Towards Computationally Aided Integrative Design

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Introduction

Concepts such as *integrated practice* and *integrated design* are increasingly seen in architecture as promising paradigms for a much needed (and long overdue) change in the building industry. 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 or simply better and less costly product at the end.

Integrated design and integrated practice have emerged as a result of several initially unrelated bottom-up developments within the building industry. At one end, the (re)emergence of complexly shaped forms and intricately articulated surfaces, building envelopes, and structures has brought a close collaboration among architects, engineers, and builders from the earliest stages of design; initially out of sheer necessity. The binding agents 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 existing legal structures of clearly delineated 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 of 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 toward 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 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.

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 disintegration started with the cultural, societal and economic shifts of the Renaissance that challenged the medieval traditions of master builders. Leon Battista Alberti wrote that architecture was separate from construction, differentiating architects and artists from master builders and craftsmen. 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, into the currency of building. Architects no longer had to be present on site to supervise 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 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 then brought 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 Neccesity

Over the past decade we have seen a transformation in architecture 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 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 "blobby" architecture became closely involved in the digital making of buildings. Thus 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 had the digital information that could be used in fabrication and construction to directly drive the computer-controlled machinery; making the timeconsuming 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. These days it is not uncommon for builders and fabricators to become involved in the earliest phases of design and for architects to 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 digital fusion. As observed by Toshiko Mori,[2] "The age of mechanical production, of linear processes and the strict division of labor, is rapidly collapsing around us."

In addition, 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.[3]

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.[4] *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 firms such as *designtoproduction* from Zurich, 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, *Zahner* in Kansas City, and *Octatube* in 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

While integrated design could be understood as a well-defined (and thus closed) constellation of related disciplines and professions within the building industry, I would argue that we need a much more open conceptual and structural platform on which architecture could continue to develop as it embraces ideas, concepts, processes, techniques, and technologies that were until recently considered to be within the domains of "others." In other words, integrated design should be much more fluid, pliable, and opportunistic in its search of collaborative alliances and agendas. I refer to this alternative approach as *integrative design*, in which methods, processes, and techniques are discovered, appropriated, adapted, and altered from elsewhere, and often computationally 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. Increasingly, 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 intricate forms, patterns, surfaces and structure in architecture, and collaborations with mathematicians are increasingly sought out.

Engineering, mathematics, and science 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 as it addresses sustainability as a defining socio-economic and cultural issue today.

Computational Opportunities

The various developments described so far are part of the perceived broader shift towards integrative design as an emerging trajectory for architecture as it embraces ideas, concepts, processes, techniques, and technologies from elsewhere. A variety of computational techniques, from complex patterning algorithms to sophisticated simulations, are used today to elicit innovative design proposals. That is hardly surprising, as almost every field of scientific inquiry deploys an arsenal of computational techniques and technologies to gain new insights into complex phenomena around us. Whether it is chaos theory or fluid dynamics, computation is often the enabling platform for research.

As unexpected similarities are discovered behind various phenomena, researchers in different fields often deploy computational processes from "alien" domains, which are then tweaked to meet particular disciplinary circumstances. Architecture as a highly creative endeavor is no stranger to such disciplinary exchanges. We have seen some remarkable projects resulting from cross-disciplinary "computational" interactions ("Watercube" at Beijing Olympics being one recent prominent example). More are to come as computation becomes a lingua franca in creative domains where new ideas are constantly sought out. By looking at other domains for promising conceptual ideas and enabling computational techniques, entirely new and unexpected opportunities could open up for designers of buildings and cities.

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Notes

1. B. Kolarevic, ed., "Architecture in the Digital Age Design and Manufacturing" (London: SponPress, 2003).

2. T. Mori, ed., "Immaterial/Ultramaterial: Architecture, Design, and Materials" (New York: George Braziller, Inc., 2002): xv.

3. B. Kolarevic and A. Malkawi, eds., "Performative Architecture: Beyond Instrumentality" (London: SponPress, 2004).

4. B. Kolarevic and K. Klinger, eds., "Manufacturing Material Effects: Rethinking Design and Making in Architecture" (London: Routledge, 2008).

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Study Questions

1. Who was/were responsible for the building design and construction works before the renaissance?
2. What developments caused the separation of building design and construction disciplines?
3. What is integrated design and why is it needed?
4. What are the reasons that cause integrated work?
5. What is the contribution of digital technologies to the integrated way of working?
6. How does the integrated design practice transform the role of the architect?