

Process Innovation

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It's a problem of our time. The range of human knowledge today is so great that we're all specialists and the distance between specializations has become so great that anyone who seeks to wander freely between them almost has to forego closeness with the people around him.

—Robert M. Pirsig, *Zen and the Art of Motorcycle Maintenance*

If the late twentieth-century architectural canon was defined by its portrayal as a solo act, the early twenty-first is on a trajectory to usurp this representation. The processes by which architectural works are created are becoming increasingly innovative and diverse, reaching beyond the boundaries of the profession, eschewing the traditional client-practitioner-consultant team structure to include interdisciplinary researchers and academic specialists. Likewise, the architectural design team is becoming more diverse, calling upon skill sets that are more akin to software and application development. Synthesis becomes increasingly critical as we attempt to leverage computational methods, environmental design, and academic collaboration towards the creation of new opportunities and potentials for intersection of architecture with contemporary issues, redefining definitions of practicing “generalist” as we develop and implement focused project-specific specialization.

Custom Tools

If we examine, as a whole, the current relationship between architecture

and computational assistance, we can see there is a progressive trend toward a new paradigm which has, relatively recently, begun moving with real momentum. Software adoption has transcended CAD into the multidimensional world of BIM. And yet still, as much as our livelihoods now depend upon specialized software applications, architects have been reluctant to delve into their inner workings. This hesitancy is understandable. Few disciplines require as much specialized knowledge in as many distinctly separate fields as architecture; computer expertise can sometimes be seen as a necessary evil tacked on to an already overwhelming knowledge-base.

One of the earliest benefits resulting from the merging of design and programming training has been a steady reclamation of our digital toolsets. As hand-drawn production drafting gradually gave way to CAD, the maintenance of a sizable part of our craft was relinquished to software developers. We were left largely dependent upon an outside party to determine what features were important. Only firms of the highest clout (or purchase power) have had any persuasive say in the composition of our software. However, even with this influence, we have sometimes been forced to wait through many product release cycles before vital functions can be implemented to applications to support our workflow.

Efforts to reclaim our tools have started small, but are rapidly gaining

momentum. Through the use of API (Application Programming Interface) we have been able to create custom extensions which enhance functionality of a host application. This allows us to sidestep the software industry's often slow implementation schedule, and empowers us to create custom solutions for our needs. Our process may, in certain ways, be intrinsically linked to the medium in which we choose to work, so this opportunity is important because it affords the architect the ability to break free from the mold in which the software packages are cast. Interdisciplinary designer Bruce Mau, in his “Incomplete Manifesto for Growth,” argues that “the problem with software is that everyone has it.” With the ability to create our own software, we now regain differentiating elements of analog process by making our own tools again. The visual programming environment of Grasshopper has lowered the bar of entry into the world of scripting by allowing us to experiment with code in a more fluid, intuitive way which is more natural for those in a field dependent upon visual and spatial intelligence. More importantly, however, is the camaraderie of the architectural scripting community that has blossomed around open programming environments where people freely exchange new ideas and methods. Bits of code are posted, analyzed, rebuilt, and shared again for the benefit of the entire community rather than a privileged group of developers. Now that we are empowered to develop our own tools instead of waiting for third party implementation, and because of

the increased focus on programming education, we're amassing more staff that is literate in both architectural design and our newly adopted languages of logic and mathematics.

Within our studio practice, we leverage desktop computing to accomplish things that would often be impossible or take us far too long to perform with a manual method—which is the model of computing in general and not in itself anything new. However, we are increasingly reliant upon advanced computational methods to transcend the typical UI (user interface) of commercially available software applications. Leveraging programming and coding with languages including C++, computational designers on our team create custom applications with corresponding UIs that allow us to more effectively design, understand, and manage complex geometry. With this improved management of three-dimensional digital geometry, we communicate more directly and accurately with other partners of our project team, including fabricators, consultants, design partners, and engineers. Though not born entirely of current necessity, our methodology is shaped predominately by the challenges of practice today, a market wherein reconciliation of quality, schedule, and budget often determines ultimate success for our clients and stakeholders. Within the construct of this model, and particularly with high-profile sports stadia, our efficacy relies upon our ability to understand myriad complex in-

terrelationships of constraints of physical, empirical, temporal, spatial, financial, and experiential origin. Increasingly, this understanding requires such bandwidth, that we must divert our thinking to create mechanisms first for understanding and then for processing vast quantities of information so that the requisite synthesis that enables design can occur.

