CRAFT OF THE DIGITAL: DISCOURSE ON A NEW POTENTIAL IN CONTEMPORARY TECTONICS

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Architecture as the corporeal manifesto of cultured ideas has continuously drawn its expression in part from a relationship which exists between material, its processing, and its subsequent intelligent assembly. In any architectural idea, discoveries of elementary material properties are expanded and projected toward the potential boundaries of architectonic space. Two primary assumptions characterize this relation of material and process in architectural design. The first pursues a primordial conception of space combined with the search for supporting material entities. In this case, these entities become, in a sense, surrogates to architectural form. The second assumption considers directly the study of architectonic potentialities residing in material entities and their assemblies from which new forms of architectonic space are derived. In either case, the search for propriety of boundary as an element of space remains categorically a question of architectural knowledge in the quest for proper form.

To govern the discourse herein, the material-space relation is overtly argued as an isolate determinant. However, without question, implications of other important forces, for instance the mode of representation and its relation to material, cannot be omitted in the totality of the phenomenon. For the moment, they should be considered as quietly existent.

HISTORICAL TYPOLOGIES

The formulation of architectonic space prior to the Industrial Revolution relied primarily on materials which were processed directly by the hand tool. The short extension of hand to tool to material embodies by its very nature a kind of human variance in multiple dimensions. This extremely direct relation of human ability to manipulate raw material reveals properties and qualities in the object which can be easily assessed and comprehended by a perceptive human mind. In this sense, bricks individually formed resemble through their variations a notion of singularity. Consequently, their thoughtful architectural array defining for instance the concept of wall continues to offer tacitly the reading of the relation between clay, forming, and firing. The stacking of field stone, minimally refined by either separation or rough breakage, requires a commensurate amount of physical dimension to form the tectonic composite dimension of the wall. In this example, geometric inconsistencies in the stone caused either by selection, or by ability, or even by shear will, to cut a uniform contact surface will inescapably take architectural expression.[1] The wall itself becomes the physical carrier of the relation of material and process. This relation is most evident in walls made of uniform industrial brick in juxtaposition to walls formed from "high tolerance," handmade brick.

The first Industrial Revolution can be taken as an artificial datum, where processes of direct hand involvement yielded medium and high volume industrial production. The machined object produced on assembly line in a series of discrete specialized processes increased not only output volume, but also homogenized qualitative attributes of material.

The impact of such drastic change in the making of things was significantly felt in all aspects of western civilization. The new product surrendered its singularity to the series of virtually identical material objects. Availability increased through improvements in transportation methods which were, in turn, fueled by the industrial production of transportation means. This drastic increase in the export of products was simultaneously accompanied by an export in knowledge. For architecture, this meant not only knowledge about the material itself, but also processing techniques and imbedded expression were exposed to many geographically and intellectually separate cultures which absorbed these phenomena through the making of their buildings.

Most historians would argue that the Industrial Revolution redefined two known materials to become pivotal in the articulation of modern space. Glass, cast in larger sheets, and cast iron, rod iron, and later, steel initially penetrated the world of utility fabrication, then evolved into the key elements of modern construction. Their increased availability, scale, and uniform quality initiated the transition of introverted room bound by masonry into the extroverted space. Mies van der Rohe is an iconic representative of an Avant-garde, who was able to allocate the potential of architectonic space supported by these new materials. Slenderness, transparency, and long spans became the natural undercurrent to such works like the Fagus Werke, the Barcelona Pavilion, or the Villa Savoye.

Interestingly, preceding the enthusiastic embracing of industrial production by orthodox Modernists, exemplary buildings such as Paxton's Crystal Palace or the Eiffel Tower remain as splendid mannerist examples of a transition in which the relation of materiality and its potential form enter the realm of architecture, still more as experimental innovations than concretized, theoretic ideas imbedded in architectonic artifacts.

Gottfried Semper's rejection of the "almost invisible" quality of iron illustrates this peculiar contemplation of recognition of material properties and the initial reluctance to leave familiar tectonic territory. Semper views the slenderness of iron as a contradiction to the desired mass properties of the "monumental" building. However, in his historicist slanted search for a "new style," he is not able to resolve the contradiction between his proposition that architecture is the result of a complex interplay between ideal and material forces depending on the intelligent use of all materials, and the almost categorical rejection of "iron" as a primary structural material "in serious architecture."[2] The art historian Kruft sees the value of Semper's and also Schinkel's contribution in the foresight that the validity of iron based construction technologies can only be achieved with the rise of a symbolic dimension.[3]

