Post-Digital Architecture: Towards Integrative Design

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Abstract

In this paper, an alternative vision of integrated design is proposed that is more open, fluid, pliable, and opportunistic in its search of collaborative alliances and agendas. This alternative approach is referred to as integrative design, in which methods, processes, and techniques are discovered, appropriated, adapted, and altered from “elsewhere,” and often “digitally” pursued. The designers who engage design as a broadly integrative endeavor fluidly navigate across different disciplinary territories, and deploy algorithmic thinking, biomimicry, computation, digital fabrication, material exploration, and/or performance analyses to discover and create a process, technique, or a product that is qualitatively new.

Introduction

Concepts such as integrated practice and integrated design have gained prominence in architecture over the past several years as relatively new paradigms. What is usually meant by these terms is a multidisciplinary, collaborative approach to design in which various participants from the building industry – architects, engineers, contractors, and fabricators – participate jointly from the earliest stages of design, fluidly crossing the conventional disciplinary and professional boundaries to deliver an innovative product at the end.

Integrated design and integrated practice have emerged as a result of several, initially unrelated organic, bottom-up developments within the building industry. At one end, the (re)emergence of complexly shaped forms and intricately articulated surfaces, enclosures, and structures has brought a close collaboration from the earliest stages of design among architects, engineers, and builders, out of necessity. The binding agent of the resulting disciplinary and professional integration were various digital technologies of design, analysis, and production that provided for a fairly seamless and fluid exchange of information from conception to construction, often defying the existing ossified legal structures of clearly delineating professional and disciplinary responsibilities.

At the same time, building information modeling (BIM) has emerged as a technological paradigm promising a way to encode comprehensively all the information necessary to describe the building's geometry, enable various analyses of its performance (from the building physics point of view), and directly facilitate the fabrication of various components and their assembly on site. BIM, as a technological platform, however, demands a structural redefinition of the existing relationships within the industry, if the various players are to fully realize the potential of better, faster, more direct exchanges of information. In other words, BIM’s message is that the integration of information within the industry requires process-wise and structural integration of the various disciplines and professions comprising the highly fractured building industry today.1
An equally important development over the past decade was the emergence of the design-build enterprises that, through the way in which they are structured, inherently imply close integration of design and building. The principal motivation behind them is a reduction in substantial inefficiencies that exist due to the fractured nature of the industry, and the implied, profit-motivated desire for integration.

The separate paths towards integrated design and practice stemming from the expansion of design-build within the industry, introduction of building information modeling as an enabling technology, and the emergence of increasingly complex building forms, are increasingly converging, leading many to believe that integration within the industry is an inevitable outcome as architecture, engineering, and construction enter a “post-digital” age, i.e. as the digital technologies become increasingly transparent in their use. While the higher degrees of integration promise buildings that are better, faster, and cheaper to design and construct, the challenge is to avoid closed systems of integration and to keep integrative tendencies as open as possible, conceptually and operationally.

While integrated design could be understood as a well-defined (and thus closed) constellation of related disciplines and profession, integrative design, I believe, implies a much more open, more pliant conceptual and structural platform on which architecture could continue to develop in its post-digital stage as it embraces ideas, concepts, processes, techniques, and technologies that were until recently considered to be within the domains of “others.”

**A Brief History of Disintegration**

Architecture and building were once “integrated.” For centuries, being an architect also meant being a builder. Architects were not only the masters of geometry and spatial effects, but were also closely involved in the construction of buildings. The knowledge of building techniques was implicit in architectural production; inventing the building’s form implied inventing its means of construction, and vice versa. The design and production, architecture and construction, were integrated – one implied the other.

The master masons of the Middle Ages were in charge of all aspects of buildings, from their form to the production techniques used in their construction. They had the central, most powerful position in the production of buildings, stemming from their mastery of the material (stone in most cases) and its means of production. As the palette of materials broadened and the construction techniques became more elaborate, the medieval master masons evolved into master builders (or architects) who would integrate increasingly multiplying trades into an increasingly more complex production process.

