Bio-Computational Manufacturing: Social Prognosis for Ecological Response

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1. CONTEXT:

> *"...housing, fashion and food still tend to constitute autonomous subsystems, closed off from one another. Each of them appears to present as great a diversity as the old modes of living in the pre-modern era. This diversity is only apparent. It is only arranged. Once the dominant forces making it possible for these elements to combine with one another become understood, the artificial mechanism of their grouping is recognized and the fatuousness of their diversity becomes intolerable. The system breaks down."*
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> —Henri Lefebvre, 1972[2]

The ever-expanding web of systematizing forces in global culture has produced one of the poignant enigmas of modernity: how to machinically extend the means of production without creating independent, totalizing systems. How does the product escape the mechanism? Prior to the industrial era, the making of architecture and urbanism constituted the principal arena for technological innovation across cultures. As it concretized the organizing effects of social relationships, the built environment infused the collective body politic with its energetic and symbolic identity. With the advent of manufacturing, the center of gravity steadily shifted toward the instrumental creation and fulfillment of increasingly specialized niches of consumption whose relationship to place and notions of permanence quickly evaporated. With a spiraling exclusivity of the ownership and means of production in late capitalist culture, these pockets have become increasingly divested of connection to cohesively negotiated goals for material culture.

Throughout the twentieth century, despite the early euphoria induced by the social possibilities suggested in mass production, architects consistently failed to fully implicate themselves in the development and culture of material innovation in manufacturing, save for a few stellar exceptions such as the Eames collaboration. Whether or not it was an inevitable rift, this growing lack of engagement on the part of architects with the industrial/corporate engines of technological innovation exacerbated their marginalization from social and political agency within the ascendant 'economy of making', which continued to diverge from the phenomenon of the one-off.

Increasingly spurred by corporate interests, institutional pedagogy in technology began to reorganize around these specialized niches, in an attempt at a theoretically infinite vertical extension of *disciplined* knowledge bases. These instrumentalized bases were initially facilitated by constricting their parameters into an intensely codified and negotiated linguistic structure. Architecture took a different tack. Excluded from the scope of this vertical specialization by an intrinsically composited social condition, architectural education[3] became disengaged from the notion of prescribed technique, and instead often focused on exploratory and singular experimentation. Although it may not be productive to polarize these tendencies, they are both late modern manifestations of a condition that has led to the increasing disjunction of design culture from technological innovation, with the concomitant material poverty of much of the current built environment, as well as its contribution to the degradation of natural context. Ironically, it may actually be in the cohesive visualization of complex information management (of multiple disciplines working at multiple scales) through computing that architecture has its most important reemergence as an administrative social force.

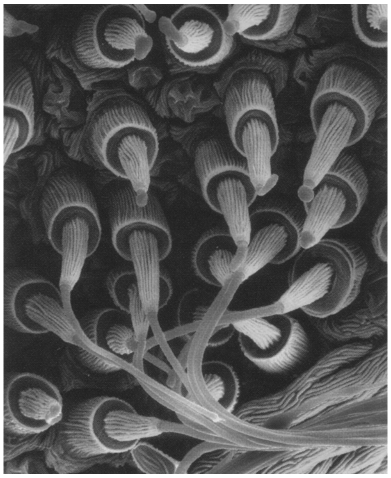

Fig. 1. Cultivated strands of high strength spider silk.

The fact that the massive loss of diversity in existing life forms is concurrent with the relentless efforts of the emerging *biotech* industrial matrix to crack the 'codes' for animate existence has become a prevalent emblematic irony. Likewise, within the design community, along with much of the ongoing fascination with complexity theory and its tenuous coexistence with extensive experiments in computer generated biomorphic form, there has been sparse dialogue concerning the information contained or produced within these alleged *datascapes*. Buoyed by the codified boundaries of the software, they are still characteristic of technological paradigms that have tended to treat available information with *objectivity*, with the expectation of being able to process and re-pattern information into a coherent problem set with any complicating information removed to afford a more comfortably legible or literal document. Coinciding with other vestigial notions from the mechanical age, the will to deploy technology in a linear and reductive sense seems to become all the more urgent the more technology threatens to slip from 'user' control.

