Integrating Physical and Digital

INTERACTIVE TECHNOLOGIES AND DESIGN OF MATTER

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"We now need more from architecture. In addition to function and form, architecture must be imbued with foresight."

-Blaine Brownell

Architecture, Systems Biology and Integration

Today, thanks to current technological achievements, deepening and broadening of scientific information and knowledge, as well as expansion in our understanding of the world around us and underlying processes that govern metabolisms of natural world, we are able to see deep connections between the made and natural worlds. With such an expansive context comes an ability to effectively and productively integrate new knowledge, information, methods and techniques back into the design and production of architecture. Confluence of various technologies and their assimilation are altering the way we perform, organize and distribute our activities and materials. The conceptual model of architecture is changing.

For Blaine Brownell "foresight shapes architecture that, like life itself, produces as well as consumes, reincorporates all of its waste, and maintains an ecological footprint in balance with the requirements of its context."[1] According to John Frazer, architecture should be a "living, evolving thing".[2] For Brownell, Frazer and others today who share similar views, processes of building and consuming architecture should be seen and practiced as life sustaining metabolic processes. This ambition to view architecture as a form of artificial life is fueled on the one hand by "material shifts occurring in the domains of energy, resources, and technology,"[3] and on the other by grasping a deeper connection between biological and cultural systems. In a world of depleting resources these developments might hold a key for establishing a holistic relationship between made and natural worlds.

The emergence of a biological paradigm and its influence on technological developments is profoundly affecting our attitude towards the notion of the integrative. On the one hand, integrative design is about "multidisciplinarity, [a] collaborative approach from the earliest stage of design, and fluid crossing of conventional disciplinary and professional boundaries." It revolves around appropriation of methods, processes and techniques from "elsewhere".[4] This "technique" of deepening the integration concept by cross pollinating the profession in terms of content is a promising approach in expanding the understanding of complex systems formed by integrative tendencies.

On the other hand, integrative design is about the functions and behaviors of integrated systems, something akin to enzymes and metabolites in a metabolic pathway. In this sense integrative might include willingness to relinquish control and allow new functions and behaviors to arise. That requires a shift in design thinking, as Denis Noble argues in discussing systems biology, which is "about putting together rather than taking apart, integration rather than reduction. It requires that we develop ways of thinking about integration that are as rigorous as our reductionist programmes, but different….It means changing our philosophy, in the full sense of the term."[5]

The influence of the "organic paradigm"[6] is changing attitudes towards adaptation, behavior and performance. Recent thinking in science is bringing down the traditional concept of nature as a closed system governed by static rules, recognizing that everything in nature operates within dynamic and open systems.[7] With the integration of interactive technologies, robotics and material sciences, new content for architecture is formulated. This new content relies on the integration of dynamics into architecture.

Alive Spaces and Material Intensities

Over the past decade, there has been an increasing interest in exploring the capacity of built spaces to respond dynamically to changes in the external and internal environments and to different patterns of use.[8] Such interest is technologically and socially motivated, and stems from recent technological and cultural changes. Advances in embedded computation, material design, and kinetics on the technological side, and increasing concerns about sustainability, social and urban changes on the cultural side, provide a background for responsive/interactive architectural solutions that have started to emerge.

A responsive architectural environment is flexible and interactive, with an inherent capacity to adapt to changes. For many, it must be also "intelligent"; but to be considered "intelligent", it must have a capacity to learn about or understand its "world" and an ability to interact with it. "Intelligence" in an architectural environment, however, should not be manifested merely through interaction; it should have a transformative effect on participants and on the environment itself. As John Frazer argues, it should be a "living, evolving thing". A truly responsive environment would enter into a "conversation" with its users and allow them to become participants. In other words, such an environment should not only sense and respond but also perceive and act.

The question then is this: Where is the boundary between the body and space and between a technological and a non-technological body? How should we design these "living, evolving" environments? Issues of complexity (or complex behaviors formed through the accumulation of simple actions) are also an essential part of such a discourse. The main point here is that the design of spaces that actively engage with their users goes beyond form and space delineation and requires design of complex behavioral and informational systems. In such an expansive and extended design context, the task of design is necessarily re-focused to include integration of disparate and complex systems of information.

In designing responsive environments, the process of design thus shifts from being a closed loop to a process that relies on flows and dynamic behavioral patterns, staying open and capable of new configurations. But how would omnipresent responsive environments change the purpose of architecture, i.e. its role in the cultural fabric of the society? They would certainly give rise to new social dimensions; perhaps they will begin to reflect new forms of social communication emerging from opportunities to operate within humanized and augmented space that is dynamic, sensing and more "alive" than ever before. How would we live in spaces that, like very comfortable clothes (or not), respond to our movements and wishes, and to external environmental and other influences? Can we leave the orbit of prefixed architecture and more fluidly interface with kinetic and changing environments?

There are additional considerations that need to be taken into account. Several years ago Mark Goulthorpe stated: "Increasingly, I think of a project as a distribution of material in space, not as the assemblage of preformed elements. We are moving from collage to morphology, looking to deploy material as material for its spatial and surface effects …"[9] In other words, there is a shift in interest away from elements and towards morphology. Distributing material, and not preformed elements, suggests a different operational scale – that of material intensities.