The tradition of master builders, however, did not survive the cultural, societal and economic shifts of the Renaissance. Leon Battista Alberti wrote that architecture was separate from construction, differentiating architects and artists from master builders and craftsmen by their superior intellectual training. With Alberti’s elevation of architects over master builders came the need to externalize information (so it could be communicated to tradesmen) and the introduction of orthographic abstractions, such as plan, section and elevation, intro the currency of building. Architects no longer had to be present on site to supervise the construction of the buildings they designed.
The rifts between architecture and construction started to widen dramatically in the mid-nineteenth century when “drawings” of the earlier period became “contract documents.” Other critical developments occurred, such as the appearance of a general contractor and a professional engineer (first in England), which were particularly significant for the development of architectural practice as we know it today. The relationships between architects and other parties in the building process became defined contractually, with the aim of clearly articulating the responsibilities and potential liabilities. The consequences were profound. The relationship between an architect (as a designer of a building) and a general contractor (as an executor of the design) became solely financial, leading to what was to become, and remain to this day, an adversarial, highly legalistic and rigidly codified process. The architect’s role on the construction site, instead of shaping the building (as master builders once did), became the contractual administration, i.e. the verification of the contractor’s compliance with the given contractual construction documents. The design was split from the construction, conceptually and legally. Architects detached themselves from the act of building.

The twentieth century brought the increasing complexity to building design and construction, as numerous new materials, technologies and processes were invented. With increased complexity came increased specialization, and the emergence of various design and engineering consultants for different building systems, code compliance, etc. The disintegration was thorough, deep, but fortunately, reversible, as shown by the various developments within the industry over the past decade, briefly discussed earlier.

Reintegrating out of Necessity

Over the past decade we have seen in architecture the (re)emergence of complexly shaped forms and intricately articulated surfaces, enclosures, and structures, whose design and production were fundamentally enabled by the capacity of digital technologies to accurately represent and precisely fabricate artifacts of almost any complexity. The challenges of constructability left designers of new formal and surface complexities – whether “blobs” or intricately patterned “boxes” – with little choice but to become closely engaged in fabrication and construction, if they were to see their projects realized. Building contractors, used to the “analog” norms of practice and prevalent orthogonal geometries and standard, repetitive components, were reluctant to take on projects they saw as apparently unbuildable or, at best, with unmanageable complexities. The “experimental” architects had to find contractors and fabricators capable of digitally-driven production, who were often not in building but in shipbuilding. They had to provide, and often generate directly, the digital information needed to manufacture and construct the building’s components. So, out of sheer necessity, the designers of the digitally-generated, often “bloppy” architecture became closely involved in the digital making of buildings. A potentially promising path to integrated design emerged.

In the process of trying to address the material producibility of digitally conceived complex forms, the “experimental” architects discovered they have the digital information that could be used in fabrication and construction to directly drive the computer-controlled machinery, making the time-consuming and error-prone production of drawings unnecessary. In addition, the introduction and integration of digital fabrication into the design of buildings enabled architects to almost instantaneously produce scale models of their designs using processes and techniques identical to those used in the industry. Thus, a valuable feedback
mechanism between conception and production was established, providing a hint of potential benefits that the integration of design and production could bring.

This newfound ability to generate construction information directly from design information, and not the complex curving forms, is what defined the most profound aspect of much of the formally expressive architecture that has emerged over the past decade. The close relationship that once existed between architecture and construction – what was once the very nature of architectural practice – has reemerged as an unintended but fortunate outcome of the new, closely coupled, digital processes of design and production. Builders and fabricators become involved in the earliest phases of design, and architects actively participate in all phases of construction. In the new digitally-driven processes of production, design and construction are no longer separate realms but are, instead, fluidly amalgamated. The fission of the past is giving way to the digital fusion. As observed by Toshiko Mori, “The age of mechanical production, of linear processes and the strict division of labor, is rapidly collapsing around us.”

**The Digital Integration**

An effective digital exchange of information is vital to the realization of the new integrative capacity of architecture, engineering, and construction. The ability to digitally generate and analyze the design information, and then use it to directly manufacture and construct buildings, fundamentally redefines the relationships between conception and production – it provides for an informational continuum from design to construction. New synergies in architecture, engineering and construction start to emerge because of the use of digital technologies across the boundaries of various professions.

In this scenario, the digital model of the building (a building information model) becomes the single source of design and production information that is generated, controlled and managed by the building design team. It encodes all the information needed to manufacture and construct the building. Layers of information are added, abstracted and extracted as needed throughout the design and construction, as architects, engineers, contractors and fabricators work in a collaborative fashion using a single digital model from the earliest stages of design.

