Reconfigurable Molds as Architecture Machines

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In The Architecture Machine (1970), Nicholas Negroponte postulates the development of design machines wherein the “design process, considered as evolutionary, can be presented to a machine, also considered as evolutionary, and a mutual training, resilience, and growth can be developed.” The book, dedicated to “the first machine that can appreciate the gesture,” argues for developing machines with human like qualities. This paper aims to develop an alternative trajectory to the “evolutionary” architecture machine, this time not towards anthropomorphism but responsiveness. The aim on one level is the same: to create machines that appreciate the gesture. However our approach is tied to more modest aims and means that bring current thinking on evolutionary processes and the forming of materials together. The reconfigurable mold (RCM) is an architecture machine that produces parts that can be combined to create more complex organizations. The molds are simple analog computers that employ various continuous scales like volume, weight and heat to develop their unique components. Parametric alterations are made possible by affecting these measures in the process of fabrication. An underlying material that is instrumental in the molds is rubber, whose variable elasticity provides unique possibilities for indexing the gesture that remains elusive for industrial processes.
Introduction

The "architecture machine" was Nicholas Negroponte’s term for a “computer-aided” as opposed to a “computerized”, design tool. I would like to resurrect this term to introduce a set of architectural machines that have been developed at the University at Buffalo that bridge computational processes with material agency. In the process I would also like to reflect on the evolution of the architecture machine from Negroponte’s anthropomorphic inception, to its current machinic manifestation in contemporary digital design and fabrication tools, and propose an additional research trajectory for developing other architecture machines.

To talk about “machines” in 2008 may seem anachronistic in lieu of the “biological” turn in both the sciences and computing. However, the machine had already become biological well before Norbert Weiner’s 1948, *Cybernetics: Or the Control and Communication in the Animal and the Machine*. And so writing in 1970, Negroponte’s invoking of “the architecture machine” is well removed from any mechanistic allusions and instead teetering on pathetic fallacy. It is in this same biological vein that I would like to use the term, however not in its anthropomorphic tendencies, but more in its responsive and generative possibilities. The reconfigurable molds that I will discuss are machines that work off of the principle that wholes must be greater than the sum of their parts. Hence they engage the act of making as an evolutionary process where emergent effects are sought. As architecture machines they take on the problem of designing as a “shaping” of material rather than an instantiation of shapes. They are not representational but full scale prototyping tools that produce parts which are subsequently assembled to make more complex wholes. They address fabrication as dialogue between materials, designer and the contingencies of production and are as much heuristic tools as they are machines for making objects.

The Architecture Machine revisited

Negroponte’s *The Architecture Machine* (1970) and *Soft Architecture Machines* (1975), persuasively argue for computer aided design systems that are “conversant” [Pask, 1969] with the designer. These systems “problem worry” [Anderson, 1966] in addition to “problem solve,” providing the designer with a collaborator rather than a tool. Negroponte envisions such a machine as an artificial intelligence that has a precise predictive model of the designer such that it can read his/her gestures and body language. It “would be so personal that you would not be able to use someone else’s machine...The dialogue would be so intimate—even exclusive—that only mutual persuasion and compromise would bring about ideas, ideas unrealizable by either conversant alone. No doubt, in such a symbiosis it would not be solely the human designer who would decide when the machine is relevant.” [Negroponte, 1970, p.13] This suggests a machine capable of some form of reasoning not necessarily available to the designer. As such the Architecture Machine, upper case as it would surely be a proper noun, would be capable of making decisions contrary to those
of the designer so that it is not simply a means to carry out the designer’s will but potentially capable of exerting its own subjectivity into the mix. Negroponte, recognizing the potential anthropomorphism of his proposal and the objections it would elicit, clarifies that it should not be understood as a separate entity from the designer but a “symbiotic” system which could provide “reciprocal ripening of ideas and ways.” Invoking cybernetician Gordon Pask, famous for his Conversation Theory and work on human-machine learning systems [Pask, 1975 and 1976], he clarifies, “Eventually, a separation of the parts could not happen: “The entire ‘symbiotic’ system is an artificial intelligence that cannot be partitioned” (Pask, 1964).