The debate in nineteenth-century England is similar. Ruskin's and Morris' polemic on the role of iron, relating to ornament and building material is further confirmation of a pending decision of the material and space relation in architectural works. Ruskin's discourse is very particular:

But the moment that iron in the least degree takes the place of the stone, and acts by its resistance to crushing, and bears superincumbant weight, or if it acts by its own weight, as a counterpoise, and so supersedes the use of pinnacles or buttresses in resisting a lateral thrust, or if, in the form of a rod or girder, it is used to do what wooden beams would have done as well, that instant the building ceases, so far as such applications of metal extend, to be true architecture.[4]

Morris hold similar convictions regarding the notion of industrial production and machine involvement. A romantic propensity toward a workshop based arts and craft society overtakes his initial cognition of a development of *making* as a manufacturing process which extends the simple hand-held tool to the industrial, machine-based production.[5] It seems that Morris mourns particularly the loss of the skilled hand in the crafted artifact. Torn between a romantic retrospective and the recognition of the cultural change, he is strangely challenged by the formal uncertainty arising from the industrial reproduction techniques in casting iron and the associated mimetic pretense of appearing similar to the hand-made, laborious ornament.

Prototypes, such as the Crystal Palace, Labrouste's St. Genevieve library, or the Eiffel Tower prevail despite their initial rejection as significant architectural works. They embody the spirit of new industrial materials and become the model to the paradigm of Modern space. An important identification mark of their significance is a trend to the proliferation of increasingly composite assemblies. This tendency of assigning specialized obligations to specialized composite parts can be detected in the dissection of most walls and other building components constructed today. In those early works of Modernism, layers of pragmatic and decorative intent separate load bearing material from enclosing structure, venting, and climatic insulation. They are followed by layers to control sound, vapor, and numerous other components. Inadvertently, the aesthetic of a successful tectonic suggests the necessity of understanding this distribution of obligations and their layered nature as a composite.

SECOND TIER OF THE INDUSTRIAL REVOLUTION

The first stage of the Industrial Revolution has been characterized as the age of machine involvement in production. It is paralleled by a shift in craft, redirecting the hand skilled craftsman as the tender of the machine to fabricate industrial products. A short examination of the second tier suggests that one of the most significant changes in what we make, and how we govern our processes, is a digital involvement. This concerns not only the work of architects, but virtually all activities of Western culture. This second tier offers new, yet perhaps similar, promising advances for architecture. At this point, many of our architectural artifacts reveal that only minor traces of computational strengths have risen to a tectonic level.

As proposed earlier, the historical transition from experimental cognition to potential form seems to embrace a mode of surrogate imitation of previous conceptions of space, form, and material. Prejudice and experiential security of professional practice initiate this analog of Kuhn's paradigm shift in architectural work. This mimetic phase in today's practice of architecture dominates current qualification requirements of an architect. Many practitioners are concerned with the substitution of conventional means with computing tools to simulate their previous mode of operation. As marketing tools for architecture, computational rendering that achieves photo-realism seems to dominate the advertising of CAAD system features, followed by the digital drafting capacities, and interfaces for based budget controls. There is no doubt, that each of those processes will have an impact on architectural form, be it by increased speed of process or the simple recognition that a proposal is out of the budget range. Nevertheless, the mimesis of tradition can merely provide minor refinement possibilities with little opportunity of radical progress. Assumed that digital technologies have already become a normative circumstance in Western cultures, a successful modern tectonic has no choice but to leave the mimetic phase and exploit the digital undercurrent to its fullest potential.

Three aspects of the digital potential shall be discussed as they may relate to the practice of architectural making.

MODELS

For the moment, it shall be permissible to characterize, at least in part, the work of an architect, prior to the actual making of a building, as a series of simulations to anticipate the reality of the phenomenon. In this capacity, the drawing of a plan as an orthographic projection becomes an abstraction simulating various aspects of the "thing" to come. In the best sense, this kind of simulation takes the form of an analog or iconic model, revealing insight into the qualities of the projected artifact. Models of thought or physical models employing various abstractions become instrumental in the discovery and prediction of the anticipated outcome.

Typically, numeric models embrace calculations on space and volume requirements, structural loads, and other parameters which tend to offer some of their prime properties in numeric expression. In this field, the infusion of digital computing resulted in an augmentation of sophisticated predictions on component behavior, the results of which should confirm or correct the design assumptions. While prediction methods assume a compelling role in the building process, this rise of numerically computed accuracy also generates stringent budget control models with little ambiguity and chance. In most cases, previous mathematical models were simply transferred to a digital computational setting for expedient execution. Aside from an increase in speed, most of these operations point candidly to issues of refinement in architectural design rather than innovation.

