Emergent Models of Architectural Practice

Tom Wiscombe

The idea that innovation, whether scientific, technological, or architectural, is a by-product of artistic chance or a result of singular genius can no longer be sustained in the 21st century. Complexity theory reveals that innovation-- the creation of the new-- is the direct result of bottom-up evolutionary processes. Science knows this; industry is learning. Architecture is just beginning to engage the concept.

In order to move into this space of innovation, architects will have to accept the value of multiplicity and dynamic feedback over the retrograde nature of authority. They will have to accept that architecture might not be about essences and theoretical positions, but rather about exchanges of techniques, expertises and materialities in multiple industries. They will have to accept that the architecture is no longer a heroic center, but one micro-intelligence among many. They will have to let go and begin to love the swarm.

Through the ambient exchange of technologies and tools, members of new collectives may find themselves suddenly more agile and resilient, not only through their expanded network, but also through their own learning and transformation in the process. For architectural practice, what is at stake is more than a reorganization of heirarchies in architectural organizations, but rather the birth of an entirely revolutionary way of thinking about the production of ideas in general.

Parts and Wholes

Architectural practice has mutated and flowed between various identities for centuries, moving toward and away from engineering, toward and away from construction, becoming sometimes more specialized (focused on parts), and sometimes more convergent (focused on wholes).

Renaissance architects sought to distance themselves from the building and engineering trades and instead associated themselves with the culture of taste. Their work exemplifies this limitation as much as it reflects the historicist ideals of the Renaissance itself. It is flat and decorative, concerned with orders and proportions in elevation rather than with dynamic, intensive forces. Modern architects reassociated themselves with issues of performance and new materials. Nevertheless, they often assembled technical experts in a heirarchy designed to serve the social and formal ideals of their architecture, such as transparency. Postmodern architects in the 1980s reverted to a Renaissance mode of mannerist designing and the attendant lack of interest in processes and material complexity. These models of practice are either conflicted or exclusive. They are part of a lineage of dematerialization and atomic thinking, where layers of engineering, materials, and processes remain striated, and always reducible into their parts.

Gothic architects operated in a more integrated, smooth way. They were involved in all of the building disciplines of the time simultaneously. The point of departure for a Gothic building was more than a set of proportions or elevations, it was the scientific and technical behavior of structures and properties of materials. Parameters were dynamic and performative rather than compositional. Moreover, Gothic architects were versed in the evolution of structures to the point that they regularily pre-visualized the consequences of solutions and fed this information back into the design process at the front end. As their ambitions repeatedly reached the limits of the materials and engineering of the time, innovations (mutations) in this evolutionary process became as important to success as self-regulation.

While the Gothic architect had expertise is several fields at once, and was able to fold them together into coherent wholes, contemporary architects finds themselves navigating in an ocean of expertises and interests too numerous and different to unify. The Gothic all-in-one model becomes impossible to sustain. New models of practice therefore might be based on dynamic organizations in which entities can operate both independently and in collectives at the same time-- that is, as parts and as wholes. Parts, which are more specialized than wholes, can rarely evolve or become innovative on their own, just as a single neuron in the human brain can never have a thought. Evolution occurs in the system.

Perhaps the best way to frame this discussion is through the phenomenon of *emergence*. Discovered in the 1970s, emergence offers a new precision to the study of evolution, complexity and the 'new', and it appears to be strangely applicable to a huge range of disciplines and scales, from the micro-biological to the macro-economical. It forces us to reconsider the pervasive atomic, collage-based view of the world, which is concerned with parts, even parts in seemingly complex arrangements. An emergent organization exhibits behaviors or has properties which are not predictable by observing any of the behaviors or properties of its constituent parts. That is, the emergent whole always exceeds its parts qualitatively. The beautiful coherence and dynamics of a swarm of bees can never be traced back to the behavior of a single bee.