Fast forward thirty-five year to Schodek, Bechthold, Griggs, Kao and Steinberg’s Digital Design and Manufacturing: CAD/CAM Applications in Architecture and Design (2004), and our current invocation of the architecture machine, lower case now. Such a machine is composed of discrete parts: a computer-aided design (CAD) system for modeling and analysis, a computer-aided manufacturing (CAM) system for controlling the machines that will manufacture the model and a computer numerically controlled (CNC) system that translates these instructions into machine operations. In such a machine the authors tell us: “The final shapes will have to be exactly defined a priori. Machines must be told exactly what to do, which in turn means that it is necessary for the designer to exactly specify the complex shape... in a numerically based language that the machine control system can understand.” [Schodek et al, 2004, p. 8] While not completely reducing the tool to mindless mechanization, Schodek et al. take a pragmatic view on the architecture machine and highlight how multiple levels of automation can provide smooth transition from design conception to fabrication. Their invocation of machinic efficiency, which includes communicating on the machine’s term through its universal machine language, recognizes the efficacy of a generic platform—with a language and techniques of its own—through which multiple experts can participate and collaborate on a design. This is in stark contrast to Negroponte’s designer specific Architecture Machine.

In Negroponte’s formulation, “computer-aided design” involves a dialogue between computer and user in the process of designing, while “computerized design” refers to the use of computing for its automation and calculative possibilities. This distinction highlights two qualities of computing tools that have been part of computer aided design from the beginning: interactivity vs. automation. Their difference can be highlighted is the way in which “information” is produced by either method. In interactive systems information is dynamically constructed through feedback between designer and computer, while in automated systems it is the product of algorithmic tasks performed by the computer on representations. Both suggest generative processes except that they are different; in interaction complexity is emulated whereas in automation it is simulated. Both emulation and simulation are forms of imitation, except that in the former it is achieved through actions in the real world while in the latter it occurs on models or representations of the world stored in the computer’s memory. Architecture Machines exhibit both these qualities in different measures. For the Architecture Machine computation is a means for more idiosyncratic engagement while for the architecture machine it is to facilitate increased participation by
multiple users. Where the first flirts with anthropomorphism, the latter has instituted an acceptable mechanization. Rather than take sides on this disjunction I would instead like to use them as extremes of a gradient within which we can imagine many architecture machines that engage interaction/automation in different proportions. To this we can add other oppositions like idiosyncratic/generic and iterative/recursive. Iterative/recursive refers to the way information enters the system. In an iterative computation information is added to the function in time whereas in a recursive system the information is self-generated from within the function itself. Another way to describe this would be that in iteration the system is open to the contingencies of its context, allowing new information to enter it in time. In recursion the system is closed to the outside and self-computes acting on its internal organization. It is within these associative gradients that I would like to situate our work with elastomers and reconfigurable molds.

3 Reconfigurable molds

Reconfigurable molds (RCMs) have the capacity to be reshaped to produce a controlled variety of products. A key component of all the molds that I will discuss is rubber, either as the molded or the molding material. Rubber’s unique property of varying elasticity plays a critical role in our concept of shaping. This is quite different from the way in which a rubber mold is usually used where elasticity is simply a means to provide enough flex for the mold to release itself from the molded object. In our case elasticity (mold or molded) has far more agency in the forming of materials and space. Molds occupy a liminal stage between formal conception and object materialization. In conventional molds the relationship between object to mold is spatially indexical, that is that there is a direct linear correlation between the mold and its product. This is understood as a mapping of negative (mold) to positive (object). However, in the history of automation there are examples of “molds” that don’t follow this directive and instead exhibit more non-linear capacities. A good example is Joseph-Marie Jacquard’s 1801 mechanical loom that used punch cards to control the weaving of fabric patterns. The holes in the cards corresponded to a “bolus” hook which would either raise or lower the warp thread that in turn determined whether the weft thread lay above or below the weave. The punch card offers an example of a mold that has
Reconfigurable molds, as architectural machines, are fabrication tools for making parts that can be combined into larger architectural assemblies of columns, walls and surfaces. They engage interactivity and automation in different proportions. I will describe four molds, the RCM-J, RCM-D, RCM-C and RCM-T and their products. These will be discussed further in light of their affiliation with the interactive/automation and associative gradients.

### 3.1 Passive Reconfigurable Molds

The reconfigurable mold J (RCM-J) (Figure 1) was designed to produce linear components made from urethane elastomer composites of two different Shore hardness. Our experiments with fusing elastomers had found that we could get varying elastic performances from the same sized object simply by altering its hard to soft rubber composition. The RCM-J positions and repositions 18 aluminum rods to consecutively produce different cavities for hard (80 Shore) followed by soft (40 Shore) rubber pours. The two rubbers fuse overnight to make a single component which when combined with other similar types can develop more complex objects like the columnar structure that we have designed (Figure 2). The RCM-J is capable of producing a tremendous variety because of all the parametric variation—length, pattern and hard/soft ratio—that it can control. The single mold produces all the parts that we need. Of the four I will describe it is the most mechanistic, in that at any stage of the fabrication process it can give us precise feedback of measurements (rubber quantities and dimensions) as well as produce identical repeatable products.