A current project, a stadium in Los Angeles, features an enclosure comprised of over 70,000 unique metal panels. The scope and scale of this endeavor, while perhaps impressive in some way, is not a consequence of the availability of sophisticated computer applications, but rather a manifestation of the convergence of context and progressive thinking. The project scope necessitates a high degree of computational

efficiency. Processing of image-based perforation patterns using commonly used architectural design applications can be problematic and inefficient for large scale implementation. A team of invested collaborators is aligned in the idea that the experiential quality of design remains an important criterion for success of this project. Computational designers in our studio implemented a custom-scripted application

designed to allow us to design, develop, visualize, coordinate, and deliver the enclosure to a fabricator through a digital text file of descriptive information of each panel. The application is developed in C++ using Visual Studio 2015. Various open source libraries are implemented including OpenGL for visualization and ArrayFire for GPU based matrix calculations and image processing. (Figure 1)



Figure 1

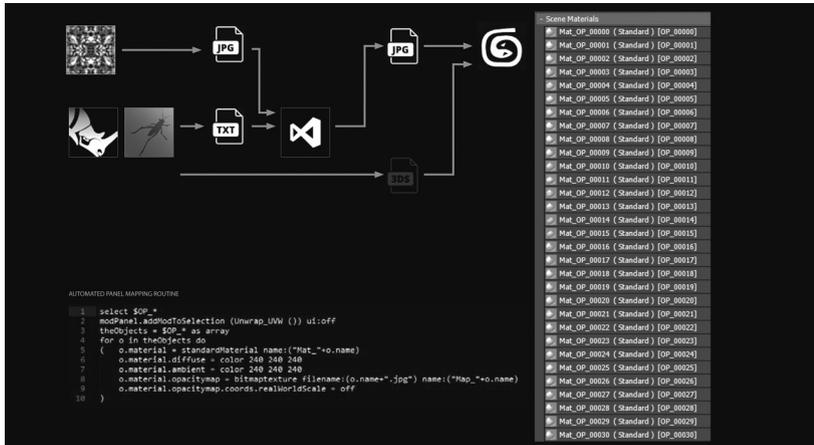


Figure 2

The functionality of this application includes provisions for transformation of panel geometry within a design development model with world space coordinate orientation into the local machine space coordinate description. It also calculates perforation patterning and image processing based on global mapping of an image file and fabricator-specified constraints. A GUI describing panel and perforation analytics at both global and local levels accompanies the provision for writing local alpha mapping files for rendered visualization. (Figure 2)

Since this project will utilize a file-to-fabrication workflow with the shell enclosure being documented and delivered in digital model format in lieu of paper drawings, per our recent development with the California Architect's Board,¹ we are also using the application to write local .txt description for fabrication post processing into G-Code. In the event that traditional shop drawing review becomes necessary, we also have a provision for writing local .dwg files. (Figure 3)