One of the clearest examples of an emergent phenomenon, that is, of the moment where an organization of parts becomes a new whole with divergent behavioral patterns, can be found in the cellular slime mold. This organism, originally stumbled upon by the ancient Greeks in their furvor to categorize everything into flora or fauna, behaves sometimes as a plant and sometimes as an animal, depending on environmental conditions. When food is available (decaying wood,etc.), the slime mold organizes into a single, multicellular blobby organism and becomes carnivorous, but when food is scarce, it breaks down into a swarm of single-celled organisms which take on the form of stalks and begin to photosynthesize. This process of not just transforming in *degree* but in *kind* is keenly relevant to the discussion of new forms of practice, and in particular, to the creation of emergent networks.

Emergent Networks

Within the realm of architectural practice, an emergent network is more than an arrangement of expertises or an overlapping of spheres of influence. It is a collective which exhibits emergent behavioral patterns that are unpredictable by examining the behavioral patterns of its parts. Beyond simple collaboration, which is the result of an alignment of interests, an emergent network can create new and complex coherences out of divergent interests. The concept therefore goes beyond what has recently come to be known as 'network practice' which is more often than not used to describe the late 20th century tendency of architectural offices distribute and make affiliations in order to administer an increasingly global range of projects. Although an emergent network, like a 'network practice', dissolves the architectural studio the source or center of the architectural 'Project', it does this through swarming--snapping into new coherent organizations-- rather than by simply engendering affiliation.

The products of emergent networks are non-linear and non-predictable, which is a risk, but one with exponential rewards. Linear processes will always create products which are calculable and applicable in particular industries, but they will never exceed their inputs. Non-linear, emergent processes create innovation and newness out of proportion to their inputs, and often applications which lie outside the original trajectory. The U.S. military and space industry, one of the most productive enterprises of the 20th century, has had some of its biggest impacts outside of the battlefield precisely for this reason. Involving swarms of expertise—from aerospace engineering and materials science to biotechnology and communications—the research and development arms of the Department of Defense and NASA have been responsible for at least 30,000 emergent spin-off technologies in the private sphere, ranging from the internet, medical resonance imaging, and GPS, to new materials such as transparent ceramic and aerogel. The value, both economically and culturally, of these secondary innovations massively outweighs that of the primary innovations.[1]

Consider BioSteel, an example *par excellance* of the emergent network. Biosteel, first presented by Dr. Jeffrey Turner of Nexia Biotechnologies in 2003 at a trade conference, is the direct result of active feedback between the agricultural industry, the genetic engineering industry, the textile industry, and the military-industrial complex. It is a fabric which is woven out of genetically recombinant spider silk. Because spiders are impossible to domesticate, spider silk genes are implanted and incubated in the DNA of goats. Silk genes are then harvested from goat milk, and raw silk is spun into fibers. Fabric woven from these fibers is stronger than steel, lighter than aluminum, and more elastic than natural spider silk. Because of its exceptional emergent properties, this material is being used by the U.S. military for soft body armor and helicopter blades, but also by the medical industry for sutures and artificial ligaments.[2]

Some young architectural practices are exploring emergent network model, working with extra-professionals as a rule rather than an exception. SERVO's recent installation 'Lattice Archipelogics' was the combined product of various SERVO offices (they have four), interactive computer programmers (Smart Studio, Stockholm), MIT acoustical engineers, and industrial molding experts. In the development of this project, no one behaved as a consultant, implying a linear flow of information, but rather all behaved together as a collective of knowledge cells linked by digital technology. The project reflects this heterogeneity, operating simultaneously as atmosphere, as furniture, and as computational matrix-- something which oscillates spatially and categorically, but also which maintains an overall emergent coherence. SERVO's work is in general focused around embedding technologies in architecture in a way that it cannot be unwound again, reduced back to its parts. Similar to Biosteel, their 'products' are the result of the feedback processes and technologies. Novelty emerges not out of random artistic accidents, or recombination of existing logics or histories, but rather from the dynamic cross-wiring of various material intelligences. It is in a sense completely logical for architects, who during the past twenty years have been sampling from theoretical disciplines, to break out and build up productive, emergent networks with groups in industry and science.