Today, three-dimensional Cartesian modeling is used most often to achieve representations of the spatial delineation of buildings. Mitchell calls this the construction of shape algebra from which all further deductions and transformations are derived.s While the principle of seeking these kinds of representations is still unrivaled in digital geometric or analog models, it seems ill-conceived to pursue so strongly the substitution of the hand constructed axonometric or perspective drawing with digital means. The strength of a digital model is without question logical structure. So far, the vast amounts of data associated with the construction of such models still remain largely undiscovered. It is important to emphasize that not the numeric quantity itself, but the quantitative layer is sometimes crucial in the construing of qualities.

The enormous collection of data in Cartesian three-dimensional modeling, ranging from volumetric notation to inferred statics, should provide at least at this level a decent framework for innovative architectural models of ideas to be built. New representations not only offer the possibility to align themselves closer to methods of construction and material, but they prepare the ground for new cognitive study tools in pursuit of the art of building. While the pragmatic functionality of building may occur as primary in these representations, few building processes will take exception to a strict economical accountability. Thus. most physical contributions to architecture not only had to overcome difficulties of budget, but also judgment in purpose,[7] making the integration of knowledge of technology in the design process a historic prerequisite. New, intelligent models, regardless of whether their basis is in exploratory morphological analysis[8] or logical prediction, hold the key to success in built architecture and should fulfill the pragmatic requirements of habitation with ease and set the course for the dimension of art.

From this perspective, the questionable desire to achieve a close similarity to traditional representations may be taken as an indication that innovative models which could potentially provide new readings of the corporeality of an architectural idea still linger behind a "computational picturesque" which expends its mathematical floating point power in service of simulating an antecedent analog simulation. Clearly, the visual persuasion of the investing client has taken the lead in that what is trivially considered the forefront of digital representation. The argument that an architectural artifact will not exist in its corporeal dimension, if funds are not committed, is valid. However, when lack of architectural content hides in the "computational picturesque," the notion of digital persuasion transpires quickly into a damaging weapons, facilitating immature architectural constructs.

TRANSMISSION

Of the multiple impacts of computing, the transmission of information via binary encoding[10] has particularly flourished in Western Societies. Telephone, facsimile, and other digital file exchange comprise a standard digital operating environment for basically every profession. This digital environment produced a proliferation of data packets to which interfaces are assigned to decode, order, and represent the transmitted data.

The phenomenon of transmission is not recent. Export and import of data, information, and knowledge are propelled by human nature to migrate. The contraction of selected information beyond established traditions has historically always been an important catalyst to refine materials and processes.

The difference today lies in the incomprehensible speed by which knowledge bits transgress into all aspects of life. With respect to architecture, the increase of transmitted packets has several significant consequences. Undoubtedly, data quantity and knowledge have little direct relationship. This means that the dramatic increase in data availability does not necessarily equate to an increase in knowledge, or sophistication of any built work. It does pose a problem for the architect insofar as the selection of material parts and techniques of assembly require more than classified registration. The shear quantity of available industrial materials and processes break the boundary of every known geographic and cultural domain. With increased choice, the management of data, its distilling to information, and the need of deliberate choice, demands more than ever from the architect an ability noted here as *judgment of relevance.*

Pre-industrial availability, including knowledge of materials and techniques introduced a natural constraint to architectural design. The materiality and space relation presumed a more limited, and therefore more intimately known set of techniques as their basis. Consequently, the techno*logical*[11] focus was placed on questions of refinement. Exhausting the potential of a technique to achieve extraordinary form described the impulsive activity of an architect at this level of design.

Since the Industrial Revolution, some of these operating parameters have changed in their magnitude. Once a multitude of processes and materials has acquired presence in a knowledge domain, a modern notion of crafting has no choice but to embrace an idea of intelligent selection. Presence of materials and processes arises through a manifold of dissemination channels, in which printed text and images still dominate. But the rising competition of interconnectivity of digital media, such as the Internet or portable digital compendia, e.g. CD-ROM, have already initiated a behavioral migration, indicating that such sources cannot be ignored any longer as information instruments, and, more importantly, as cultural forces.

While actual packet transmission remains largely standardized, the building of interfaces, implying order, representation, and even interpretation of transmitted data is at the core of a new craft. In other words, neither the material itself, nor the process to arrive at a particular viable building material or technique, but the inventive detection and judgmental selection permit deviation from an otherwise extreme normative design approach. The filtering process which assigns a potential tectonic to a product may be viewed from this perspective as an aspect of modern craft.

