DESIGN PAPER SESSION

Expressive Form and Digital Craft:
Necessary Allies for an Alignment of Design and Fabrication Processes in the Digital Age

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> *"...Architecture depends upon its time. It is the crystallization of its inner structure, the slow unfolding of its form. That is the reason why technology and architecture are so closely related. Our real hope is that they will grow together, that some day the one will be the expression of the other. Only then will we have an architecture worthy of its name: architecture as a true symbol of our time"* (Mies van der Rohe, 1950).

Craft in architecture relies upon a careful consideration of both the design and construction processes. The synthesis of design conception and fabrication has always been integral to the process of creating architecture. Le Corbusier reminded us by saying "almost every period of architecture has been linked to research in construction" (1931). Further, "the architect should have construction at least as much at his fingers' ends as a thinker his grammar" (Le Corbusier, 1931). What is the difference if a computer assists in the generation of a form, or a designer generates the form using traditional drawing techniques, and imagination? If the computer assists in the form generation, it may also be employed in the fabrication processes. With the computer assuming more responsibility in the design conception and fabrication, is there any potential for craft in a digital age? In order to examine the issue of digital craft, we must consider the nature of a "tool".

MIND-TOOL

Typical tools of craft are extensions of the hand, thus skilled craftspersons were purported to have developed good hand/eye/mind coordination. Central to the hand/eye/mind relationship was the connection between hand and mind. The industrial revolution machines extended these tools of craft with rapid extrusion of mass-produced repetitive units. New tools of mechanistic technology encouraged efficiency through standardization and repetition. The skilled craftsperson in the industrial age was able to employ the processes of industry resulting from these new methods in fabrication. Industrial craft resulted from innovative and repetitive employment of machined parts.

What exactly is a tool? Malcolm McCullough offers a comprehensive definition that a "tool is a moving entity whose use is initiated and actively guided by a human being, for whom it acts as an extension, towards a specific purpose" (1996). Considering this definition of a tool, the computer is not quite a tool, at least as an extension of the hand. The computer is more akin to an extension of the mind. Further, in terms of making things, or physical output, the computer may be situated as the mind of other tools. It encourages a repetition and variation that affects the making of many distinct things (most noticeable today in industrial design "objects" and rapid prototyping). This mind-tool can be integrated into a critical process between the designer(s), the visualization software(s), and the fabrication processes. Even still, the computer in concert with fabrication processes has its own inherent techniques for making things. What constitutes hand/eye/mind coordination when the computer governs the process of fabrication? What makes a skilled craftsperson in the age of information technology? Indeed, the software programmer plays an ever more important role in the relationship of form generation and direct translation to fabrication techniques. However, the programmer has no responsibility for an end fabrication. Who then will bear the responsibility for construction/fabrication potentials and implications in the generation of a final expressive built work, a master-builder? To make inroads into the discussion of expressive form through computer visualization and fabrication, it is useful to turn to historical expressive forms aligned with processes of fabrication.

EXPRESSIVE FORM

Expressive form challenges prevailing ideas of architecture, as well the limits of understanding in engineering by encouraging the development of innovative fabrication solutions. William Mitchell points out that "as buildings evolve in directions represented by new ideas and pioneering experiments, construction materials, products, and processes will change" (1999). Further, Branko Kolarevic continues this point by acknowledging that today, "building construction is being transformed into production of the differentiated components and their assembly on site, instead of conventional manual techniques"

(2000). Manufacturing processes employed in the physical realization of expressive form will continue to evolve as a direct result of the influence of the computer. Therefore, a complete discussion and definition of principles of expressive form in contemporary computer generated physical architecture must include the synthesis of innovative fabrication processes with creative, aesthetic, and formal aims.

MASTERED CRAFT: EXPRESSIVE MEDIEVAL FORM

The medieval master builder was a master of stone. The design of the cathedral evolved from an exhaustive knowledge of this specific material. The medieval master builder was, in fact "an imaginative and creative designer on the one hand," who was "comprehensively and intimately familiar, at the same time, with the means by which his design could be brought to realization in actual stone and mortar" (Fitchen, 1961). The master builder was a skilled craftsperson rising out of the stonemason craft with a thorough knowledge of the material and the tools with which to manipulate this material. The stonemason tools were extensions of the builder's hand. The precision of the craft depended upon the knowledge and skill of the craftsman and the ability to translate ideas into built form given the tools of the craft. A master builder architect deeply understood this relationship between tool, material, structure, and form.