One firm that has succeeded in pushing the limits of architectural practice is Imaginary Forces (IF) in New York. IF New York is itself spin-off of IF in Los Angeles, which is a group of special effects gurus and marketing creatives. IF New York, lead by Creative Director Mikon von Gastel, has positioned itself somewhere between the film industry and the building industry, leveraging one to open up potentials in the other. IF concentrates on architectural 'special effects', all of that which has been latent in 20th century architecture but never developed or understood as its own expertise. These special effects cut across the disciplinary boundaries of interactive media, industrial design, animation, art direction, and engineering, and are convergent with, rather than supplemental to, architecture.

As a form of practice, this is an emergent model that relies on feedback for success. It is conceivable that the IF model could in fact become more widely accepted as the role of the architect more and more often resembles that of 'creative director'. It may also be a more resilient model in general because of its flexibility and its access to multiple markets. More importantly, IF has a broad knowledge base, which allows it not only to exhibit complex behavior, but to be innovative in several fields simultaneously. Peter Frankfurt, one of the founders of IF, has noted that he now intends to leverage this potential in an experiment involving a jump from science fiction to reality. Using the diverse team he organized for the production of parts of the the film *'Minority Report'*, his plan is to develop futuristic products envisioned in that film and bring them to market. Frankfurt has reportedly called on Steven Spielberg to finance and 'produce' this project.[3]

Co-evolution of Building Systems

Sadly, relationships between architects and engineers and engineers and each other still tend away from the potentials of emergent organizations. All too familiar is the scenario where the architect designs an envelope based on a space program, and then passes it on to the structural and mechanical engineers. They collage-in their systems without majorly altering that envelope, as if retrofitting. No one expects the other to sublimate the demands and behaviors of the systems of the other, or react to them generatively. The result is often a stratified, incoherent mess of infrastructural conflicts.

This is not only a problem of coordination, but of a basic acceptance of a zero-sum, win/lose, world-view. In a win/lose world, a beam is a beam and a duct is a duct, and one system can operate optimally only at the expense of another. In a win/win world, 'optimum' is calculated differentially. Parameters rule: a beam becomes a set of loads and reactions, and a duct becomes a flow-form of streaming particles of liquid and air, and both can operate on a consistent plane. Heterogeneity arises in this case at the intensive level of becoming, where structural 'beamness' can be reconfigured to include trajectories of mechanical 'ductness' in multi-optimized constructions. Architectural systems, interdependent like ecological systems in nature, begin in this way to operate in ways that are not only more complex and intelligent, but potentially more beautiful.

This new kind of complex arrangement, where both entities benefit from an interaction to the point that they operate *more* successfully by giving up some of their short-term interests is, biologically speaking, an example of co-evolution. Co-evolution is more than symbiosis, where two or more species align in order to increase their own fitness. Species are co-evolutionary when they learn from one another across time, to the point that they begin to fluidly exchange behaviors in order to increase the combined fitness of the collective. One example of this can be seen in the relationship between lions and hyenas in the African Savannah. The lions are generally assumed to be predators and the hyenas, scavengers, and the two species are also generally assumed to be enemies. Nevertheless, recent study suggests that lions and hyenas constantly de- and re-territorialize each other by switching from predator to scavenger and back again. By doing this, they increase their combined resilience (ie. they multi-optimize) within their harsh environment.

Co-evolutionary practice is not ecological in the sense that it should produce 'green architecture'. Its goal is not necessarily stability and sustainability, although those could certainly be emergent properties of the system. Instead the goal is to work generatively in areas of the profession which have often either been excluded from the design process, or dealt with expressionistically. The feedback of structural engineering on form is certainly not a new idea, and is being explored by the some of the most innovative architects this generation such as Reiser/Umemoto, Foreign Office Architects, and UN Studio. But the introduction of multiple engineering parameters, particularily mechanical engineering parameters, into the system has often been overlooked.