The inescapable change of an architect's work environment will include the handling simple data sets, such as contour maps or the documentation of existing proximate objects. On the horizon are data sets ranging vastly in nature from detailed digital climatic conditions to demographic migration pattern. Those will compete with parametric system components, life cycle cost simulations, and taxation models. All of these models represent some aspect of an anticipated reality of the built artifact. What will be relevant in construing a modern tectonic dimension as the unequivocal determinant of architectural space will depend on a sophistication of the craft of filtering or selection. As quantities in materials, technologies, and other special knowledge increase, the ability of discrimination of irrelevant information has to grow accordingly in order to maintain an adequate level of architectural contribution.

MAKING

The previous aspect of selection points to one end of the spectrum in the design process. A tectonic dimension based on intelligent contraction and choice of prefabricated parts is the central thesis.

In the "making" processes itself, an other aspect of digital involvement cannot be omitted. Clear tendencies in the actual manufacturing process of objects are exhibited through the increased use of digitally controlled machines. Two profound changes can be anticipated in a pending redefinition of propriety of form. The first idea addresses a reconsideration of building economy based on high and low volume output; the second, certainly related, addresses a reconsideration of potential form of objects based on the digital controlling of machines.

The first Industrial Revolution yielded a process which defined a relation between hand, machine, and resulting object. Normative stock of homogenous material was the result. In architecture, this meant an increased precision in plane, rectilinear materials. The art of assembly can be seen in many Modernist works which do not agonize over the loss of hand crafted ornamentation but take advantage of the inherent qualities of such materials. This mode of construction still governs much of the design process, often premised under the heading of economy.

Thus far, industrial production economy justified the expense for extraordinary preparation of form work and fine tuned, automated machined processes with high volume output. The car industry is a vivid example for extreme formal complexity and tight assemblies. This scenario is difficult to pursue in architecture as the demand for individuality in place and time, and scale normally prohibits extensive prototyping as a viable option. As such, most buildings have prototypical ideas imbedded despite their ultimate obligation as a finished product.

An emerging trend can be observed in research pioneered mostly by the aircraft industry, and lately by the medical community, tagged as *rapid prototyping*, which is based entirely on digital computing and a working manufacturing extension (CNC). The direct transfer of conceived objects, modeled through quantity, geometry, appearance, and numeric expression in digital form alters once more the relation between conception and object. In this case, the hand, machine, and resulting object relation almost defies the notion of *manu*facturing as the hand diminishes its "making" involvement in the process. The term "digitally controlled" clearly characterizes this further reduction of hand related skills. The result is an object with a formal potential which depends largely on the designer's knowledge of raw material and machine capacities. The form relation is construed more from an understanding of computer model with respect to physical material resistance in a digitally controlled manufacturing process. The consideration of manual labor as significant economic influence is offset as the digital process bypasses an intensive engagement of a craftsman or a machinist at the controls.

Intended for low volume series, rapid prototyping presents a particular opportunity to architecture. For now, many of the small parts in buildings are derived from normative high volume output. Examples range from door handles to handrail pairs. Even masonry units could be classified as such. With the potential of manipulation directly from the architect's desk, the digital shop drawing becomes simultaneously the active production code for the object.

Exemplified in the case of a handrail, the making of pieces for a tactile assembly based on complex surfaces could under normal current circumstances be cost prohibitive. The labor to manufacture a limited number of pieces does not warrant industrial assembly line production. The digital data set passed to a computer controlled machine will employ optimization routines to produce the part in the shortest time possible. Imperative though, is an profound understanding of the machine capacity and the raw material. In the case of a digitally controlled mill, for example, form parameters for parts are defined necessarily as a subtractive process, combined with reach and interference of tools and resistance of material. Beyond that, a highly complex formal potential can be attributed to the spatial capacity of the mill's movement. The resulting object, previously highly depended on an economy of straight passes, may have any complex surface as long as the digital data set can be provided. The high degree of particularity and intricacy which such pieces may exhibit suggest a revision in both conception and contemplation of form. Crafting a handrail under these circumstances will require control of the digital manipulation potential at an early design stage.[12]

Digital controls are not only possible for small parts. By inference, construction robotics propose similar concepts which will redefine many aspects of crafting large scale parts and operations in the building process. Aside from the novelties accompanying a change in technique, architectural consequences can be expected. A concrete masonry unit, for example, which defines a wall through an array exists in its current form in part because it is meant to be lifted in place by the mason. The appearance of such a wall captures the limitations of human physiology in its scaled texture of joints. The scale of a CMU which is intended to be placed by a construction robot with increased lifting capacities and presumably increased precision, will not only demand a reshaping of the CMU itself but change the tectonic of such a wall. Crafting itself will take place once more at the digital control which produces the instructions for the robot and the construction process at large.