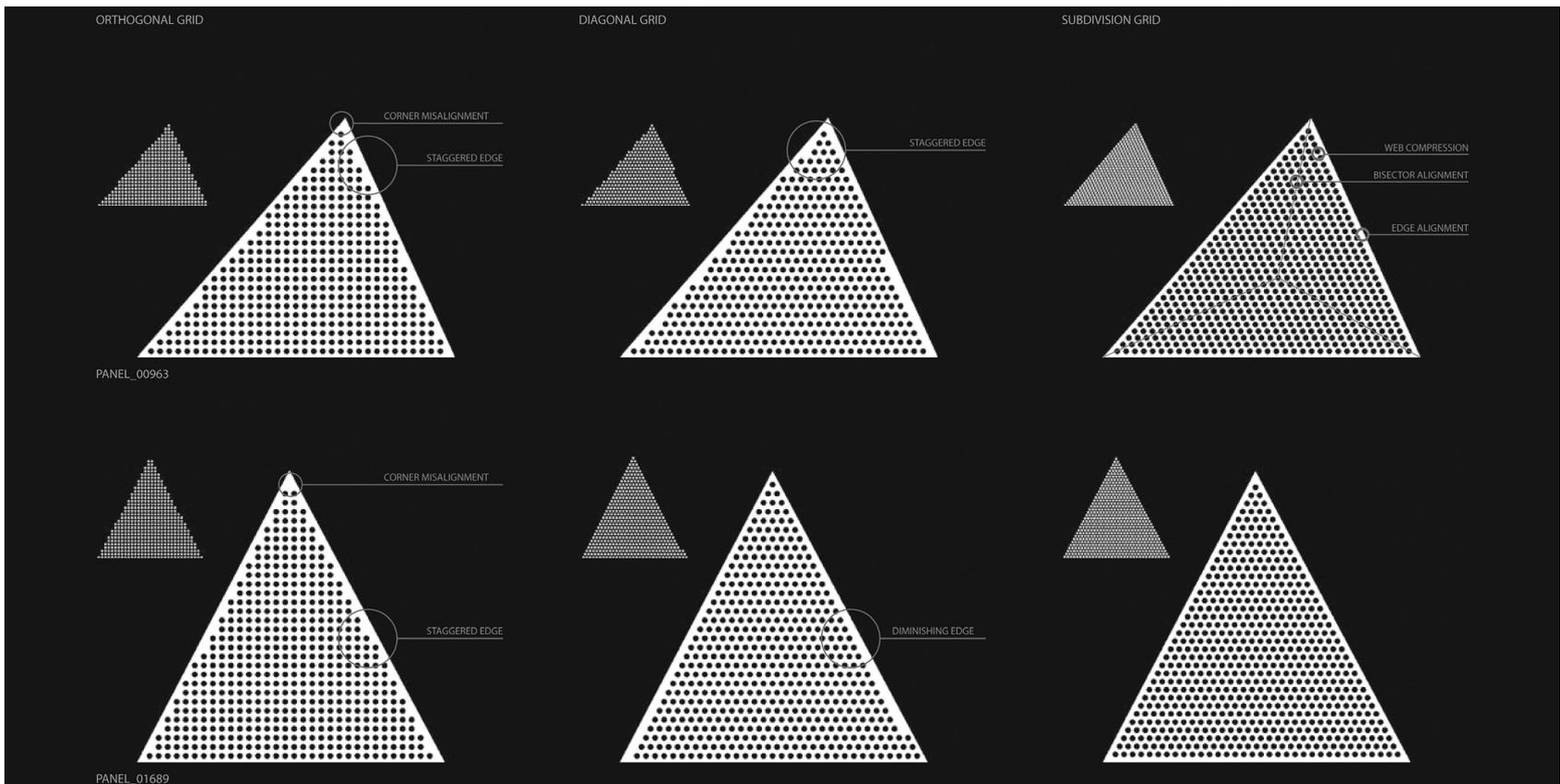
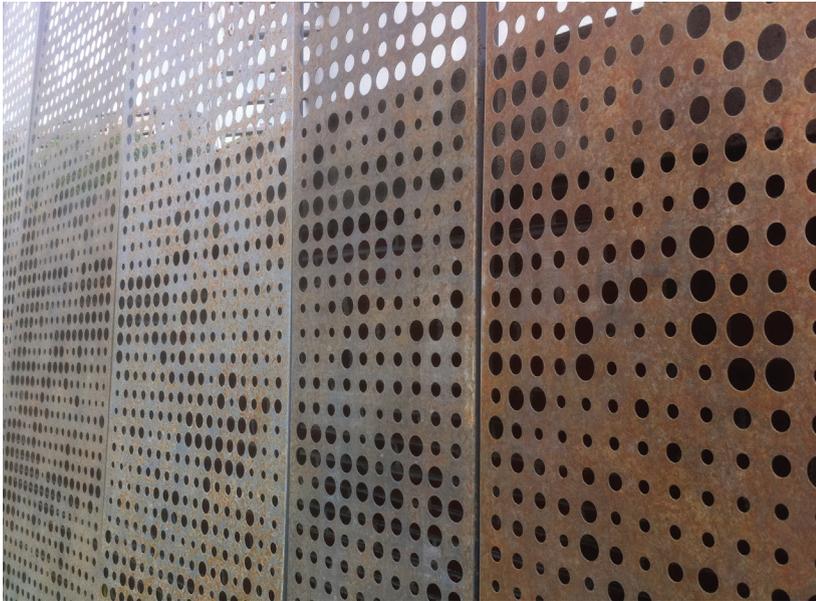
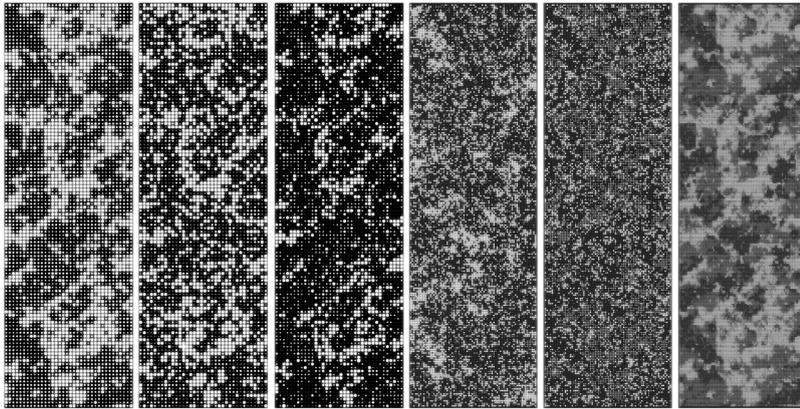