The 'BMW World' project from Coop Himmelb(l)au, which is currently under construction in Munich, reveals how co-evolution between structural and mechanical intelligences can begin to generate new properties and possibilities. The centerpiece of this project, called the 'Double-cone', is in fact a technological prototype in this regard. Its structure consists of a non-heirarchical lattice of welded tube sections which are filled with water. The water is circulated throughout the lattice and down into a geothermic piles, creating a three-dimensional heat-exchange system where excess heat can be absorbed and released. More than that though, the performance of the mechanical system feeds back on the structural system. Blast tests, for instance, have concluded that the presence of the water has a beneficial effect on the total structural stability of the system. In addition, the fire protection system for the steel structure is based on exploiting the water-lattice as a sprinkler infrastructure, employing an array of valves integrated directly into the structural members. This concept is currently under consideration by the local fire authorities, and if approved will be a landmark for in the development of convergent practice.[4]

Digital engineering tools, more than anything else, will sustain this kind of research and development in the coming decade. Analysis programs, including finite element, vectorbased, and computer fluid dynamic (CFD) softwares, are beginning to bridge the gap not just between design and structure but between various engineering disciplines. Structural analysis programs which were brought to market in the late 1980s are now much more sophisticated and can model not only structural reactions to loading patterns, but dynamic forces in real-time. The mechanical engineering industry, although slow to react to the paradigm shift, is also beginning to utilize these new tools more regularily and in a more productive way. Even acoustic and fire-safety engineers have entered the mix, beginning to employ various modelling systems which can visualize previously invisible events. Engineers at Ove Arup NY, for example, have developed a propreitary software which allows them to simulate the motion of people exiting a building in an emergency using character animation software with an integrated swarm dynamics routine. In addition, they have developed a prototype acoustic studio, called SoundLab, where designers can interactively develop building geometries based on the acoustical performance.

Digital analysis is however still in its pioneering phase- the assumption still tends to be that 'design' proceeds analysis, and that dynamic forces act on fixed objects. The other assumption is that various engineering disciplines are independent and that there is no value in feedback between them. The first step in dissolving these assumptions is moving away from reverse-engineering toward forward-engineering, that is, toward the generative use of these tools and techniques. The next step will be the development of cross-platform digital engineering tools, which will be able to *differentially* model dynamic forces and provide iterations of various degrees of evolution and multi-optimization. Still, increasingly complex digital tools will likely never replace the intuitive, open-ended feedback loops that can occur between professionals in the studio, such as in the almost legendary sessions several contemporary architects have had with the structural engineer Cecil Balmond. They will, however, certainly create a virtual plateau where multiple expertises, techniques, and materialities can interact and evolve with unexpected consequences.

Forward-Fabrication

During the 20th century, building 'arts' and building 'trades' were more often than not, exclusive. This was in part due to the establishment of licensure at the turn of the century, and the desire of architects to define themselves in relation to other white-collar professionals. Architectural practice in general came to be seen as seperate from processes of fabrication and construction which led to their inevitable loss of influence on project delivery during the 1970s. The birth of the 'construction manager' in the United States and Europe, who took over the coordination between architects and builders, was a sign of this lack of cohesion. Nevertheless, architects and builders have recently begun to re-integrate. This is due to the establishment of linkages between methods of designing and methods of production brought about by the digital revolution.

The convergence of manufacturing tools and design software in general over the past ten years has had an overwhelming impact on the construction industry. The revolution in digital modeling and computer-aided fabrication techniques such as numerically-controlled (CNC) machining and laser-cutting are revolutionizing not only methods of production, but potentially also the role of the architect in the building process in general. The architect has been classically responsible for 'construction documents' which are a general definition of the scope of work, materials, and connections to be contracted; construction documents tend to be analogous to the built work, but never equivalent. Now, with the advent of digital modeling, scope, geometry, and detail can all be defined precisely by the architect, and produced without such an extensive preparation process. The documentation procedure as we know it collapses-- three dimensional data is delivered to the contractor, processed through a digital machining routine, and fabricated without translation. Endless sets of analog two-dimensional drawings are replaced by digital routines and algorithms which can take even the most complex geometries and unfold them into digital templates required for machining.