2. MANAGING INFORMATION INTENSIFICATION:

Unlike the simplistic connotations that permeate much of contemporary 'environmental' rhetoric, the organizational mobilization required to effect a truly alternative mode of existence implies a complex engagement of communities and specialists in a context of information intensification.[4] However, if as designers we are to address the complexity of environmental ecology, which is a theoretically infinite series of interdependent scales, then our current notions of vertical control over information (or completed cartographies[5]) must give way to a different procedural posture of multiple but situated maps and diagrams, a series of partial engagements. These documents cannot be indeterminate, but should at least embody locally co-determinate decision making which, by intrinsically acknowledging its partiality, remains tractable and pliant. That is, in order to participate in the development of 'bio-compatible'[6] environments, design practice must be able to incorporate and respond to 'problematizing' information from multiple disciplines (that work at potentially vastly differing scales, from the material to the geologic) from the *outset* of the design process. Granted, there is currently no viable economic structure in place for such an exchange and subsequently reverberant iterative process to take place within architectural practice. However, with corporate engines in the materials (3M) and automotive industries (BMW) being in a more realistic position to recognize and reap the benefits of a (zero waste) metabolic material cycle within their own massive operations, they are at the forefront of an emerging paradigm shift that engages computational manufacturing procedures to imbed increasing degrees of material and temporal flexibility into the production of designed objects. It is ironic that the various computer-aided processes that architects are currently engaging to regain 'vertical' control over the means of production through customized manufacturing, would also be the ones that may allow for the relinquishing of singular subjectivities into a more truly collaborative product. The biggest challenge then, is how to design within, manage and communicate multiple complex data sets, whereby partial and problematic criteria must not be excluded in an evolving design process. As computational processes evolve to accommodate responsive adaptation between shared files, how do we adjust our current notions of 'control' in order to gain the real power to adapt?

3. *SHIFT:* FROM A 'THROUGHPUT' ECONOMY TO A 'METABOLIC' MATERIAL CYCLE:

The practiced development of such situated mappings within a professional design context is difficult enough to imagine, let alone a full-scale material implementation *open to reassessment*; that is, designed for disassembly and recombination. Yet within the nascent international movement of *Industrial Ecology,* the development of recoded imperatives is already enforcing a paradigmatic shift away from the linear 'throughput' economy of materials (extract, heat, beat, treat, and discard) to a cyclical or 'closed-loop' metabolic economy (designed for reuse within the same or corresponding manufacturing procedures).

In a metabolic material cycle, in contrast to a throughput economy, one is required to engage rather than objectify material because the considerations of its immediate application and expendability must be expanded to include its re-adaptation into another economy. The design therefore becomes responsive to a mutating context, one that is not necessarily dictated and is more difficult to anticipate. The complexity of this task could require levels of computational analysis that are currently not embedded into most design processes. Unfortunately, even the necessity for the integration of material performance data into drawing software has been very slow to be recognized, leading the focus of generative computer aided design toward formal experiment that is devoid of layers containing behavioral data that can be cross-referenced across scales. Which leads us to the current crux of necessary development: aspects of adaptability must be embedded into the material performance itself.

Putting aside the make-do strategies of ironic disengagement that have enabled the design community to rationalize its role in the implementation of a material culture from which it is increasingly disenfranchised, if our economy of planned obsolescence can give way to an even more 'productive' paradigm of biotechnology as a strategy for accumulation[7], then we have to recognize the extremely reductive barbarism of accepted technological ecologies that resemble much more closely the immature first phase of an opportunistic ecosystem. (For example, being able to shift from the tired fantasy of expendability of a throwaway society that delivered us such material innovations as *Drivet*™, and instead working with a self-healing material version that has sentient intelligence and a snap-to fit that affords recombination by its very behavior) Ecosystems can be divided into 4 phases: the first type is opportunistic, rapid growth, non-diverse, and migrating — a meadow full of weeds after a fire; the second and third type strive toward complexification and diversity; the fourth type is a mature fully diverse self-sufficient system with no waste and only solar energy imported — a redwood forest

4. CULTIVATING A BIO-ADAPTIVE MATERIAL ECONOMY:

Smart materials embody the radical transformation shifting our fundamental technologies from a mechanical paradigm deploying *structural* materials like steel that guarantee operational 'stability', toward a responsive one that deploys miniaturized machinic processes into *functional* materials that are designed at the molecular scale to transform themselves in response to various stimuli. From within a mechanistic value structure that sought to exploit and process materials for strictly objective purposes, any change in a material's properties (its elasticity or volume) was most often seen as a problem to be contained or removed. For much of our history of making, this has not been the case. Indigenous and vernacular technologies are replete with examples of sophisticated techniques for harnessing the dynamic behavior of natural materials, usually woven into composites that exploit the synergistic capabilities of hybrid structures, such as the baidarka kayaks, fabricated by the Aleut for several millennia.