Expressive medieval form was as expressive as the stone structural system allowed it to be. In reference to the flying buttress at Chartres, Viollet-le-Duc submits that the flying buttress "is a completely oblique construction intended to resist weight that also pushes obliquely" (1876). The application of the flying buttress supported the evolution of gothic cathedral form, as this innovative structural solution set a new standard. Thus, "the development of the structure of churches set out with a new vigor in a new direction" (Viollet-le-Duc, 1876).

THE CRAFT OF INDUSTRY: EXPRESSIVE MODERNIST FORM

The industrial revolution led to a separation of traditional forms of craft from the actual process of building through a mechanized off-site extrusion of repetitive units, pre-manufactured and shipped to sites ready to assemble. The universal impact of industrialization on architecture led to efficiencies through industrial processes in manufacturing. Architects aligned with the spirit of this time took advantage of the new developments in structural systems available through mechanization. The realization of expressive form in modern architecture, however, challenged the building industry to develop special solutions on a per project basis. These innovative architects were able to explore an industry-wide craft in the fabrication of architecture, unlike medieval stonemasons, by governing the processes in industry resulting from developments in materials, structure, fabrication, and manufacturing.

The use of reinforced concrete employed by Eric Mendelsohn in the Einstein Tower was a direct translation of the potential use of innovative material developments into an expressive form of architecture. Eric Mendelsohn demanded, "new methods of construction be translated into design" (Stephan, 1999). Later, modernists experimenting with expressive form, such as Eero Saarinen and Jorn Utzon, remained consistent with the structural necessity for the realization of these forms. Eero Saarinen argued for the integration of expressive form (or as he refers to it, plastic form) with fabrication processes. He states: "plastic form uncontrolled by structure rings a hollow note" (1962). Likewise, the philosophical position of Ove Arup, structural engineers and collaborators with Jorn Utzon for the Sydney Opera House, explains "the willingness of the engineers to expand the limits of problem-solving by moving towards the principle of 'total design,' that is to say, the integration of all design and construction processes for the sake of the project as a whole" (Sommer, Stocher, Weiber, 1994). As craft evolved with technological developments and industrial manufacturing processes, design aims and realization of innovative expressive forms in architecture were clearly aligned with intentions for fabrication.

DETACHED SKIN AND BONES

The minimization of structural systems suggested by pushing the limits of stone in medieval times and fully realized in the manufacturing processes of the industrial age has facilitated the ability to freely express form as surfaces. When façades were freed from the structural system and hung from the building as envelopes, the two systems (skeleton and skin) were allowed to evolve independently from one another. Façade was free, plan was free, and thus simultaneously, form (as skin) was "free" from structure. Corbusier tested the implications of this separation of skin and bones at Ronchamp with the application of new methods of fabrication available with malleable concrete, which was sprayed onto a mesh to create the skin of the building. The columns that bear the weight of the curved roof form are hidden in a wrapped non-structural concrete skin (although the skin still serves to stiffen the total structure). In Daniele Pauly's analysis, "one can imagine this building as a skeleton with a skin stretched over it, both inside and outside" (1997). At Ronchamp, expressive form was articulated independently of structure, thus suggesting the evolution of expressive form created by surface articulation. This separation of skin and bones is no more apparent than in architecture today with the proliferation of expressive forms in an image-saturated society. Software tools add to the propagation of image based surface articulation by supporting rapid digital visualization of expressive form.

DIGITAL VISUALIZATION: SURFACENESS AND IMAGE

Indeed, with digital visualization software, it is possible to develop architecture entirely on the basis of its surfaceness. This kind of expressive skin form may be generated with the assistance of algorithmical calculations of the computer based upon input variables established in negotiation between the designer and the visualization software. This new surface architecture has raised significant issues about evaluation criteria for innovative formal expressions. Do we evaluate the form/surfaceness or the input parameters? Do we abandon traditional formal principles in a search of new principles for expressive surfaceness? Which responsibilities in form generation lie with the architect and which with the software developer? The current critique of surfaceness leans toward an evaluation of the image of the architecture. Architecture considered as image, or even brand identity, then becomes akin to image-based output of consumer goods, such as the iMac computer, Nokia telephone, or Volkswagon Bug. Thus, the proliferation of an image-based surface architecture could potentially lead to a family of architectural flavors based on the image power of the expressive form.

