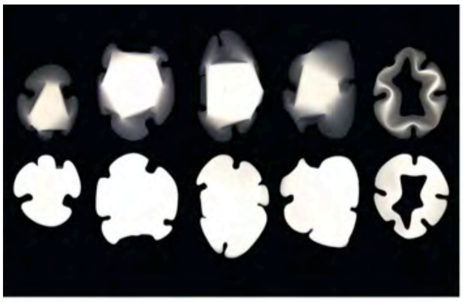
Analog and Digital Craft

Most manufacturing software evolves in response to the particular demands of a material in order to maintain consistency and standardisation. This is inherently at odds with the variability associated with manual forms of craft. In some cases, a given material's curvature cannot be described using rational geometry. It is easy to overlook this aspect of digital tools, but inadequate tools can easily sidetrack the design process. Consequently, many designers have either begun to script their own tools, work with animation software, or prematurely suspend the use of software in favour of physical models. Our focus has been on the later, primarily because we are interested in giving the material as much agency as possible in the design process. This keeps the homogenising effects of any particular software at a safe distance and it allows the design to integrate the inherent limits of the material in question. By situating the analog model as a protagonist to the instrumental bias of the software we are able to continue to apply the tools in new ways, and this kept the variability of the membrane in play.

Figure 6. *Flabella II,* Partial ceramic prototype, European Ceramic Workcentre, 2010.
© Rhett Russo. Photo © Nathan Sayers

The nature of the curvature that is associated with nonwoven sheet material is unique. While these surfaces are remarkably consistent, they proved nearly impossible to draw. While it is possible to replicate some of the curvature with NURBS geometry, the topological continuity of the surface presented challenges to the piecemeal approach of building regions and joining them together. It also became tedious to maintain the tangency across the seams of the digital model. Most of the curvature could not be reduced to an affiliated set of geometric arcs or lines without compromising the plastic character of the model.

Consistency was not only a difficulty with the computer, but it also became an issue while making the model. The textile rarely behaves the same way and, because it is elastic, it can introduce both desirable and undesirable states of buckling. The use of textiles and membranes requires a cataloguing of possible features which are then cultivated in the design process.



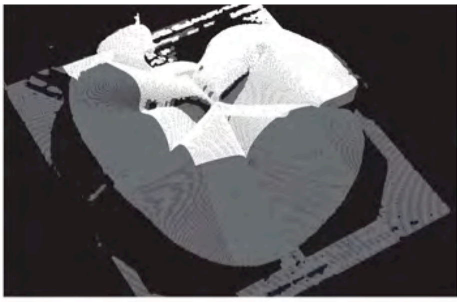


Figure 7 (top left). *Flabella I*, plaster test casts poured into folded mylar sheet, 2007. © *Rhett Russo & Katrin Mueller-Russo* / Figure 8 (bottom left). *Flabella I*, final plaster model cast inside a closed waterproof membrane, tests for Project 4 Gallery, 2007. © *Rhett Russo & Katrin Mueller-Russo* / Figure 9 (top right). *Flabella II*, Three dimensional scan of the sheet model, 2007. © Rhett Russo / Figure 10 (bottom right). *Flabella II* The original model developed from a single folded sheet, prior to scanning, 2007. © *Rhett Russo*

A very concise description of this phenomenon, as it relates to craft and maritime navigation, has been eloquently described by Margaret Cohen:

> The process of knowing is a process of developing 'know how.' Like sailing, craft is a form of 'know how,' in contrast to science and philosophy ('knowing that'). 'Know how' emerges through cunning and 'finding a path through the impasse' ... from the maritime perspective it becomes clear that while metis [cunning] can of course abet domination, its specificity is rather to outsmart superior forces (including nature and foe) that cannot be subdued. (Cohen, 2004 p.76)

To this end, Cohen provides a description of Captain James Cook's ingenious redeployment of his ship's sail underneath the hull as a means to momentarily seal the leaks and free his grounded ship from the Great Barrier Reef. This action is more than technique, it is a novel (alternative) solution, emerging from particular circumstances and 'know how.' In a similar fashion, working with membranes, rather than against, them has been at the core of our research.

Figure 11. T-Stool, Digital rendering of full size ceramic prototype 65cm (w) x 94cm (l) x 48cm (h), 2010.
© Rhett Russo & Katrin Mueller-Russo

The most suitable modelling software to replicate the behaviour of our analog models uses subdivision surface algorithms. It is widely used to model flesh and characters for video games. There are several aspects distinguishing it from the curve based software. It is designed to address the malleability associated with the tone and muscular definition of bodies, and it allows the user to control organic surfaces without using curves. Only surfaces, edges and points are used. Secondly, detail is conceptualised in a new way, by anticipating the computational demands that are inherent to video games, it allows polygons to be added only where they are needed. This results in low polygon counts and it provides a means to efficiently place polygons only in places where there is higher curvature or a need for more detail (Figure 5). For video game designers, subdivision software, represents a new economy for balancing surface detail with speed, but as a design tool, it offers a medium for refining complex topology without breaking the form into pieces or sacrificing continuity. This represents a significant change in approach. Detail is not achieved by adding elements; instead it is a process of parametric refinement to a single topological surface that is closer to the formal characteristics of skin and textiles. As a process it closely resembles the plasticity that is afforded by the analog membrane and its ability to be modulated locally. The similarities associated with modeling the nuances of skin and textiles became increasingly apparent. When it came to placing the polygons it was necessary to anticipate their placement so they can be manufactured using a different machining process. It became clear that this was not only an analog or digital problem. In both environments we relied on similar forms of craft and technique to define the wrinkles, and folds that are native aspects of the analog sheet material.