Further implications of digital influences on making can be anticipated through the direct interfacing with already digitally controlled material manufacturing devices. Many wood or glass processing plants already operate with CNC parameters to optimize their output. Their supply still responds to a demand for normative sections. However, with the provision of digital processing instructions, flexibility in the section will become the standard. "Common" sizes become a choice rather than a datum, leaving the architect with a mandate for a well considered restraint.

SUMMARY

Industrial production has significantly transformed the majority of human societies. Its impact is most clearly understood in the type of work which individuals pursue and in the things which a society fabricates. While fewer individuals work directly in production, industrial output, the actual volume of tangible things, has simultaneously increased. The result of this transformation is clearly a commitment to a machine based treatment of materials and assemblies in which the term *manu*facture loses its direct significance.

We might think of this phenomenon as a recent attribute of our culture. But historically, human kind has always been troubled by such transitions. Often, an idyllic notion of previous treatments of materials and associated processes is responsible for a paradigm of *craft* which tends to ignore the potential of the status quo. In this paradigm, the "traditional" tool mark residing on the tamed material signifies the engagement of the intellect resisting strongly the incomprehensible innovation.

Historically, an understanding of craft and its objects frequently defined the pretext to architectural form. This understanding still provides a basis of how spatial boundaries with integral architectonic expression may be formed.

Taken as the art of building, architecture, as most other aspects of culture will be affected by this digital involvement, although presently the visual appearance of architectonic artifacts seems to suspend their actual potential in a mimetic phase preceding the discovery of new form.

A contemporary architectonic mastery must entail a profound understanding of what governs modern making and assembly processes. In particular, the relations of transmitted information and digital control to material will assume active or passive responsibility for the tangible existence of the new corporeal dimension of architecture. Prospects for a digital involvement in making are a renewed possibility for an economic singularity of parts, suggesting a complex tectonic of individual, situational response. A forward thrust in the embracing of modern making, combined with an education of the intellect should spawn a generation of architects capable of delivering integral modern space as a true cultural contribution.

NOTES

1. The argument still holds under the assumption that field stone wall could be assembled like mosaic, in which a great variety of pieces is fitted. In this case, naturally found, but fitted contact surfaces distribute the internal loads of the wall to permit a more slender or straight construct. The tenacity of searching for the next, correct element, the ability to detect the symbiotic relation between the individual pieces resides not only in the irregularity of the tight surface, but as stated before, in mass, volume, and other dimensions.
2. Semper, G., *Der Stil in den technischen und tektonischen Künsten oder praktische Aesthetik. Ein Handbuch für Techniker, Künstler, und Kunstfreunde.* Vol 2. Munich: Bruckmann, 1878-79. Reprint: Mittenwald, 1977.
3. Kruft, H.W., *Geschichte der Architekturtheorie.* Munich: Beck Verlag, 1984, p.361
4. Ruskin, J., The Seven Lamps of Architecture, New York: Dover Publications, Inc., 1 989(1880), p.41
5. Morris, W., "Art under Plutocracy" in *Collected Works,* New York: Russell & Russell, 1966, 1910-15.
6. Mitchell, W., *Computer Aided Architectural Design.* New York: Van Nostrand, 1977.
7. This should not be confused with a evaluation methods based on simplistic criteria. [Kantian] Judgment entails the holistic assessment of parameters of form in their relation and service of a potential architectural and cultural contribution. Hence, programmatic requirements are to be viewed not as unimportant, but the obligation of a built artifact extends itself into an aesthetic realm which typically outlasts initial habitation requirements.
8. Simon, H.A., *The Sciences of the Artificial.* Cambridge, MA: MIT Press, 1969, p.6
9. Bruno Zevi extends this argument even further, stating that the richness of architecture has suffered from the perspective representation, stating that "instead of inventing spaces for human life, packages were designed. With perspective, it was no longer architecture, but its container that was dominant." Zevi, B., *The Modern Language of Architecture,* New York: Da Capo Press, 1994, p.23
10. Shannon and Weaver's idea of the "reduction of uncertainty" by half became the paradigm binary information encoding. See Shannon and Weaver, *The Mathematical Theory of Communication.* Urbana: University of Illinois Press, 1963,1949.
11. Peter McCleary's proposal of "technology" as the "philosophy of technique" differentiates adequately those two related ideas. (From an undocumented conversation on March of 1996, Blacksburg, VA.)
12. It is not the intention to declare an architect the operator of the machine. Advocated is an understanding that digitally milled form, in this example, has different constraints than a traditional milling approach.