By meshing small pieces of bone into a wooden superstructure in the strategic zones requiring maximum flexibility, the baidarka kayak makes an interesting functional comparison with the most 'high-tech' carbon-fiber composite models. For all its apparent optimizing of performance, the carbon fiber craft is a homogenous structural solution that possesses none of the localized adaptive resilience of the ancient prototype. The latter's combination of variable stiffness and flexibility, due to micro-insertions of a specialized material within a composite, reflects the current challenge for the development of 3D templating. Free-form manufacturing has allowed us to build complex 3D prototypes from the ground up, one layer at a time. But one of the keys to bio-performance is the micro-compositing of more than one material. Two or more must be employed (for example, a layer of chalk separated by a layer of proteins) mimicking the blurred boundaries of natural systems at multiple scales within composite structures, facilitating symbiotic performance behavior, as well as greater flexibility for adaptive recombination.

It seems impossible to project the effect of the emerging biotech revolution on our material economy with possibilities of catalyzing the self-assembly of strong light composite skins, resilient ''ceramic' shells or super high strength structural 'silk' without the use of high heat or chemicals or the extraction of large amounts of non-renewable resources.[8] The widespread social anxiety associated with the advent of genetic engineering could be mitigated by focusing on the real hope that cell-culturing holds for finding more benign ways of manufacturing that eliminate noxious chemical by-products and high energy fluxes.[9] In fact this anxiety itself may effectively contain the wave of technophilia that typically accompanies major innovation, thus exempting it from the kind of critical scrutiny so crucial to its socially conscious application. However, the fundamental questions still lie with the shifting of our collective subjectivities due to new material possibilities: namely, whether or not sentient qualities in our built environment will sensitize us to the revealing capacity that technology could have in our lives, and allow us to shift our focus from the elusive attainment of 'control' and 'stability' towards attempted compatibility with natural phenomena that are fundamentally in flux.

5. SOCIAL PARAMETRICS:

The potential for fascistic forces dominating any such material reorganization is daunting[10], save for the fact that universal theories and ideologies become less and less tenable when they are projected into a closed loop.[11] The 'other' becomes 'another'. Thus, the parametric diagram begins to work at all scales, global and local, microscopic and macroscopic. Working within a socially parametric mode in design, a criterion, or programmatic desire, that may initially be considered as independent is expressed through other functions. In a sense, we have always been implicitly doing this within any design process that is given to trade-off decision-making that is highly partial. The promise of multiple computational mapping in the design process has been to render explicit those parametric forces that were previously subsumed into conventional typologies or later on into the singular subjectivities of late twentieth century design. That is, situated cartographies of programmatic intention become a means not just for legibly sharing subjectivity within the design process, but also for tracing potentially conflicting criteria that — pre-computing — seemed too cumbersome to reconcile without reductively excluding important information.

Because all programmatic aspects, whether they are material, contextual, or economic, have values that are fixed as well as those that are pliant or mutable, they can be characterized as *variables* within certain parameters. Therefore, if there is enough information that can be cross-referenced through these variables, reverberant relationships between multiple data sets can be actualized into fluctuating cartographies. As Donna Haraway has maintained, 'although figures do not have to be representational or mimetic, they do have to be tropic[12], that is, they cannot be literal and must involve at least some kind of displacement that can be a means for troubling identification and certainties (stabilities).' Displacement is inherent to the procedural stance, whereby iteration is a means for revealing and supporting variance rather than for the fixing of identities. As co-generative computational mapping techniques are applied in material practice across the various specialties contributing to the building process, the maps are both instruments *and* signifiers of spatialization as they situate multiple requirements with often mutually conflicting intentions. Unfortunately, although nascent, there has not been thus far nearly enough supported research or attention focused on the means through which mapping processes in computing can productively cross pollinate programmatic content. Again the architectural discipline's partially self-imposed exile from the substantial funding engines for technological innovation exacerbate the degree to which computational processes are given to the fetishistic adoption of mapping processes from other disciplines rather than in a dialogic relationship of real collaboration.[13]

Although recently invented and explored techniques of modeling have certainly called into question the legitimacy of our default to orthographic projection in the communication of architecture, the preoccupations engaged by these techniques have tended to remain rather singular with respect to the production of form and space. Additionally, construction packages, although increasingly parametric, still largely work within the modality of layered montage and configuration, whereby much performance criteria specific to discreet systems is lost in modification procedures.