Such a model of production requires that all tools for design, analysis, simulation, fabrication and construction be integrated into a single, cohesive digital environment that can provide information about any qualitative or quantitative aspect of building under design or construction. An example of the integrated application of the multiplicity of information about a project can be seen in the proliferation of ecological and biological design considerations surfacing in contemporary architecture in relation to greater availability of information about natural and human circumstance. For example, the current interest in building performance as a design paradigm is largely due to the emergence of sustainability as a defining socio-economic issue and to the recent developments in technology and cultural theory. Within such an expansive context, building performance is being understood by some architects very broadly, across multiple realms, from financial, spatial, social and cultural to purely technical (structural, thermal, acoustical, etc.). The issues of performance (in all its multiple manifestations) are increasingly considered not in isolation or in some kind of linear progression but simultaneously, in an integrated fashion, and are engaged early on in the conceptual stages of the project, by relying on close collaboration between the many parties involved in the design of a building.
In such a highly “networked” design context, digital quantitative and qualitative performance-based simulations are used as a technological foundation for a new, comprehensive, highly integrated approach to the design of the built environment.

**Integration Varieties**

The emergence of “integrated practice” and “integrated design” as promising professional and disciplinary futures was driven primarily by two parallel, mutually reinforcing developments: the emergence of design-build as a fundamental, structural change in the building industry, and building information modeling (BIM), as an information technology platform that can support new collaborative modes of working.

Design-build, however, is only one way of actualizing the emerging professional synergies of digitally-driven modes of production. A more interesting possibility is the structuring of building teams as dynamic, geographically-distributed digital networks of design and production expertise, which change fluidly as the circumstances of the project or practice require. Architects will increasingly find themselves working in an environment of multidirectional digitally-mediated exchange of knowledge among various members of design and construction teams. In the emerging fluid, heterogeneous processes of production, the digital data, software and various manufacturing devices will be used in different ways by different members of the building team, who will often operate in different places and in different time zones. Two different trajectories are often pursued: the horizontal one that integrates different disciplines across the same scale, and the vertical one that integrates similar disciplines across different scales. In the context of building design, a horizontal strategy would mean the integration of architecture, engineering, and construction, and a vertical one would mean the integration of industrial design, architecture, and urban design, for example. (Other, cross-axial combinations are also possible.)

In light of the technologically-enabled changes, innovative practices with cross-disciplinary expertise are forming to enable the design and construction of new formal complexities and tectonic intricacies. *Front, Inc.* from New York is perhaps the most exemplary collaborative practice to emerge over the past decade; acting as a type of free agency, they fluidly move across the professional and disciplinary territories of architecture, engineering, fabrication and construction, and effectively deploy new digital technologies of parametric design, analysis, and fabrication. Similarly, entrepreneurial enterprises, such as *designtoproduction* from Zurich, Switzerland, have identified an industry niche in the translation of model scale prototypical designs into full-scale buildings. Design firms, such as *SHoP Architects* and *LTL Architects* in New York and *Gang Studio Architects* from Chicago, have integrated in-house design and production in many of their projects. Meanwhile, integrated fabrication specialists such as *3form, Inc.* in Salt Lake City, *A. Zahner Company* in Kansas City, and *Octatube* in Delft, the Netherlands, represent an industry-oriented broadening to engage the emerging innovative design processes directly and more effectively through close collaboration with designers.

**Broadening Integrated Design**

Integrated design should be much more open, fluid, pliable, and opportunist in its search of collaborative alliances and agendas. This alternative approach is referred to
as *integrative design*, in which methods, processes, and techniques are discovered, appropriated, adapted, and altered from “elsewhere,” and often “digitally” pursued.

The distinction between being *integrated* and being *integrative* may seem minor, but I think it is rather significant, as it implies a fundamentally different attitude towards collaboration, which need not be limited to the professions and disciplines comprising the building industry (or the particular scale of building). The designers who engage design as a broadly integrative endeavor fluidly navigate across different disciplinary territories, and deploy algorithmic thinking, biomimicry, computation, digital fabrication, material exploration, and/or performance analyses to discover and create a process, technique, or a product that is qualitatively new. Scientific and engineering ideas become starting points of the design investigation. For example, concepts such as minimizing waste are engineering tactics that are increasingly applied to architecture from the outset of design projects. Other engineering concepts, such as optimization, are finding favor too, not just in budgetary considerations and fabrication procedures, but also in formal and organizational strategies. As discussed earlier, greater attention is given to the analyses of simulated building performance as essential feedback criteria in the design process.