EXPRESSIVE CONTEMPORARY SKIN-FORMS

Software tools facilitate the immediate visualization and manipulation of expressive skins as forms. In fact, in the virtual modeling environment, form can exist entirely as surface without structural considerations. It has become increasingly uncomplicated to visualize, manipulate, and generate complex geometries using new software technology. In its relatively short existence, software that encourages surface manipulations has led to the creation of inventive formal languages for architecture. Fundamental principles of design have been challenged and perhaps replaced. Digital visualization software tools can be used to create a number of "digital architectures," outlined by Branko Kolarevic, which "refer to the computationally based processes of form origination and transformations, such as topological space, isomorphic surfaces, motion kinematics and dynamics, keyshape animation, parametric design, and genetic algorithms" (2000). These new types of digital architectures represent a strong potential in defining significant new territory for architecture. Certainly, hybrid-architecture, information architecture, digital architecture, and similar categorizations can exist entirely in the virtual world. These new gravity-less virtual architectures have enlivened the debates within our discipline. Nonetheless, when we consider the translation of expressive skin-form into physical architecture, with structural systems and material properties, consideration of fabrication processes are essential in the realization of these forms. Particularly now, as Kolarevic suggests a contemporary digital fabrication process that is searching for an architecture that "conflates the structure and skin into one element, thus creating self supporting forms that require no armature." (Kolarevic, 2001). One could only imagine what Ronchamp might be like with such a thoroughly integrated skin/structure system. As new principles evolve for contemporary architecture as a direct result of expressive skin-form manipulations with digital visualization software, and new material systems evolve in concert with these new forms, these new principles should invariably include the strong potential for defining a digital craft.

NEW METHODS

A definitive discussion of expressive contemporary skin-forms in architecture would be incomplete without addressing the implications of fabrication and a synthesis of the direct digital output with form generation. In fact, the manufacture and fabrication process of components for a physical building could inform the design conception and development. If so, software developers will play a key role in facilitating these considerations of fabrication into a comprehensive modeling environment. Parameters for gravity, material properties, and manufacturing techniques could become testable components of design visualization software. Fabrication implications could then be tested from both within the virtual environment as well as through direct physical output. This design process would lead to "an exciting dance back and forth between modeling geometry in the computer and its transformation into a real product" (Pongratz, Perbellini, 2000).

A visualization/fabrication design process is more akin to a master architect programmer builder relationship. New methods in design process projects should be explored to tap further the potentials of an integrated design/fabrication relationship. New methodologies have evolved, such as "just in time" construction, as suggested by Mark Burry in the digital design and fabrication of components for Gaudi's Sagrada Familia Cathedral Rose Window in Barcelona: "Construction takes place for one part of the project, while other parts are still having the detailed design finalized." (Burry, 2001). Perhaps, the responsibility for an integrated visualization/fabrication design process lies equally in a constant conversation between architect, software developer, and fabricator. The best potential for a digital craft lies in this relationship.

SUMMARY: MAKING EXPRESSIVE DIGITAL ARCHITECTURE

The translation of a digital project into the physical world weighs heavily upon the consideration of gravity, and thus, recognition of structural and fabrication solutions in the conception of expressive form. The rapid evolution of surface considerations made available with digital visualization software, underscore the need to understand fabrication implications.

As the computer serves as the mind of the machines it controls in the fabrication of building components, it still cannot replace the critical thought process of the designer. Thus, the question remains: what constitutes a skilled digital craftsperson? Undoubtedly, a skilled craftsperson in the digital age must be skilled with strong design ideas, knowledge of a variety of software, and in a constant feedback loop with the fabrication processes. Equally, software developers become essential to the formula for an integrated digital craft. Parameters for gravity, material properties, and fabrication processes could be embedded into design visualization software providing immediate feedback during design visualization and development. Additionally, physical three-dimensional output studies facilitate a feedback loop with the process of architectural design conception and development. Either way, an architectural design process striving to realize expressive form in a physical building, and remaining consistent with historical considerations of fabrication processes, should necessarily include a rigorous research on the implications of fabrication techniques as guided by the computer. As new principles evolve as a direct result of the influence of information technology, design process methodologies will also be challenged. Appropriate methodological strategies in the design studio should confront these challenges with close attention to the surfacing idea of digital craft. Thoughtful digital craftspersons will help outline the trajectory for a contemporary architecture as a 'true symbol' of our digital time.

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