PolyForm
Biomimetic Surfaces

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Abstract

The evolution of the architectural surface from a static, fixed geometric assemblage to a responsive, biomimetic aggregate surface will be the topic of this paper. The work exhibited has been developed by the author and his students over the last two years, prompted by an interest in robotics, advanced material assemblies, and biomimetics. The work ranges in scope from digital models and simulations to working prototypes and full-scale habitable constructions. One aspect that serves to unite the emerging body of work may be summarized in the prefix “poly” denoting many, or having more than one state or form. Thus the word Polyform begins to suggest the interplay between biomimesis and adaptive surfaces. A similar term is found in the combination of poly and morph:

Polymorph:

Having, assuming, or occurring in, many or various forms; multiform.

Nat. Hist., Biol., Path. a. Having or occurring in several different forms in different individuals, or in different conditions of growth; having many varieties: as a species of animal or plant, the zooids of a compound organism, an eruptive disease, etc. b. Assuming various forms successively; of changing form: as an amoeba, infusorian, etc. c. Passing through several markedly different forms in successive stages of development; having several definitely marked metamorphoses. OED http://dictionary.oed.com/

Fig. 1. Bio-Inspired Kinetic Surface (by Author’s student, Alex Agudello / USF)
One common aspect of these semantic references concerns the notion of mutability, transformation, or change over time. This may manifest itself in architecture in terms of changing geometry, translucency, or physical response to the proximity of the body (Figure 1).

**Introduction**

The biomimetic impulse in art and architecture traces overlapping trajectories combining the machine aesthetic of the early twentieth century with the micro-politics of form, combining machinic and biological references to the body in its relation to an increasingly synthetic, cybernetic landscape. This impulse has manifested itself as a parasitical relation between the body and landscape, responding to the bio-politics of synthetic form. This may be seen in the early work of Coop Himmelblau, in particular the pneumatic living unit prototypes such as White Suit and Villa Rosa.

“It is not that we should change to live within architecture, but architecture has to react to our movements, feelings, moods, emotions, so that we want to live in it.” (Himmelblau, Coop 1983)

The “Soft Machines” of Coop Himmelblau may be seen as a counterpoint to the transgressive, machinic installations and hard-edged architecture for which the group was known during the late 80’s and early 90’s. More recently, one may observe the political dimension of biomimetic form in the work of Michael Rakowitz, in his paraSITE projects, which attempt to literally tap into existing utility and energy networks with soft, bio-inspired mobile habitations for the homeless. (Rakowitz, M. 2005)

The shift from a static, hard-surfaced modularity, based on mass production of form, to a pliable, composite approach to form, based on mutability and permeability, may be seen as one of the primary hallmarks of current practice. This approach, utilizing biomimetic qualities to generate responsive forms which adapt to the body’s proximity utilizing mechanical, electronic and chemical sensors, may be seen as the primary shift in today’s mass-customized production. This shift was recently illustrated in much of the work on display at the SAFE: Design Takes On Risk exhibit at MOMA (Antonelli, P., 2006).

The shift from static to kinetic, responsive material assemblages forms the central thesis in the investigations informing the emerging body of work, by the author and his students.

**Bio-Materiality**

The confluence of biomedical technologies, materials science and architecture leads to the “uncanny” realm of synthetic biomateriality. The blurring of natural and artificial materiality tends...
at first to evoke a reactionary, visceral response, an uncanny sensation, as in the work of Robert Gober (Fig. 2) or the Resin and Latex sculptures of Rachel Whiteread. The subsuming of (synthetic, bio) corporeality into the material of architecture, suggests a new mode of interpretation for body, skin and structure.

The shift from the (static) aesthetics of the organic to a performative biomateriality, based on responsive tactility, mutability and change, may be analyzed by comparing the modular evolution of botanical specimens with the kinetic mechanisms that have evolved to allow plant forms to respond to tactile sensory input. A look at the extraordinary images of plant life by Karl Blossfeldt immediately illustrates nature’s strategies for development of modular arrays, efficiently arranged to facilitate growth and absorption of sunlight (Fig. 3). The most striking aspect of Blossfeldt’s images is the precise modularity and granularity of nature—the use of similar geometric efficiencies of form, operating at multiple scales to adapt to changing performance parameters. While Blossfeldt’s images convey the aesthetics of biomateriality, they do not allow us to see the performative aspect of botanical structures such as those found in the carnivorous plants such as the venus flytrap. These are specialized leaf structures capable of kinetic responses to stimuli.

The delicate translucency of botanical membranes combined with the kinetic mechanisms of carnivorous plants, serves as both a geometric and performative basis for the development of synthetic biomateriality in architecture, combining emerging fabrication technologies with smart materials laced with sensors and robotic actuators.