Architects such as Frank Gehry, Greg Lynn, and FOA have begun to front-engineer industrial processes into their work, not only with the knowledge of what the building industry is capable of, but with an eye toward emerging expertises within other industries. The influence of Frank Gehry, in particular, on this new fabrication paradigm cannot be underestimated. He was one of the first to realize that the tools he needed were only to be found outside architecture-- so he borrowed them from the French aerospace industry (Dassault Systémes). CATIA, a software originally intended for the development of missiles and drones, has since become a new industry standard for high-end building construction. In the meantime, Gehry, and his partner Jim Glymph, have taken CATIA to the next level in their spin-off company Gehry Technologies, which has not only focused on tailoring CATIAs parametric modelling and analysis capabilities for architectural applications, but has re-engineered it as a project management platform. This platform, called ‘Digital Project', allows seamless collaboration between AEC disciplines in what Glymph has called a “digitial ecosystem.”[5] Rather than creating a top-down, overarching standard and process for construction, which would be bound for failure, it is based on local adaptation, where systems and standards from various disciplines, and from various countries, can be transferred into the software. Intelligences and techniques interact in real-time with no lagtime and no translation, increasing the operative intelligence of the collective. The trickle-down logic of the traditional AEC system is replaced by the bottom-up logic of swarming.

Fabricators themselves are also beginning to develop proprietary software which responds to the needs of architects, particularly in terms of routines which optimize surface geometry in order to make it more easy to produce. At Milgo/Bufkin, a sheet metal factory in Brooklyn, Bruce Gitlin is exploring new manufacturing synergies with the help of Dr. Haresh Lalvani, a self-proclaimed ‘architect-morphologist' from Pratt University. Their work centers around something they call AlgoRhythm Technologies. This is a recently trademarked process which bridges the gap between fluid architectural geometry and the limitations of flat sheet material. It involves using parametrics to break down complex surfaces in a way which exploits the structural potentials of the material and also reduces waste. Similar to fashion industry practices, which involve optimized patterning and robotic sewing, the Milgo/Bufkin process involves micro-slitting, folding, and ‘laser-sewing' standard sheet product into beautiful yet performative forms. According to Gitlin, “the undulating look of the structures results from the behavior of sheet metal under force. The forms are non-deformational, thereby maintaining the integrity of the metal.”[6] Material is therefore not chosen based on expedience; the materials' properties become integral to the morphology. While this process is currently specified for cladding systems, its logic could be conceivably projected into building superstructure design or beyond.

Feeding fabrication techniques, engineering dynamics, and materials science *forward* into the design process is a way to free architectural practice from its tendency toward stratification and provincialism. For architects, this means an end to categorical practice, where territory is fixed and guarded, and a leap into the dynamic world of emergent organizations and processes. In this world, territory can disappear and reappear in various scales and industries, and specialization is never enough.

Architects in this world might be forced to give up their afflictions of heroism and genius, in favor of a new role as instigators of innovation, fueled by a broad and open-ended exchange of expertise and technologies. The question of the role of the architect thereby ceases to be an existential, affective one, and becomes a question of material systems and effects. And design, freed from the problemmatics of expression, becomes a space of evolution and innovation.

Notes

1 NASA Scientific and Technical Information (STI)
www.sti.nasa.gov: spinoff database
It is estimated that for every dollar of investment in U.S. military R&D, a minimum of seven dollars is returned to the U.S. economy in the form of corporate and individual income taxes.

2 Jeffrey Turner, BioSteel Performance Fibers: Military Applications of Recombinant Spider Silk (CTI-DND Conference Lecture, April 3, 2003)

3 Peter Frankfurt of Imaginary Forces, conversation with T. Wiscombe March, 2004

4 This concept was developed by Coop Himmelb(l)au (Prix, Wiscombe) in collaboration with Josef Gartner GmbH (Dietrich Anders)

5 Martyn Day, *Digital Project*
AEC Magazine, October, 2004, p. 27

6 Bruce Gitlin of Milgo/Bufkin, conversation with T. Wiscombe June, 2003

The following projects-- the *MoMA/ P.S.1 Urban Beach, the Radiant Hydronic House, the Micromultiple Tower, and the Lattice House*-- involve different applications of emergence in design and practice, from the feedback of structural and mechanical behavior into form, to the integrity of cohesive swarm-structures.