Material intensities would foster not only change in delineation of space but a change in gradients within that space, which could texture and form architectural surfaces into fully functional configurations populated/programmed for various conditions and use. In this context the built environment is no longer an inert configuration of set physical spaces but a set of boundaries with changing intensities and shifting positions. It is then an unavoidable and perhaps still speculative question as to how these environments redefine architecture itself, social interaction, flow of activities and stability at large. If everything can be reconnected, re-grown or redirected, who or what is triggering the change? What is the stimulus and catalyst of this "metabolic process"? How is the role of an architect changing? Is the architect becoming a facilitator or a catalyst of an evolving design? One can only imagine the scope of social and ecological changes that this would introduce over time.

Designing Material Behavior

Throughout the history of architecture, integration of novel materials (and technologies) into design and construction has altered its course. Today, the capacity to create materials with specific properties and define material behavior, along with tools and techniques to visualize and fabricate infinitely small material structures and simulate emergent behaviors, are offering previously unimagined possibilities. Technology transfer from fields such as material science, biomimetics, autonomous robotics, interface design and computation are not only influencing the range of the materials used in architecture but the very scale at which they are deployed. As discussed previously, the latest tendencies of integrating material design and sensing technologies are clearly favoring responsiveness and adaptation for static and inert architectural conditions.

This integration of physical and digital, material design and interactive technologies, is challenging and redefining the traditional problems of motion, stasis, and order in architecture. Scaling up robotic devices to an architectural scale, however, is heavily dependent on advances in material design as well as biomimetics.[10] The real challenge is a limited capacity of materials to negotiate various spatial accommodations at the scale of a building, in terms of size and shape, without a mechanical system, substructure or frame that would facilitate that change. Material capable of doing that would have to have biological properties of easily adjusting to change.

The structure/skin concept that is so instrumental in architecture would have to give way to a more organic concept of tissue/tendon/bone transition where joints allow for certain adaptability and accommodation of changing shape. According to engineer Guy Nordenson, if a building was designed like a body, with a system of bones, muscles and tendons and ability to change its posture, tighten its muscles, and brace itself against wind, its structural mass could be cut in half.[11] Builders of architecture, on the contrary, have invested millennia into building for stability and stasis. By perpetuating this long-established tradition, building industry today is still consuming vast amounts of resources and energy.

If we look into other disciplines, we can discover potentially interesting attempts to re-define the relationship of structure to skin. For example, recent research from Harvard Microrobotics Lab and MIT proposes a preprogrammed sheet material that can fold itself into a boat or airplane origami shape. The thin resin-fiberglass composite sheet, divided into triangular segments, has heat sensitive connections that fold into a particular shape depending on the program used. This concept could one day produce objects or surfaces that can shift shape or transform into a number of useful objects.[12] Similar work at MIT and Carnegie Mellon is looking at developing small computers that can work together to form shapes.[13] These particle sized machines are conceptually the same as modular robots but work on a smaller scale – each particle is less than a millimeter in diameter. The Claytronics project[14] integrates physical and computational with a concept of "fungibility" that enables many computers to talk to each other and allows them to separate into sections without losing overall computing power.

Perhaps the most exciting work in programmable matter is at the level of the matter itself. Integrating computation, materiality and matter into a more intelligent system enables more fluent exchange between information, responsiveness and function. Integration of digital and physical is not only happening at the scale of perceptible movement, programming dynamics of the surface can happen at the molecular scale as well. Researchers from MIT and University of California have designed a "smart surface"; one that can switch properties in response to external stimulus and change from water attracting to water-repelling surface with the use of a weak electric field.[15] Switching off the electrical potential of the field reverses initial affinity for water. Even though the most immediate application of this research is in the area of biology, medicine and material science, dynamic control of surface characteristics can have truly exciting application in the engineering of architectural surfaces. The concept of writing a code that specifies the structure of the material is marking a shift from the physical world that we know towards digitally augmented matter that can be programmed as well as allowed to form new functions and relationships.

Towards Architectural Ecologies

In *The Generation of Virtual Prototypes for Performance Optimization*, John Frazer posits that a technology or a technique is not worth developing unless there is a viable problem that needs to be solved. He argues, for example, that the absence of a viable problem has impaired the development of CAD technologies at the time.[16] Could responsive technologies and programmable matter be an essential catalyst for change when it comes to social and environmental concerns?

Interactive architectural systems are beginning to take advantage of today's pervasive and constantly advancing technologies and are becoming an integral part of a larger vision where architecture utilizes and explores methods and applications that address dynamic, flexible, and constantly evolving activities. The integration of smart systems (sensors, actuators, and controllers) and kinetic systems (movable architectural components) enables spaces we inhabit (homes, workplaces, streets) to sense, respond and interact with us. This transforms static building components into active responsive surfaces, producing added functionalities in architectural spaces. Capacities of the build spaces, i.e., their interiors and exteriors, to adapt, transform, move, and interact would enable a building itself to harvest energy from its environment, control its energy use, transform its appearance, reconfigure its spaces, collect information about its inhabitants (for example in hospitals), or display information to its users (i.e., guide individuals).

The significance of integration of physical and digital worlds lies in the capacity to enable more sustainable building practices that can meet changing needs with respect to evolving individual, social and environmental demands. Buildings that could sense and interact with its environment can operate more synergistically within larger ecologies and therefore move closer towards more sustainable participation within the global environment. The responsive architectural systems could act as ecologies in themselves, allowing architectural discipline to recalibrate its participation and to pursue a direction of a more intelligent and operative participant – a participant imbued with foresight.

Notes

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