There are two fundamental types of (modular, organ) movement associated with plants. Tropism is generally irreversible response to external stimuli manifested in the form of phototropic, gravitropic, curvature. Nastic movement, by contrast, is generally independent from the direction of the inducing stimulus, for example, the raising and lowering or folding and unfolding of leaves and the opening and closing of the Venus flytrap (Stahlberg, R. and Taya, M. 2006). The generation of a Nastic Movement Field, as a biomimetic surface, may be seen as one of the primary characteristics of the author’s emerging body of work focusing on development of biomateriality.

The incorporation of ‘soft’ technologies in architecture may benefit from the emerging work in textile design, combining smart skins with adaptive movement. The recent work of Netherlands based textile designer Mariëlle Leenders manifests adaptive functionality through movement in her Moving Textiles (Leenders, M. 2006). By combining micro-actuators using shape-memory (nitinol) wire with microprocessor control, Leenders achieves adaptive functionality through interactive displacement of the fabric (Fig. 4.)
The relation between the (micro) part and (macro) whole must be redefined when considering adaptive responses as occurring at multiple scales. One example of this is the touch-induced movement (thigmonasty) of the sensitive plant (Mimosa pudica L.). At the macro scale, the plant responds to touch. At the micro scale, leaf stomata open and close for respiration (Fig. 5).

Recent advances in micro-actuator control, combined with selectively permeable, smart materials, will enable a new class of architectural systems to emerge, based on the Synthetic development of bio-materiality as a performative, as well as aesthetic impulse toward innovation (See Shodek, D. L., and Addington, M., 2004).

Deployable, reconfigurable, Polymorphic materials and systems impact the design and construction of both micro-scale assemblages and full-scale building structures. The incorporation of deployable materials and structures as part of architecture praxis has made a new resurgence, as shown in the recent interest in Extreme Textiles (McQuaid, M. 2005).

On Growth, Form and Movement

The impact of D’Arcy Thompson’s “On Growth and Form” has been a lingering presence in recent work dealing with artificial life. This work tends to focus on the patterns of growth—branching, spiraling, stacking, etc.—employed by nature to build composite assemblies with emergent order and behavior. The shift from digital simulations to physical processes and synthetic assemblages promises to inform a new generation of work, attempting to incorporate the
performative functionality of nature rather than the aesthetic mimicry of organic form. These investigations rely on an understanding of dynamic growth processes, such as phyllotaxis, the spiral formations governing growth in both plant and animal structures. Using dynamic particle systems in MAYA, students have developed complex animated sequences depicting the clustering and growth simulations relating part to whole (Fig. 6). The extreme dynamism encountered in these computer simulations suggests a new level of responsive field / object interaction, transferable to physical, architectural assemblages.

**Adaptive Assemblages**

![Fig. 6. Growth Simulations (by Author’s students- USF / SACD 2004)](image)

![Fig. 7. Bio-Inspired Robotic Assemblage (by Author’s students- USF / SACD 2005)](image)
visual and kinetic aspects, responding to the body's proximity. These aggregate skins, or assemblages, combine into a reactive composite-device, or “organism”, capable of reconfiguring the audio / visual / spatial environment. They are inherently kinetic and follow a well-established lineage back to Lazlo Moholy-Nagy’s Light and Space Modulator.

The link between kinetic sculpture, architecture and robotics can be traced to Bruno Munari’s Useless Machines circa 1940’s and to George Rickey’s sustained production of kinetic sculptures in the landscape. Perhaps the most influential artist among this group was Jean Tinquely who combined multiple materials and technologies toward the creation of large-scale kinetic or mechanical sculptures.

The current research and work attempts to link the sculptural tendencies of early kinetic art with functional assemblages deploying layered responses to the body’s proximity (Fig. 7).

The relation between the “objecthood” of the machine and the spatial flux or extension of the (body) created by the machine’s effects provides a theoretical model for the consideration of this new class of synthetic, adaptive assemblages. These assemblages may be termed Polymorphic Structures—a term borrowed from the emerging field of reconfigurable or swarm robotics (Shen 2006). The
reconfigurable, adaptive qualities of polymorphic robotics have been one influence on the current body of work produced by the author and his students at USF (Figs. 7 and 10).

From a pedagogical perspective, these polymorphic constructions pose new challenges to the traditional design studio. Small teams produced the projects with each team member acting as a specialist for a specific layer in the assemblage. Interdisciplinary knowledge was required and was obtained by inviting guest lecturers and participants from various fields to observe the development of the projects. Teams consisted of 4 “layers” or members, acting as Conceptual, Mechanical, Electronic and Materials specialists. The need to overlap fields of knowledge beyond architecture was a primary requisite to success, in order to achieve a working prototype composed of multiple technologies acting seamlessly in unison.

**Biomimesis and Architecture**

Recent full-scale constructions by the author’s students have explored the confluence of CNC fabrication with biomimetic skins (Fig. 11). Combining both traditional construction techniques and adaptive skins, these initial forays into synthetic, performative architecture provide a critical platform on which to assess new technologies and modes of incorporating biomateriality.