MoMA/ P.S.1 Urban Beach (2003)

The centerpiece of this 'Urban Beach' design-- number four of five built to date in the P.S.1 courtyard-- is an expansive roof canopy. The aim was to create structural integrity through the use of a non-heirarchical patterning of small, interlaced units, or cells. The position and geometry of each cell was determined by shading requirements, required shear and moment reactions, and also by the position and behavior of neighbor cells. The cells operated in coherent alliance, enabling clear spans and forming a kind of structural ecology. A crenellated metallic skin wrapped these elements into a singular form which provided shade during the day. At night, this superform dissolved back into a swarm of light-emitting cells.

One of the driving goals of this project was to integrate issues of fabrication and erection into the design process. As a temporary event roof which had to be designed, manufactured, and installed in just two months, the project team was forced to jump directly from conceptual design to fabrication-- a feat which was made possible by computation. The key was to avoid designing a fixed shape and concentrate on creating an iterative system which could *evolve-in* changes in structural requirements, scope, and existing conditions. All five hundred skin panels were generated parametrically as single-curvature elements making them easy to develop, water-jet cut flat, and transport. The project would not have been feasible or economical had it been defined with traditional construction documents rather than with adaptive geometry.

Radiant Hydronic House (2004)

This project is based on feeding back various building systems into one another in order to produce emergent effects, both quantitative and qualitative. The house is structured by a set of flexible bands which take on various gradients of behavior-- structural, mechanical, circulatory-- depending on various local requirements but also based on their relation to adjacent bands.

A central spine connects a series of solar baths on the roof down through the space into a radiant slab inside the house, becoming itself a radiant body. 'Ductwork' in this spine takes on foreign behaviors, opportunistically twisting up to become a structural support in key locations, and then later twisting flat to become a ramp or bridge. While each building system performs, it does so only in relation, and in a state of biological epistasis (ie. no one system is optimized but all systems are optimized in relation).

Micromultiple Tower (2004)
This research project examines options for dissolving the core-and-plate model of the high-rise. The assumption is that cores tend to be inauthentic simultaneities: sheer economic considerations have stabilized structural, mechanical, and circulatory systems into expedient adjacencies-- a collages of systems. The proposal is to relocate and recombine these systems into a thick adaptive infrastructural skin on the outside of the building, replacing the dematerialized curtainwall of Modernist architecture. This skin inflects and responds to performance criteria such as shear loading and wind forces, supports radiant heating and cooling systems for all floors, and contains naturally ventilated fire exiting and other vertical circulation systems. In addition, the degree of inflection of the skin is linked to maximum economical floor plate spans, enabling the complete obsolescence of any column grid.

Lattice House (2005)
This proposal for Vitra is based on the concept of the monocoque structure, where heirarchical orders of skins, beams, columns, ducts, and passageways collapse into a three-dimensional latticework defined by its coherentmorphology. As opposed to the Radiant Hydronic House, which is based of the flexible, adaptive surfaces as the operative medium, the Lattice House is a multidirectional array in space with an exceptional range of motion and adaptibility. Inverse Kinematics ('bones') were used to generate this array in order to maintain a dynamic coherence in the system. The lattice performs simultaneously as primary structure and mechanical infrastructure: filled with water, the array of struts creates a massive heat-exchange system-- a three-dimensional radiator-- capable of heating and cooling the space without the use of forced air. Struts also evolve locally into stairs, bridges, and secondary propping elements.

The design process involved generating hundreds of iterations of the the array and subjecting each to structural loading analysis. Those iterations deemed structurally 'fit' were bred with each other, generating even more complex and evolved mutations.