Code, Context, and Perception: Matrix Architecture and the Architect Weaver

Jenny E. Sabin
University of Pennsylvania

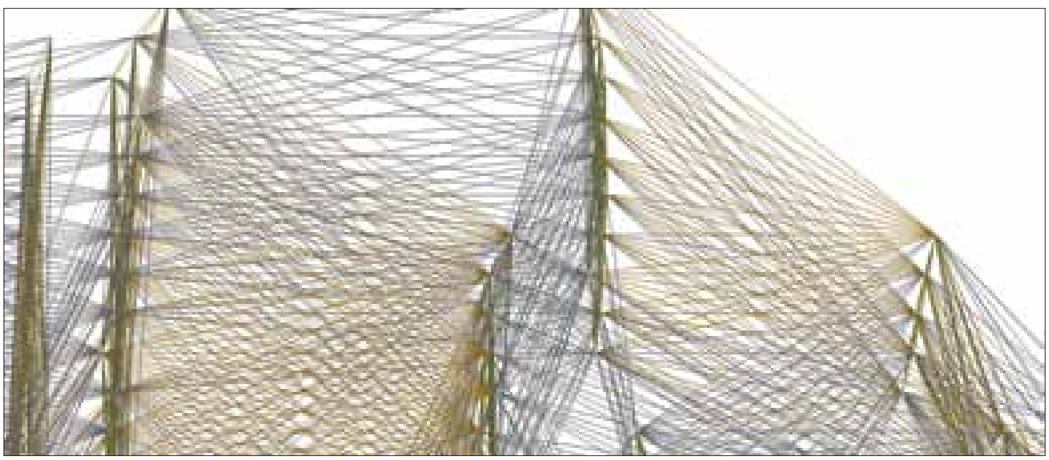


Figure 1 Networking Simulation 3, Jenny E. Sabin, 2008

Recent technological leaps in data production and computation have afforded both architects and scientists an extraordinary ability to generate information and complex form. Rather than deal in the composition of wholes, architects specializing in generative and parametric design strategies—more formally known as design computation—have adopted a bottom-up approach to the negotiation of constraints within the design process (fig. 1). This renewed interest in complexity has offered alternative methods for investigating the interrelationships of parts to their wholes, and emergent self-organized pattern systems at multiple scales and applications. The contemporary architecture avant-garde has provided many examples that showcase the proven power such digital tools afford the designer, inspiring and leading to the generation of beautiful form. But what are our next steps in addressing complexity? How should architects with expertise in design computation situate themselves in larger design dialogues concerning pressing topics such as those concerning our environment?

There is the potential, for example, to harness these skills and techniques to address such global issues through a bottom-up, systems-based approach to design ecology. This endeavor demands a closer look at the formal interplay between code and context. Biology provides useful systems-based models for architects to study to understand how context specifies form, function, and structure. While the end goals may differ in science and architecture, there is a driving necessity in both disciplines to spatialize, model, and fabricate complex, emergent, and self-organized systems. How do we intuit, see, and inhabit complex wholes that are indiscernible from their parts? Intersections between computation and material organizations reveal powerful models for visualizing and perceiving the intangible. Information gains meaning through multiple modes of expression. This desire to inhabit these realms may be driven by a deeper need to locate ourselves within this daunting terrain of digital processes, including formal, ecological, and sustainable models. Here, form is the product of the interaction of contextual events and code over time and in space. This dynamic interplay between code and context enables the production of performative and changeable architecture at multiple-length scales and oscillatory states.