The materials research of Charles and Ray Eames and the technological assemblages of Jean Prouve inform this work. A significant additional influence concerning biomimetics may be found in the relation between appearance and function in animal forms and surfaces (Cott, 1951). Architecture may derive a new level of performative response to occupants and environment by analyzing nature’s strategies for concealment and display. In his essay, *Animal Form in Relation to Appearance*, Cott describes several strategies, including: Obliterative Shading,
Disruption and Pattern, Differential Blending, Contour and Shadow Elimination. These strategies may be adapted as a source for investigation of new adaptive architectural skins, in combination with reconfigurable structures, as in the recent work of the author and his students at USF. In particular, the full-scale habitable Master’s Project by Bryan Wilson (Figs. 11, 12a, 12b) attempts to combine CNC cut ribs and traditional, stacked block construction, with a selectively permeable skin, bonded directly to the frame. This monolithic fiberglass skin is modulated in a gradient from opaque to translucent, in response to occupancy and use zones. In addition, the shell can be reconfigured to open and expand the interior out toward the landscape (Fig. 12b).

Robotics and Architecture

A consistent theme in the emerging body of work by Perez and his students, engages the confluence of robotics and architecture. Architectural Robotics investigates the latent possibilities for combining multiple disciplines and technologies. Most notably, the merger between robotics, sensors, and body-responsive architecture, utilizing deployable or reconfigurable structures, informs the present work (Figs. 13 and 14). The emphasis on developing an understanding of the aesthetic, social and art-critical perspectives relating to this body of work, distinguishes these investigations from purely rational, technologically driven initiatives normally confined to engineering. Nevertheless, architectural robotics benefits by understanding the rationalized structural principals under development in engineering programs, most notably the Deployable Structures Laboratory in Cambridge.

Several overlapping lineages inform this work, from the computational and kinetic art experiments of the 1960’s and 70’s, to the hyper-tech work of Gary Hill and Alan Rath, combining robotics and video art. The influence of Fuller and Kenneth Snelson, employing tensegrity principles, may also be seen. Most recently, the folding Origami experiments of Fredrik Owesen and Richard Sweeny have provided new insights toward the potential of pleated and folding structures (See profiles on Flickr.com).

Architectural Robotics may also find roots within the discipline of architecture, most notably the Recursive, Modular
concepts rooted in Design Science, and popularized by Arthur Loeb. Modularity is at the core of these constructions, both in terms of geometric and spatial networks, and in the layered sensor and actuator arrays required for control and deployment of surfaces and assemblages.

Aggregate Surfaces: from Simulation to Fabrication

Aggregate Surfaces are an especially useful class of surfaces or objects, within the present discussion, as they tend to approximate the materiality, growth mechanisms, and responsiveness found in nature. The major challenge facing emergent practices today, is how to
combine digital simulation of aggregate surfaces, with the development of working physical prototypes, influenced by the fluidity and artificiality of the digital, while grounded in the constraints (gravity, etc.) of the physical.

The relation between (algorithmic, parametric) digital processes, and their physical counterparts or rule-based modes of assembly, is the subject of an emerging body of work. Fortunately, there is a long history of assembling aggregate surfaces or structures, from which to draw inspiration, including basketry, weaving, and composite crafts such as kayak construction. The exploration of traditional crafts, combined with advanced fabrication techniques, will yield a new generation of work, surpassing the (static, monolithic) nature of much current production.

Recent digital and physical fabrications attempt to investigate the transfer from conceptually driven simulations to physical assemblages constrained by material properties, connections and fabrication methods (Fig. 15).

**Polymorphs**

Recent grant-funded research by Pérez has focused on understanding the implications of shifting from small-scale kinetic or responsive “machines” or polymorphic constructions, to large-scale habitable architecture. Still in the initial conceptual exploration stage, these Polymorphs attempt to pose questions concerning inhabitation, reconfiguration, adaptation, and responsive assemblies. The evolution of architecture from a machinic assemblage of static parts to an operative, performative (bio)-responsive, layered matrix of composite materials and technologies provides a fundamental basis for exploration.

**Conclusions**

This paper has attempted to continue questions posed in an earlier essay titled *The Synthetic Sublime*. Whereas the earlier essay focused on the shift from the organic to the synthetic within the context of static assemblages, this paper has focused on illustrating ongoing work which attempts to confront the concept of mutability within architecture explored
via deployable, reconfigurable structures. As new technologies and materials become available, pedagogical challenges for expanding the realm of architecture will emerge. These challenges will impact both the design studio and foundation coursework such as materials, structures, and environmental technology. The new paradigm for creative work in architecture will require a shift toward a collaborative mixture of fine arts and engineering disciplines. This will lead, hopefully, to a new renaissance in teaching and research. The effect on architecture studios will be to shift toward a truly interdisciplinary modality, which may be compared to the popular growth of battle-bot and robot soccer teams, employing fast-response onsite teams ready to deal with the latest challenges, employing knowledge of coding, engineering, and robotics. The critical imperative from within the discipline of architecture will be to continue redefining the role of the architect and of spatial tectonics in a world filled with smart, responsive, synthetic Para-Architectural assemblages.

References


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