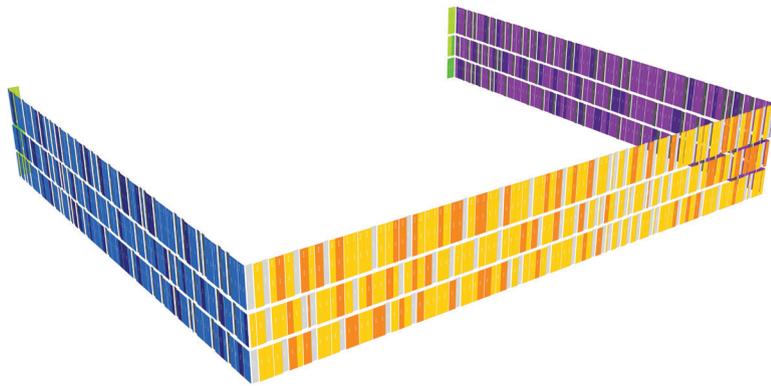
Figure 3



Prototype weathered zinc perforated panels for Children's Hospital of Richmond Pavilion, (panel by Zahner Metals)



Perforation pattern study, CHoRP panels



Panel type and location mapping, CHoRP

Environmental Design

The same processes that can manipulate such huge quantities of data into nearly unimaginable forms have a much more immediate and relevant application within the field of performance-based computational design. This approach is not presupposed by formal characteristics, but rather by information which will influence the design as a resultant of the generating criteria. The product then is not merely a formal exploration, but can be expanded to include items such as daylighting control, energy analysis, community analytics, and planning operations (to name a few).

As a studio we don't define a distinction between design versus sustainable design, it is just a way of working. We do however, seek to understand more about energy and building systems so that we can effectively practice. A critical part of our process is enabled through the translation of very specific engineering information into more generalized conceptual models of how things work. The ability to participate in energy and systems conversation with collaborators and consultants allows us the opportunity to work in an integrative way—a multi-directional dialogue between the members of the project team. While traditional role definitions might have served architecture through hundreds of years and transcended movements within different eras, contemporary conditions not only offer us the ability to blur the edges or even altogether dismiss

the idea of predefined roles, they sometimes require we redefine our process.