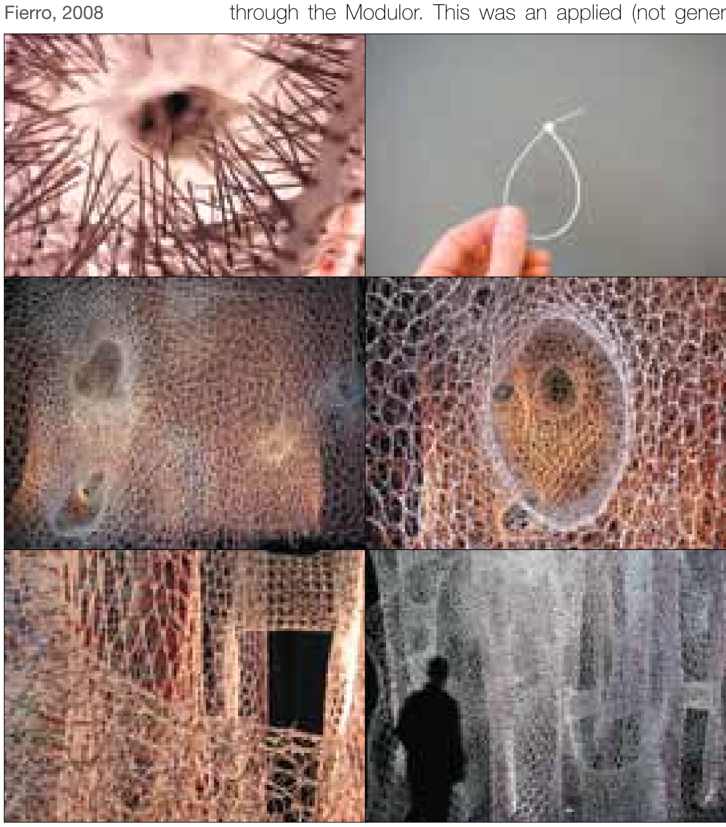
Code, Context, and Perception: Matrix Architecture and the Architect Weaver

The evolution of digital media has prompted new techniques of fabrication as well as new understandings in the organization of material through its properties and potential for assemblage. The scope of much of this experimental design work and research probes the relationship between code and pattern, material and geometry, fabrication and assembly. The following projects integrate these relationships with contextual constraints. These are frequently driven by diverse datasets arising from intersections found between science and architecture. The bringing together of code with context, through the study of natural systems and biological models, provides insight into relationships between form, behavior, and environment. Through transformations in geometry, form, and materials over time and in space, design models are found at varying scales, from that of cells to woven geometries and products to structures and forms and, finally, to building. Natural models—and, more specifically, those found in biology—offer the architect a new way of considering design ecology. The combined architectural result depends upon the visualization of complex datasets through the generation and design of computational tools. Material, geometry, and environment are not separate from each other but, rather, share reciprocal and, therefore, ecological relationships through a comprehensive modeling of inputs and outputs.

Beyond form and code or even mathematical models, this work considers contextual constraints such as site, program, and human occupation integral in the development of generative design tools and the overall scripted process. Here, code is altered, mutated, and informed by context, thus, generating not just form, but also architectural purpose and intent. In some of the listed projects, the vehicle for translation is found through material constructs and simulations that recapitulate the power of biological phenomena into different formal data constructs, while preserving essential relationships through scalable leaps into architectural contexts (see Branching Morphogenesis, figs. 2–7).

Looking to nature for design inspiration is not a new idea, but perhaps, the way that we "see" is. Architects and structural engineers, for example, have historically turned to natural models to design and build better shell and membrane structures. Cable nets have been inspired by the high strength-to-weight ratio of the spider web, as have pneumatic structures after Frei Otto's well-known soap bubble experiments, or vaults after shells and eggs composed of hard and curved materials, as well as geodesic domes after single-celled aquatic radiolarian. The structural designer Robert Le Ricolais studied the tension networks inherent to radiolarian in order to understand the dynamic properties and qualities of closed and open "skeletal" structures. Le Ricolais professed that he had "found no better discipline in this unpredictable problem of form than to observe the prodigies created by nature." Le Corbusier also looked to nature to inform his well-known proportional building system, called the "Modulor." Le Corbusier stated, "In Nature, the smallest cell determines the validity, the health, of the whole."[1] Corbusier sought to standardize and rationalize space, and the order found in nature informed many of his ideas.[2] He was intrigued by the architecture of the homes of ants and honeybees and he referred to the biology of the city.[3] He spoke of "Radiant Architecture," an architecture that would impose its influence upon its surroundings, and would be made radiant through the Modulor. This was an applied (not generative) but rule-based system Corbusier designed. In order to scale up or scale down units, the Fibonacci sequence was used to generate infinitely large or small dimensions. As a numerical algorithm whose qualities and properties are found in nature, the Modulor was a tool to modulate and arrange dimensional relationships to each other. One may even call it a very early example of a parametric and associative model.