Mathematics and geometry are re-embraced as a rich source of ideas in articulating form, pattern, surface and structure in architecture, and collaborations with mathematicians are increasingly sought out. For example, the expansive, patterned surfaces of the *Federation Square* building in Melbourne, designed by *Lab Architecture Studio*, are based on what is known in mathematics as *pinwheel aperiodic tiling*, enabling the designers to apply different scales of the same pattern across the building as needed. Daniel Libeskind proposed a patterned skin based on fractals for the extension he designed (with Cecil Balmond of *Arup*) for the *Victoria & Albert Museum* addition in London. There are other notable examples in which patterning is based on mathematics. For example, *Voronoi tessellation* is a particularly popular patterning algorithm today. Many of the patterning schemes can be extended from a two-dimensional to a three-dimensional realm and emerge from basic mathematical operations in order to achieve complex results. A simple patterning scheme was used by Cecil Balmond and Toyo Ito in their design for the *Serpentine Pavilion* in London (2002) to produce a complex-looking outcome. The apparently random patterning that wraps the entire pavilion is produced by incremental scaling and rotation of a series of inscribed squares, whose edges were extended and trimmed by the pavilion’s unfolded box shape to create a beautiful, seemingly irregular-looking pattern of alternating voids and solids. The “bird nest” random-looking structural pattern for the *National Stadium* in Beijing, China (2008), designed by *Herzog & de Meuron*, is also based on a relatively simple set of rules. The nearby *National Aquatics Center* (2008), designed by *PTW Architects* from Australia, is a simple box that features a seemingly complex three-dimensional bubble patterning. Its geometric origin is the so-called *Weaire-Phelan structure*, an efficient method of subdividing space using two kinds of cells of equal volume: an irregular *pentagonal dodecahedron* and a *tetrakaidecahedron* with 2 hexagons and 12 pentagons. This regular three-dimensional pattern was sliced with a non-aligned, i.e. slightly rotated rectilinear box to produce the seemingly irregular patterning effect on the exterior.

Science, mathematics, and engineering are not the only domains that are explored for potential ideas. Designers and researchers increasingly are looking for inspiration in nature to discover new materials and new material behaviors, so that buildings (or rather, building enclosures) can respond dynamically to changing environmental
conditions. In addition to mimicking the intricate complex appearance and organization of patterned skins and structures in nature, their behavior is also being investigated for possible new ideas about the performance of building skins and structures. In such “form follows performance” strategies, the impulse is to harness the generative potential of nature, where evolutionary pressure forces organisms to become highly optimized and efficient (nature produces maximum effect with minimum means). A nature-imitating search for new ideas based on biological precedents – often referred to as biomimicry or biomimetics – holds much promise as an overarching generative driving force for digitally driven contemporary architecture.

What is interesting to note is that in integrative design, the deployed digital technologies become much less important than the “borrowed” operational metaphors. For example, integration of time as a dimension in design thinking is manifested today in very different ways, from weathering, the need to adapt to change, movable parts and reconfigurable assemblies, to time-based modeling of geometric forms using animation software. Biomimicry has become a fertile ground for new ideas of integrating nature in design by imitating or taking inspiration from its systems, processes, and elements to address particular design issues (such as sustainability, for example). These developments are part of the perceived broader shift towards integrative design as an emerging trajectory for architecture in its post-digital phase.

Acknowledgements


Endnotes

2 Ironically, architecture’s disassociation from building started in the late Renaissance with one of its most celebrated inventions – the use of perspective representation and orthographic drawings as a medium of communicating the information about buildings.
4 The challenge is (and has been for almost four decades of computer-aided design) how to develop an information model that facilitates all stages of building, from conceptual design to construction (and beyond, for facilities management), and provides for a seamless digital collaborative environment among all parties in the building process.
5 Voronoi diagrams are named after Russian mathematician, Georgy Voronoi, who studied the general n-dimensional case of the conceptually simple decomposition scheme in 1908. In Voronoi tessellation, the decomposition of space is determined by distances to a specified discrete set of objects (points) in space.
6 The Weaire-Phelan structure is a complex three-dimensional structure devised in 1993 by Denis Weaire and Robert Phelan, two physicists based at Trinity College in Dublin, Ireland.
7 The term biomimetics refers to man-made processes, substances, devices, or systems that imitate nature. It was coined by Otto Herbert Schmitt (1913–1998), an American engineer and biophysicist, best known for establishing the field of biomedical engineering. Velcro, the hook-loop fastener, is perhaps the
best-known example of material biomimetics: it was created in 1948 by George de Mestral, Swiss engineer, who was interested in how the hooks of the burrs clung to the fur of his dog.

8 Imitating forms and structures found in nature also has a long history in architecture: Joseph Paxton’s Crystal Palace was allegedly inspired by the lily pad’s structure.