Considering the observed increasing rate of change of our climate, and respecting our commitment to the 2030 challenge, we must design for our changing world in ways that go beyond doing less harm. Despite the prevalence of green-building validation institutions (i.e. LEED), project teams often lack alignment, and architect ego and client criteria can drive a project forward, bereft of integrative environmental strategies, with technical experts brought in late in the process to reconcile environmental impact with design. The natural conclusion to this process is an effort to apply sustainability via external solutions that are often implemented in a vacuum. We challenge this archetype in pursuit of meaningful impact on the built environment through design. This endeavor requires a deeper understanding of the non-linear, combinatorial effects of our design decisions, as well as the ability to address them earlier in the development of the project. Therefore, a careful analysis of ecology, climate, cultural precedents, and contextual relationships should be used to develop the organizing concepts.

A general knowledge and understanding of the fundamentals of thermodynamics and energy allows an architect to progress beyond the defined boundaries to collaborate with the team, leveraging the topical

expertise of the engineer to achieve improved performance. The critical path to this methodology is developing the general knowledge required to engage with the specialist in a meaningful dialogue. Alternatively, more specialized educational curriculum now exists which enables us to employ design architects who have hybridized knowledge and skill sets more inclusive of engineering. The person with this kind of education brings a nuanced depth of understanding in the realm of climate, energy, and environmental performance. The benefit of a core team with these capabilities is that now we can do better work because we can

accomplish two critical things—we can simulate with a building energy model even when we lack an engineer on a project, and we can also perform more of the energy analysis and simulation when collaborating with an engineer. The former benefit allows us to work more effectively in early concepts or in competitions when partnering with an engineer day one is either problematic or otherwise not an option. The latter allows us to more closely knit climate and energy simulation into our design process, with generative design available when we have a direct link between our geometry model and our simulation models.

Perhaps more important than the creation of fluid forms and form-finding are the analytical drivers behind the process of finding the form, accounting for processes such as the psychological aspects inherent in geometric forms, their relationship to human physiology, and the influence of physical environmental factors on real-world objects. In this way, architectural modeling today has advanced since its predecessors of the 1990s and the oft-derided, but developmentally important, “blob-architecture.” Parametric and algorithmic modeling allows us to input useful numeric data [such as climate data, structural analysis (stresses and

strains), fluid dynamics testing (the effects of wind and water), thermodynamics, and acoustic analysis (to name a few)] toward the creation of geometric form. This allows models to be designed not just by their geometric Euclidean definition, but rather by the relationships between objects and the physical forces acting on them over time. This allows designers to advance beyond form-for-form’s-sake (created in a vacuum), but gives the ability to measure form (and other like variables of a given project) against performance/fitness criteria. This brings us to another innovative leap, simulation, which enables designers to simulate sce-



narios with real world physics and view the possible outcomes before construction occurs. Previous eras, through trial-and-error, needed large lengths of time to test the fitness of built designs over decades and centuries, fine tuning their built-designs by making incremental adjustments. The present time period evolving from manual analysis toward computational analysis and simulation in building design may be likened to a time period in human evolution when humans were transitioning from body gestures to spoken word or from spoken word toward the transfer of ideas through written word. Once ideas were able to be