Figure 2–7 Branching Morphogenesis, Jenny E. Sabin & Andrew Lucia with Peter Lloyd Jones and Annette Fierro, 2008



Contemporary design tools have also made the generation of complex patterns and forms accessible to architects. Concurrently, the sophistication of our design tools provides methods and means for seeing and modeling natural systems. Consequently, designing through complexity to achieve coherent results demands an ever-closer look at truly dynamic systems and a return to the study of natural models. Organic models such as those found in nature offer up modes for understanding issues of feedback, adaptation, growth, and self-assembly, as they negotiate truly dynamic environments. A rigorous understanding and analysis of these types of models will allow architects to retool and reevaluate how we negotiate topics such as complexity, emergence, and self-organization in architecture. It is not possible to translate directly these micro-scale examples to macro-scale applications, as there is no logical linear and scalable jump in geometry and material make-up from the micro to the macro. Rather than mimic or directly translate these scientific models to the human built scale and vice versa, this type of research requires a break from perceived pedagogical boundaries, thus, giving rise to new modes of thinking and working in design and science. It is through this immersion that our design tools may become more flexible by engaging a thorough assessment of truly complex and emergent systems.

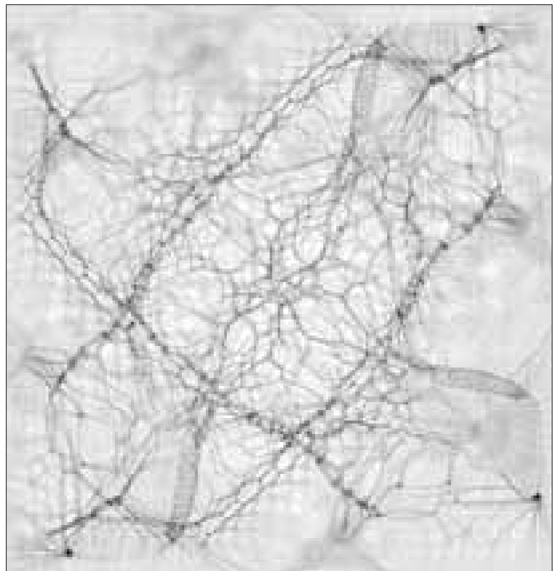


Figure 8 networking simulation, Christopher Lee and Andrew Lucia, 2008

MATRIX ARCHITECTURE: CODE IN CONTEXT

This immersion within trans-disciplinary work found at the interface between architecture, computation, and science was initiated and further fostered through the Nonlinear Systems Organization (NSO), a research arm at PennDesign founded by the visionary structural engineer, Cecil Balmond. This interface has been substantially bolstered by a 4-year strong collaboration with Dr. Peter Lloyd Jones, Professor of Pathology and Laboratory Medicine based at the Institute for Medicine and Engineering at the University of Pennsylvania. Within the context of this collaboration, we have co-founded a hybrid architectural-biological research and design unit, the Sabin+Jones LabStudio; therein, we are primarily interested in architectural models and design tools that emerge through the study of cells and tissues within tissue-specific, dynamic, extracellular matrix environments. More specifically, we are observing how micro-environmental architectures, at the level of the matrix, control cell behavior at the geometric, biochemical, and biophysical levels. The matrix environment is a cell-derived, woven and globular protein network that contacts most cells within the body—an architectural textile of sorts. Importantly, as I have come to learn from my collaboration with the Jones laboratory, this environment changes dynamically throughout development and disease; we are specifically interested in models that show how these alterations feed back to control cell and tissue behavior at the level of code and beyond, in multiple dimensions including time.

This exchange of information between the inside of the cell and its exterior environment presents a potent architectural model for understanding how context or environment shares a reciprocal relationship with code, geometry, and matter. Matrix Architecture, a term that we have coined, features formal and material attributes that are based upon interdependent relationships between environment and code. In one project, we have developed advanced imaging and scripting procedures to generate new forms and structural organizations within architectural design. This project (figs 2–7), titled "Branching Morphogenesis" (design by Jenny E. Sabin and Andrew Lucia with Peter Lloyd Jones and Annette Fierro), investigates part-to-whole relationships that are revealed during the generation of branched structures, which are formed in real-time by interacting lung endothelial cells[4] placed within a 3D gelatinous and fibrous matrix in vitro. The study and quantification of this network allow for a greater understanding of how variable components might give rise to structured networks in both biology and architecture. The "Branching Morphogenesis" installation, originally installed in the Design and Computation Galleries at Siggraph 2008 and now currently on exhibit at Ars Electronica in Linz, Austria, materializes five slices in real time to capture the predicted force network that interacting endothelial cells exert upon the neighboring matrix. The time lapses manifest as five vertical, interconnected layers made from over 75,000 cable zip ties. Gallery visitors are invited to walk around and in between the layers and to immerse themselves within an organic and newly created "Datascape." The dynamic matrix change fuses with the perceiving body through human occupation, all through the constraints of a ready-made.