Singularities: The T-Stool

When conceptualising matter it is hard to imagine how any material process could be considered a singularity. The term singularity as it is used here does not refer to the number of materials, but instead to the distinct behaviours resulting from a single cascade of development. A significant portion of our work with membranes involves casting and forming and has evolved through singular processes. The *Flabella* series represents a significant change in the way we approached the material's agency. We began to develop a more conservative approach towards variation. The character of the form we were after was a malleable response to the pressure of the plaster and the elasticity of the membrane. Our interest stemmed from wanting to achieve a differentiated form through the plastic development of a singularity. While we could not achieve this with the open forms of *Flabella I*, it was eventually achieved in the design of the *T-Stool* (Figure 11). The resulting modularity of the stool is the product of buckling, and folding, a single, two dimensional ellipse (Figure 1). We developed more precise methods for locating the placement of the folds, the tiebacks, to hold the exterior of the surface in place, and knockouts that would keep the internal surfaces separated enough that we could cast between them. Our success with the stool was due largely to the fact that we were able to develop a topological method of folding the membrane inward to produce internal modularity, while offsetting the pressure of the cast.

In designing the *T-Stool,* the singular nature of the surface was developed internally, by folding inward, similar to the way it had with *Flabella II*. The folding of the flat disc presented fewer possible outcomes once we took into account all the demands of the textile during the casting process. The form of the *T-stool* is a complex product of the membrane's surface area, volume, and its elasticity. There was a balance between the convex and concave surfaces that had not been present in the other models. With this balance, its computational behaviour became much more robust. In the process of designing in parallel with the membrane we reached a plateau where the same degree of variability would not only produce nearly identical results, but the textile would not close under another set of folds.

Conclusion

The plastic nature of membranes offers a rich territory for formal exploration. Sheet materials, when put into disequilibrium, can generate remarkable structural and formal consistency. This is more clearly observed when the surfaces are closed volumes, rather than open surfaces. The structural benefits of the closed surface that was observed in the design of the T-Stool, was proven during its fabrication in ceramic. Without its characteristic folds, the realisation of the full scale ceramic stools (102 cm (l) x 60 cm (h) x 79 cm (w); 1.5 cm thick) would not have been achievable. These folds gave the form the capacity to withstand the increased plasticity that occurs during the firing process at 1100-1220 degrees Celsius, thus minimising the amount of deformation and cracking. This suggests that a wide range of alternative solutions employing textiles as topological tools are possible and this behaviour needs to be finely calibrated to the nonlinear behaviour of the material in question. The opportunity for the development of computational tools that can address the topological and generative relationships between area, volume, pressure and elasticity remain an open question for architects and designers to expand upon the dynamic role of material in the design process. Many of the complex relationships which are native to sheet materials and their performance remain open questions in the digital design domain.

Notes

i. It is worth noting that in our research the sheet material used is technically a non-woven, without a bias, and by definition it is not a textile. Throughout this text we refer to the sheet material as a 'membrane' to distin¬guish its plastic behavior from the woven nature of 'textiles'. Throughout the history of architecture the conceptual implications of wovens v. nonwovens has been a considerable source of debate.

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Rhett is an Associate Professor at NJIT, Curriculum Coordinator of the Graduate Architecture programme, and principal of Specific Objects Inc. Rhett's work is inspired by the transmissive capacities of matter and the ecologies of form that are part of the natural world. This approach parallels his interest in alternative modes of craft and its role in the development of complexity within the discipline of architecture. Rhett has received numerous awards including the SOM Fellowship, the Van Alen Institute Dinkeloo Fellow at The American Academy in Rome, and the Young Architect's Award from the Architectural League of New York. In 2009 he was awarded a research residency at the European Ceramic Workcenter. His work and writing have been published in: Second Nature; Meander - Variegating Architecture; Matter - Material Processes in Architectural Production; 306090; and, Metropolis magazine. Rhett was one of five invited architects and designers chosen from the United States to represent the East Coast in the 2010 Beijing Biennale. In 2011, Specific Objects participated in the Suzhou Fast Forward exhibition and the smart textiles exhibition *Ambience 11* in Boras, Sweden.

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In 1997, Katrin founded *Specific Objects Inc.,* an interdisciplinary, sustainability-oriented design practice in New York. Her design experience and collaboration with her partner Rhett Russo allow her to combine product design and architectural services as part of an integrated design approach. Her firm has designed a fair booth for Hamilton watches as part of the Swatch environment in Basel, Switzerland; and a series of commemorative objects for the MoMA store to sell in conjunction with the PS1 Young Architects Programme. Katrin is a Professor at Pratt Institute, and also teaches a Contemporary Furniture Design course at PennDesign. Her work as been exhibited internationally and her awards include the Ideas Competition Design Plus at the Frankfurt International Fair Ambiente for her hearing aid design. In 2007, her prototype for the design of the Flabella table was part of a furniture exhibition at Project 4 Gallery in Washington, DC. With her partner, she was chosen as a finalist for the Newark Visitors Center competition in 2009. Katrin is currently researching and prototyping textile-based applications for earthenware and furniture and was awarded a residency at the European Ceramic Workcentre (.ekwc) in the Netherlands in 2011.