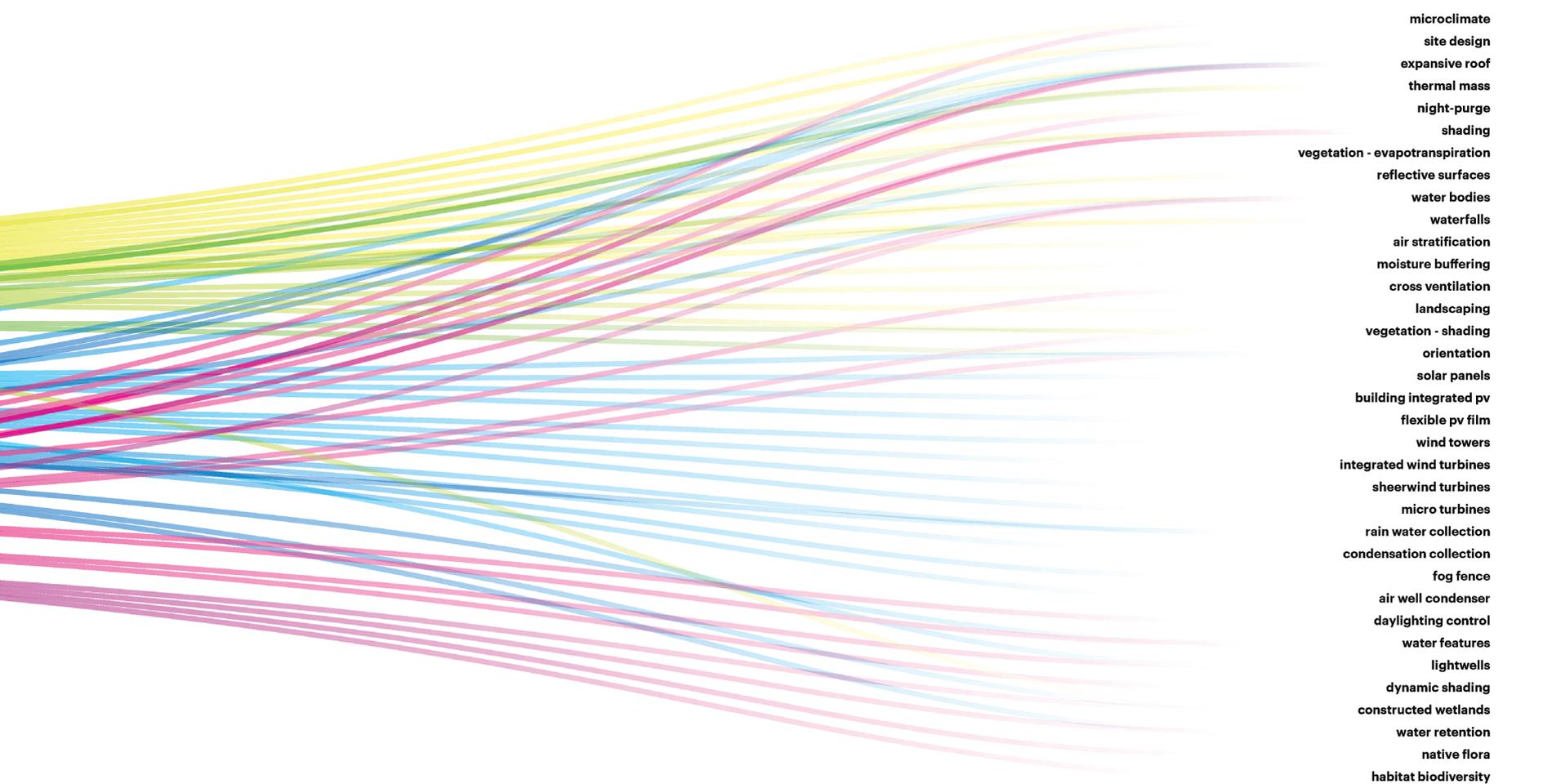
written down and transmitted over subsequent generations, knowledge and learning grew exponentially. In the larger context of human evolution, the processes of simulating ideas before they occur in the real world through implementation of real-world analytic data is another such milestone. Through the use of simulation, such as in the case of implementing evolutionary genetic algorithms, we are able to evolve the design of buildings and components through thousands of generations, even simulating millions of generations that evolve through factors of environmental influences (fitness criteria) upon a form or structure.

Rather than waiting decades to fine-tune real-world structures we are able to simulate this in a matter of minutes, hours, or days (depending on scope of criteria, geometric complexity, and computational affordance), arriving at the fittest solution before construction even begins.

Systems Thinking provides a way for us to understand individual issues as parts of a larger system; the components of a system can be better understood when considered in the context of their relationships with other components. Rather than focus on specific issues, events, or outcomes, we construct strategies

capable of addressing a problem that are more dependent upon the inter-relationships of components and are more resilient to external influence. Key to defining these strategies is a firm understanding of the local context. Systems thinking influences the methodologies behind our project-specific Design Briefs and their resulting influence in our design process. (Figure 4)

Thanks to the plethora of data made available by various federal and commercial entities, we have unprecedented access to historical climate information in a format that we can directly apply in our design workflow.