Figure 9 deployable study model informed by cellular mechanics, as response to matrix environment, Misako Murata, 2008

Many student design projects have also applied the ideas set forth by the Sabin and Jones LabStudio collaboration, as well as those explored within the context of our co-taught research elective at PennDesign titled Nonlinear Systems Biology & Design. Elective courses and design studios have further developed these principles. For example, students Misako Murata and Christopher Lee applied generative tools and simulations developed in Nonlinear Systems Biology and Design to a design project calling for a public pavilion and student bookstore on the Schuylkill River waterfront in Philadelphia, PA. This second investigation took place in an advanced research studio co-taught by Cecil Balmond and myself. The students observed the networking behavior of lung cells in both normal and diseased contexts (fig. 8). In addition, the students were investigating how internal cellular mechanics, as a response to the matrix, may inspire the novel design of deployable systems and structures (fig. 9). Here, the algorithmic and digital exploration of relationships between interacting cells and their immediate tissue environment gives rise to an abstract, yet deeper understanding of architectural form as it relates to a dynamic boundary condition. The students used the tools and simulations designed to track and model these behaviors through time and in space in scalable architectural contexts for the final pavilion design. No longer working with cells, the students replaced what were

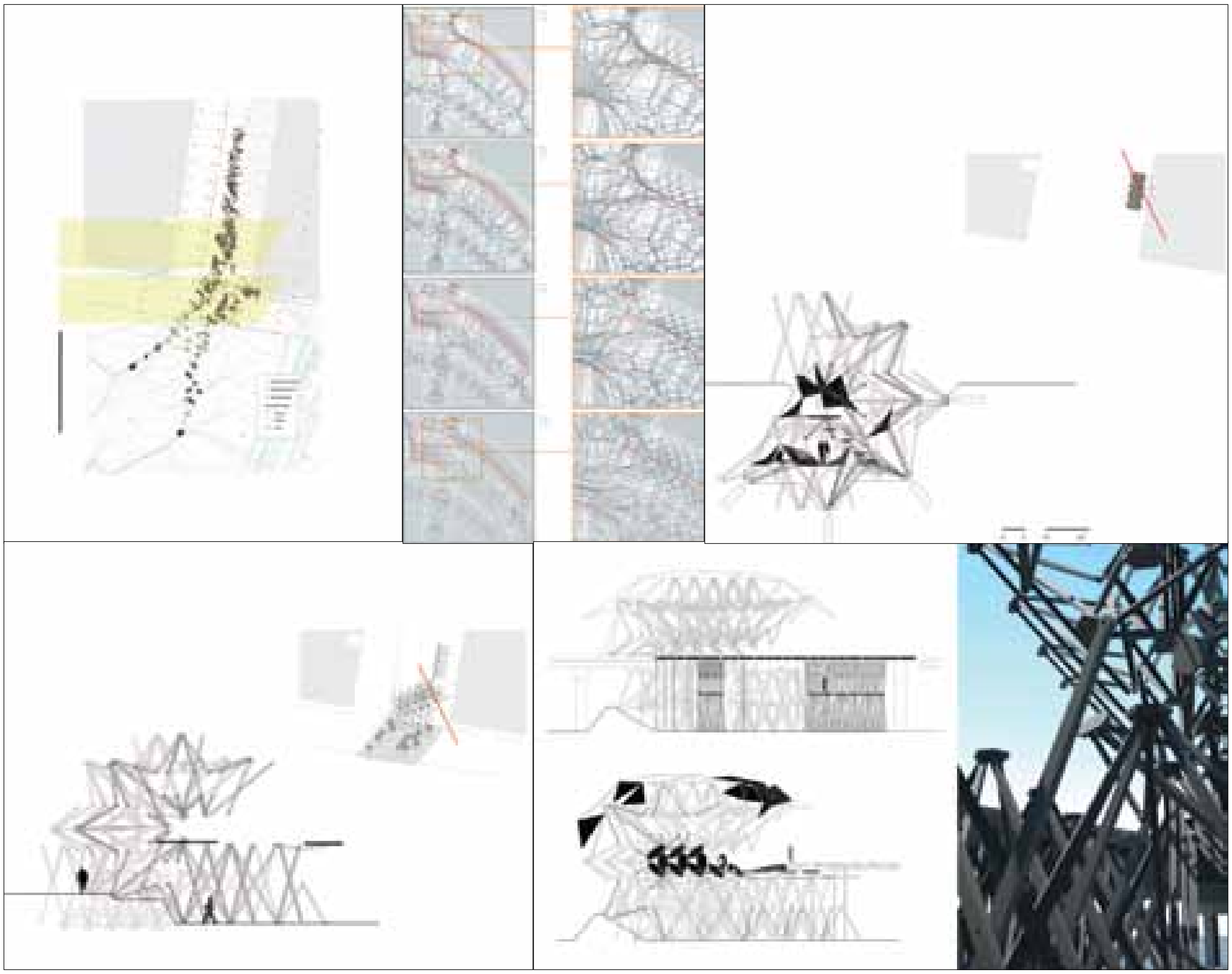


Figure 10–14 Final Pavilion Design—The deployable systems, earlier informed and programmed by the inner workings of cellular morphology, now respond, adapt and grow in concert with their existing environment, the UPenn campus waterfront along the Schuylkill River in Philadelphia. Misako Murata and Christopher Lee, 2008