6. PARAMETRIC MATERIAL INTELLIGENCE:

The search for a design framework that could allow for a simultaneous reading of complex or reverberant data informing the process of making has many important precursors to the computer. It is probably not coincidental that the term 'organic' has been variously associated with them, although unfortunately the label has often been understood in a formal or resultant sense rather than in a procedural or generative one. For example, Gaudi's hanging model transfers unanticipated feedback response throughout the tensile structure, in an attempt at a simultaneous performance model that could reveal complex reverberant behaviors as the lines of tension are registered and later 'trapped' into an inverted compressive matrix at the building scale. The expensive and time consuming experiments were unfortunately not given to imitation because the information was deployed to singularly drive the design process, one that excluded most other criteria from the generation of form. Ironically, although his process does question the legitimacy of the subjective gesture it does not subvert the totalizing system, which in itself is singularly subjective. Within the contemporary context, opportunities for computational techniques in information intensification will continue to evolve the terms of negotiation in design. If they are to assist in a wholescale shift in material culture, the onus is on educational curricula to ensure that these techniques develop in a milieu that can be inclusive of ecological criteria from the most elementary and experimental level.

NOTES

[2] Lefebvre, Henri ''The Everyday and Everydayness'' in *Architecture of the Everyday* Steven Harris and Deborah Berke, Eds., Princeton Architectural Press, 1997.

[3] In some extreme cases, such as the American context, formal architectural education shrank from what began in the last century as a nine year course to a mere three years, as opposed to

[4] The role of architecture and urbanism as the adhesive administrative mechanism so necessary to this linking of multiple interdependent scales and disciplines is crucial, yet missed. (and yet it is the prerequisite for an ecological practice) There has been much debate within the American context surrounding the architectural profession's decreasing capacity to effectively influence general criteria informing the design of our built environments. Although societal pressures placed on the organizational means of design production must be acknowledged, it is rather surprising that theoretical discourse has largely avoided focusing on the pressing ecological issues that could, ironically, place architectural concerns at the center of an inclusive and compelling social agenda. It is hard to deny the massive role that current building practices assume in contributing to the increasing degradation of the environment, yet unlike industrial concerns, the architectural profession has little stake in protecting the norms, and perhaps much to benefit from a large-scale shifting of priorities.

[6] The term *bio-compatible* is used in the widest sense to connote designed materials or environments that are conducive to the biological health of all life forms, both within the temporal frame of their implementation, as well as within a much larger temporal frame of the 'life-cycle' of materials.

[7] IBID p.14. In her arguments on behalf of the *cyborgian* reinvention of nature, Haraway posits a difficult but compelling argument in her ''abiding suspicion that 'biology', the historically specific, congealed embodiments in the world as well as the techno-scientific discourse positing such bodies is an accumulation strategy'' that may be ''more kind than alien'', ''more strange than capital''.

[8] far from the mimicry of biomorphic form, this development is rather about imitating the self-assembling manufacturing process itself, how organisms manage to grow, for instance, perfect crystals and form them into structures that work.

[9] In her pop treatise on *BIOMIMICRY,* Janine Benyus maintains that even in many of the applications within our present economy where one would imagine dumb structural materials to suffice, in a cyclical material economy, certain degrees of imbedded intelligence may prove to be more viable.

[10] Myerson, George *Ecology: and the End of Postmodernity*, Icon books, London, 2001.

[11] With signs that Virilio's dreaded *teletopia* (*Open Sky*, Verso, London, 1997) is beginning to reach temporary exhaustion, the new transparency may produce a tipping point in the possibility for social/ecological accountability.

[12] Although we are often loathe to account for the metaphorical aspects of our cognitive processes in design, 'all language, including math, but especially figural language, is made up of tropes, constituted by bumps that make us swerve from literal-mindedness' (Haraway, p.11).

[13] The demands of heterogeneous and apparently conflicting criteria present an opportunity for the negotiation of possibilities in which the tendency towards fetishizing the manipulation of a particular cartographic or material technique is mitigated by problematizing information. Fetishism belongs to a world without tropes, to a literal mindedness in the interpretation of cartographic output. ''Non fetishized maps index cartographies of struggle or more broadly, cartographies of non-innocent practice, where everything does not always have to be a struggle'' (Haraway, p. 136).