Combining this access with the ability to generate digital simulations of our buildings and building systems gives us extraordinary influence: within a relatively short time frame we can iterate through many design options and evaluate each of them via their simulated performance in a given environment. This closely mimics the natural trial-and-error method of vernacular architectures worldwide, within a timeline that is compatible with a contemporary construction schedule. However, care must be taken to avoid the pitfall of one-dimensional optimization wherein a particular design solution is studied without regard to other influencing constraints. Our structures and occupants must actively work together to form singular, cohesive wholes in order to optimize the use of resources while maintaining human comfort. We must emphasize that synthesis of information, both collected and generated, enables us to develop a layered approach to

environmental optimization across a variety of scales and typologies.

The design of a high(er) performance building starts with a deep understanding of the local climate and site context. Climate information pulled from the last 30 years is meticulously analyzed to formulate passive energy-effective strategies which, when combined and layered upon one another, help guide the design team in their derivation of initial massing concepts. These broad brush strokes are further refined during a series of simulations that can quickly evaluate multiple design options and their relative success in addressing a number of criteria including: solar exposure, glare, and building envelope thermal performance. Simulation allows us to predict the real-world behavior of various building systems using physics-based analysis software. These metrics can then be used as a basis of comparison when evaluating existing precedents and/

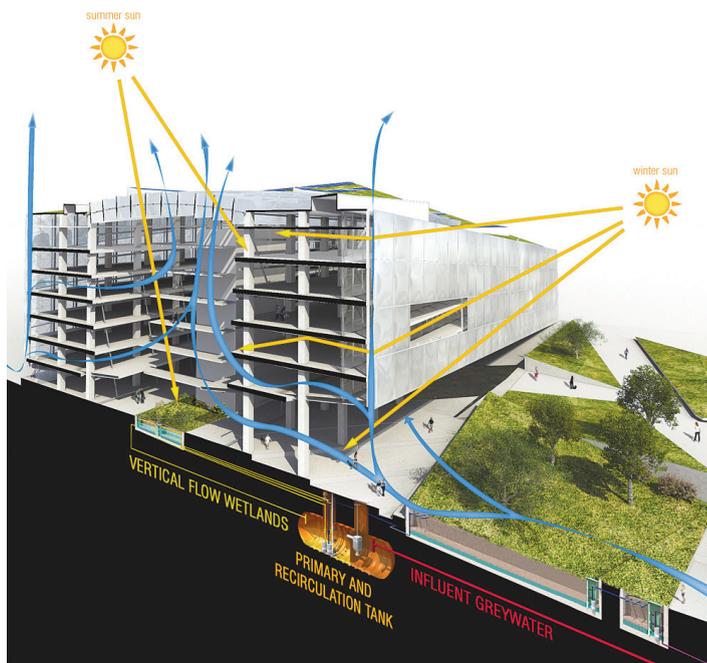
or multiple iterations and permutations of potential solutions.

Further refinement of the design can then be achieved via optimization routines that finely tune portions of the design in response to conditions unique to each building's context and typology. Key to this process is the idea of a parametric model which generates a geometric form based on the relationships among design criteria (parameters). This approach allows us to generate a nearly infinite number of design possibilities within a given rule set, and plot their performance relative to one another in a recursive simulation loop. The end result is a design that leverages both intuition and computation, and reconciles aesthetics and performance.

Academic Collaboration

In a time of marked, rapid change within the design and construction industry, architectural education must evolve to provide the founda-

tion for designers in this era to learn to synthesize the often incredibly complex interrelationships involved in contemporary practice. Issues of environmental responsibility are now simply part of our work, and any developmental model used with students should prepare them for the lifelong learning that architects must embrace to be effective. Key to the development and implementation of the aforementioned skill is a solid grasp of the mechanics of computer programming. It is anticipated that considerations of literacy in the near future will require the ability to read and write the language of our machines. It should then come as no surprise that there has been a persistent effort by academia in recent years to introduce scripting into the design curriculum of universities around the world. Fluency in this new architectonic language will allow us to work directly with information to simulate, solidify custom components to fabrication, and enhance the