once micro-scale parameters with macro-scale site-based constraints such as existing bridge and road networks and fluctuating car, bicycle, and pedestrian traffic patterns (figs. 10, 11). The deployable systems that, earlier, the inner workings of cellular morphology informed and programmed, now respond, adapt, and grow in concert with their existing environment, the UPenn campus waterfront along the Schuylkill River in Philadelphia (figs. 12–14). For example, existing constraints governed by bridge and campus infrastructure inform and alter the overall programming of the deployable pavilion. Additionally, seasonal events sparked by local campus programming, infuse the pavilion design with variegated structural and spatial behavior in response to user need.

CODE, CONTEXT, AND PERCEPTION

The international SmartGeometry Group has also served as a testing bed for several of the design ideas explained above. In one project by student Devin Jernigan, for example, he addresses the topic of waste with generative design strategies in networking models (figs. 15, 16). Jernigan's project represents a network of U.S. Environmental Protection Agency dirty waste points in New York City. The points themselves represent a diverse network of different types of waste: sewage, hazardous waste, and air emissions. These hazardous waste points are then activated as sensors for the city to determine highest density regions in the city. These regions are then equipped with cleansing "seed" towers that are able to precisely store, clean, and redistribute the waste material, acting as a local ecological contact within the city. This geometrical model is based specifically on self-justifying point sets that will create their own sub-networks specific to individual "seed" locations (fig. 17). In moving forward with this project, Jernigan hopes to produce analytical data systems, which will program and influence the design of the "seed" towers.

Like Jernigan's project, the notion of constantly recombining architecture in response to contextual circumstances is perhaps best visualized in architecture through Cedric Price's architectural proposals of the early 1960's. Price sets forth an initial coded hardware or component that is then exposed to unlimited variation through circumstances external to the actual building units. As Arata Isozaki comments on Price's Fun Palace project in his essay titled Erasing Architecture into the System, "Fun Palace would change its entire appearance as performance spaces moved about and contents shifted. The important thing was that there no longer was any strict time or space composed by the