The reconfigurable mold D (RCM-D) (Figure 3) was designed to produce a weaving of hard and soft rubbers that would be combined to produce a screen. Conceived as a series of bar codes the templates of the mold are consecutively added to produce cavities within which alternating hard (80 Shore) and soft (40 Shore) rubber layers are poured. Like lasagna, the layers are built until the desired thickness is reached. When the rubber is removed from the mold and hung as a screen, gravity’s effect on the patterned pours creates variable morphologies and transparencies. The RCM-D is the closest in concept to the Jacquard loom but here the punch cards are not just instructions but the mold itself. While not a weaving it amounts to a recursive process in which different patterns derived from a more generic pattern can be processed on the fly (Figure 4). This temporal mode of production creates a unique engagement with the material and its ultimate shaping.

The two molds that I have described derive their generative possibilities from the mutability of their mechanisms. The “18 rod” or the “bar code” have enough geometric variation to instantiate patterns, which when coupled with other parameters like elastomer hardness can produce a large number of unique products. On our gradient, these molds rest closer to the automation/recursive/generic pole. They produce parts that are precisely repeatable with consistent accuracy while requiring no other input besides their own mechanism to produce all the variations. However, in the RCM-J the parts can be produced in any sequence, while in the RCM-D precise sequential pours are consequential. In the former the production is more generic, modularized and repetitive, while in the latter it is more idiosyncratic and contingent on the user’s ability and inclination to carry out a particular set of patterns. Their products are combined to make very complex larger wholes (Figure 5 and 6).

### 3.2 Active Reconfigurable Molds

James Brucz’s reconfigurable mold C (RCM-C) (Figure 7) takes on the idea of form-finding as a calibration of quantity, weight, elasticity and orientation. Inspired by Gaudi, Otto and Eisler’s catenary strategies, it re-imagines the idea of natural curvature in a uniform cord due to weight by introducing elasticity to the equation. As such, the mold, suspended between two points, stretches in direct response to the weight of the fiber reinforced concrete that it will shape. Changing the amount of concrete or the location of the hanging control points changes the mold’s shape and consequently that of the material (Figure 8). These relationships can be tuned in different ways to produce a large variety of conic (hyperbolic,
parabolic, elliptic) components which are sequentially cast one after the other. The entire assembly is the result of an iterative computation where the previous product becomes a formal input to the subsequent pour. The fabricator has considerable control on the fly to change directions based upon contextual conditions. In this way the mold is reflexive to its situation and the fabricator’s desires.

Nicholas Bruscia’s reconfigurable mold T (RCM-T) (Figure 9) takes the idea of reflexivity one step further. Similar to Brucz’s RCM-C in that the rubber mold is re-shapeable, Bruscia devises a system in which the heat produced by the curing molded material, is fed into a generative algorithm that controls a series of servos which in turn shape the molds. In this case shaping is understood as a network of relations, where the contingencies of the process—material heat, pour sequence, time—are fed back into the shaping process such that the final form cannot be deduced to the actions of any particular parameter. Also, by passing these inputs into a generative algorithm, the RCM-T opens the recursive processes of algorithms to the unique inputs of the situation. It is sensitive to information that would otherwise be irrelevant or would be simplified in order to make its production more generic. With the RCM-T each product becomes in a post-human sense authentic.

Both the RCM-C and RCM-T occupy gradients closer to the interactive/iterative/idiosyncratic pole. They are more open to the contingencies of their actual production, interacting with the shifting desires of their users and the environmental factors of their context. Information comes from outside the system to generate unique and idiosyncratic possibilities that are not repeatable (Figures 11 and 12).

4 Conclusion

Negroponte’s last chapter in Soft Architecture Machines, “Intelligent Environments”, postulates the “distant” future of the architecture machine, where “they won’t help us design; instead, we will live in them.” A key part of this is the way in which materials take on increased agency in the shaping of architecture and the spaces it encloses. Negroponte notes two strategies for material responsiveness that are made possible by computation—“softs” and “cyclics”. Softs refer to building materials that are mutable to shaping and can retain memory of past forms which can be recalled for present conditions. Cyclics deal with the ability of materials to continually assemble and disassemble as they do in nature. These ideas are incredibly prescient thirty-three years later as we contemplate more efficacious ways to deal with our limited material resources. Our work on RCMs argues that a first step involves the way in which we form architecture’s basic building blocks. Rather than continue to invoke the “industrial” architecture machines that produce “sameness through repetition, amortization through duplication,” our alternative suggests more responsive architecture machines that produce customizable and reflexive products. In addition, we are not interested proscribing a best practice as that is relative and unproductive. In contrast, we would rather present a gradient of possible qualities which such machines could emulate as they search for their own performative relevance.

5 References