Section diagram illustrating systems, gsa_next generation renovation proposal



Rendering illustrating ETFE panelized exterior air curtain, gsa_next generation proposal

performance of our buildings. As part of initial strategic conversations with Professor Brad Bell leading toward his creation of the Digital Architecture Research Consortium (DARC) at the University of Texas at Arlington, I have witnessed a new paradigm of education coalesce. Disruptive to the status quo, our collaborative education effort has provided a space for practice and academy to overlap in a way that promotes innovation in not only how students are learning, but even how they are entering into and influencing the profession. With this type of education, practicum can assist academia in teaching students the value of reflection and awareness so that they can honestly critique their progress and learn to identify deficiencies in their work and interaction within a collaborative environment. With structured, collaborative research and project work, DARC students engage more fully and realistically with their team, including consortium fabrication partners. This is a critical

and increasingly important aspect of practice that prepares students to impact projects immediately upon hiring because they have learned how to ask the right questions and speak the language of those responsible for helping to implement and realize the design. An understanding of the file-to-fabrication process is valuable and increasingly necessary for contemporary practice, and students of these kinds of programs can offer use this understanding to work with employers and clients as contributing partners in the project team. (Figure 5)

A recent collaborative research studio exploration into Polyvalent Structural Systems offered our studio a chance to work directly with a team of DARC students as they investigated the potentials of this topic, and the resulting research was featured in an article in *Architect* magazine in 2015. We value the developmental potential in leveraging regional and professional partners to invest in the

education of our next generation of architects, and this evolving paradigm is already making a difference in the profession. DARC helps students with the well-rounded thinking to work as a generalist architect and the acumen to engage computational design and digital fabrication experience for implementation of innovative design solutions.

Moving forward

The essence of process innovation is rooted in change. It is explicitly a response and a precursor to change, both reactive and catalytic. Rather than conclude with a prescriptive strategy, we advocate that our position within an interdisciplinary collective enables us to evolve first our awareness, then our thinking—and through this framework, we can most effectively design our processes.

Notes

1 HKS independently sought and received approval from the California Architects Board to stamp and seal a digital model in lieu of drawings, in anticipation of the LA Rams stadium.



Interior rendering illustrating atrium with operable ETFE roof, gsa_next generation proposal

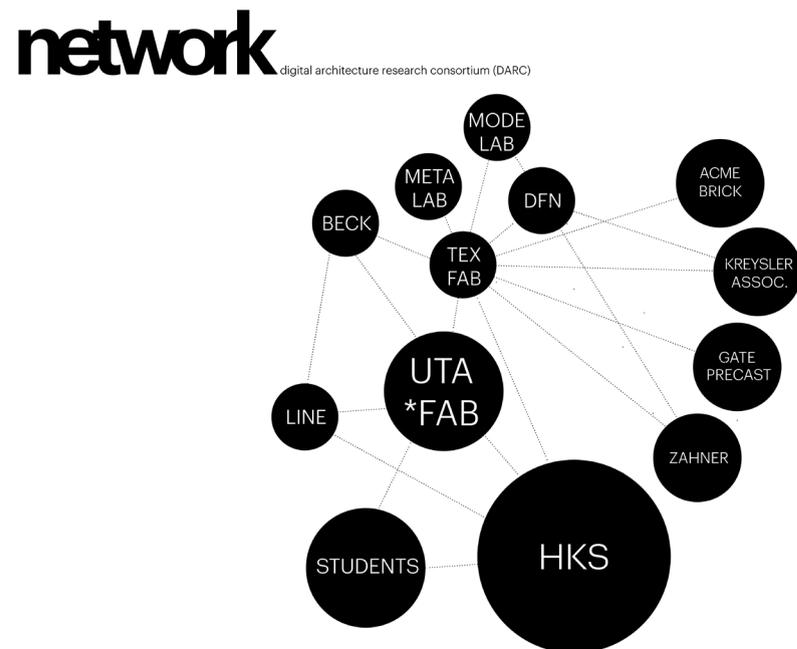


Figure 5