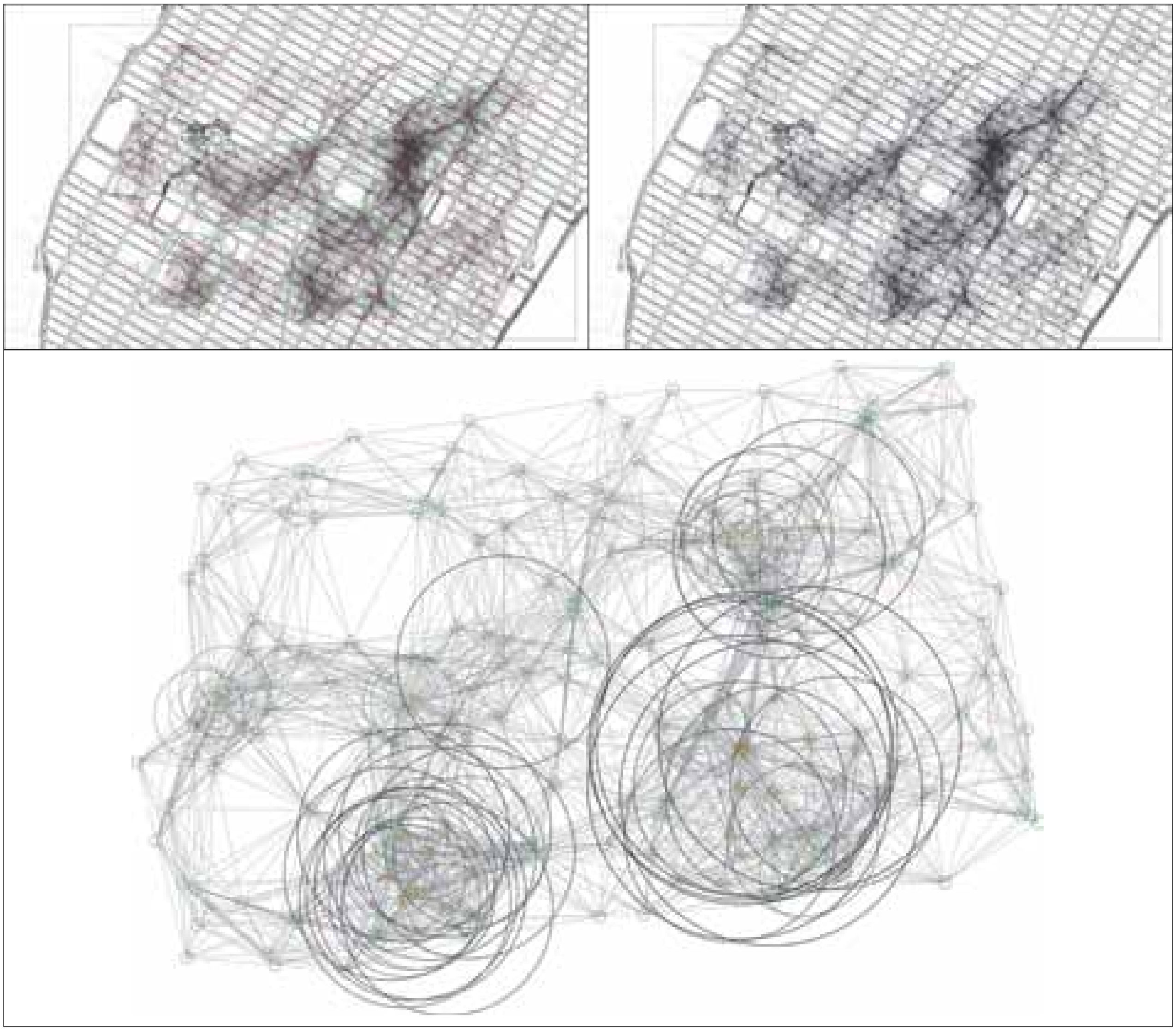


Figure 15–17 WASTE – networking strategies to address the topic of waste in NYC – Devin Jernigan with Smart Geometry senior tutor, Jenny E. Sabin, 2009

artist but, rather, mechanical systems reconfiguring in every possible way in response to circumstances." Isozaki continues by stating that this may even be called anonymous design. Here, Price gives us a minimal selection of networked units that may reconfigure into architectural elements (screens, light poles, inflatables, frames, and sunblinds) based on users' requests, programmatic need, environmental factors such as weather, or just plain fun. Fun, in this sense, is generated by improbable events elicited by the uncertain chance of hardware (component networks) recombining and responding to human occupation and play. Code and context form a reciprocal loop where the newly created by-product is architecture of excess and unpredicted activity. Our own perceptive prowess now enters the mix.

The possibility of bringing biomaterial behavior into tangible architectural constructs presents new models for architecture. These models express how context-driven form is, substantially, the result of a complex interaction of code with contextual events and/or constraints. This format challenges our contemporary understanding of digital and generative design through rigorous collaborations with scientists and a return to the study of nature. In turn, it calls for greater responsibility and agency on the part of the architect. Given today's suite of environmental and economic issues, architects working in design computation should expose themselves to larger questions surrounding the topic of complexity. We need to address issues of performance, feedback, and ecological building in new ways, alongside those of human experience, occupation, and perception, among others. As was presented in the project "Branching Morphogenesis" (figs. 2–7), geometry and code alone do not complete an architectural and spatial proposal. It is the insertion of the human body, and of perception coupled with code and context, that works to create a generative interface, a perceiving and sensing architecture, one that is fleeting and boundless, and constantly being woven and unraveled by radical codes, relentless environments, and perceiving bodies.

Design ecology, therefore, is a product of reciprocity, where code, pattern, geometry, material, issues of fabrication, and, especially, the body in its environment are inextricably linked. This reciprocity situates our roles (researcher, architect, teacher/student) at the interface between environment and entity at multiple-length scales and oscillatory states. The once daunting terrain of digital and generative processes may challenge and afford us not only beautiful form, but also informed form.

CONCLUSION: THE ARCHITECT WEAVER

The exploratory and experimental architecture described here demands collaboration and requires participation in two-way dialogues. It favors process-driven research over goal-driven research. Its vitality is dependent upon intuition or knowing where to look along the way. This clarity comes forth from doing, making, collaborating, and failing. "Knowing where to look" requires a constant refinement of one's intuition.

There are no fields in this artful and scientific pursuit; rather, it undulates within a multi-set of refined intuitions. It embraces, teaches, and explores abstract concepts that reflect across and over perceived pedagogical and disciplinary boundaries. Spikes along this continuum articulate discovery and new ways of seeing. It is neither about breaking down walls nor sampling across, but rather is about continuity and connectedness. Specificity, specialty, and subjectivity are in the "seeing."

In this act of "seeing," the architect designs through a space of connectedness. This space is an unfolding body that draws itself from an undulating matrix of data rich in qualities. It is more than just sampling bits. As opposed to connecting the dots, the architect intuits the next, the prior, and the adjacent simultaneously. The architect is a conceptual weaver working backwards, forwards, and across linked data sets. Here, loose-loop and tight-loop configurations give rise to new rhythms, new effects, and perhaps, new visions for an adaptive and performative architecture.

The generosity of this collective creative force draws itself from the undulating plane at a distance, which takes in all past, present, and future collaborative acts. We might call these momentary acts of disturbance "fray." Intuition enables the architect-weaver to locate zones of fray within the undulating plane, where geometric figures, matter, and form reside.

Historically, the visionary and short-lived Black Mountain College of the late 1940s and early 50s occupied one such conceptual zone of fray. Here, designers, artists, choreographers, structural engineers, and musicians gathered to push forward new techniques and proposals in design and the arts. Bucky Fuller's failed attempts at his first geodesic domes gave rise to new questions and new ideas on tensegrity structures. Simultaneously, the artists and Black Mountain College instructors Anni and Josef Albers introduced a concept that they called Meander. They used this concept to teach a bottom-up approach to pattern generation and simple mathematical relationships to describe parts in relationship to their compiled wholes. Such abstract concepts reflected across and over perceived pedagogical boundaries gave rise to new ideas in design and the arts. Perhaps we are in our own Meander, this time embracing established disciplines in a collaborative environment devoid of boundaries, sifted through, compiled, and woven by architect-weavers.

Code in context informs the weaving of structure and space to generate a boundless and undulating architectural fabric. Intuition offers the on/off nature of the weave a fourth dimension. Systemic oscillations undulate along the conceptual fabric, and the pattern responds. Architecture resides within the events elicited by the undulating and interlacing conceptual threads. In loose-loop and tight-loop configurations, an event emerges from chaos. The architect-weaver engages a space that is about working across disciplines, where collaborative design drives new visions in structural and intensive flows. What is even more potent, however, is the conceptual space these linkages offer. The fabricated result may always exist within metric space, but the process itself engages a smooth space that undulates and moves horizontally as it searches for optimal applications, either material or digital, within a coded and contextual logic. What lies immanent finds meaning and material through a filtered space, a woven space that holds the residual tracings of code, context, and perception.

ENDNOTES

1 FLORA SAMUEL, LE CORBUSIER IN DETAIL (OXFORD: ARCHITECTURAL PRESS, 2007), P. 1.

2 IBID., PP. 15–16.

3 IBID., P. 16.

4 ENDOTHELIAL CELLS LINE THE INTERIOR SURFACE OF ALL BLOOD VESSELS, FORMING AN INTERFACE BETWEEN CIRCULATING BLOOD IN THE LUMEN AND THE REST OF THE VESSEL WALL. IN THE HUMAN LUNG, THE SURFACE AREA OF ENDOTHELIAL CELLS IS APPROXIMATELY THE SIZE OF A TENNIS COURT!