Rethinking architectural vocabulary. Comprehensive design resolution via integrated BIM platforms

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Abstract: This paper revisits established practices in architecture related to the instruments of production and addresses their profound influences upon the design outcome. Cartesian geometry has been used as a common reference to represent architectural elements, a view that has been applied into mainstream design software. The enduring ideologies assume the architectural product to be the result of aesthetic-driven operations supporting geometric regularity in defining elements’ shape and relative positioning. These approaches are compared to alternative ones described as form-finding, making extensive use of the computer’s power, often deviating from Cartesian basis, setting the ground for contemporary design research. In these cases, architectural elements are topological compounds undergoing generative operations. Architectural form is seen as an organic output emerging from interactions, shared functions, performed relationships and feedback loops, rather than ones typically offering full aesthetic control. It is noted that processes related to data inputs, agent management, simulation and recursive testing generally applied to facilitate tectonic resolution via integrated BIM platforms may equally describe those of early design decisions. Such a prospect may set the framing to update existing BIM software, so that the phases of analysis, ideation and conceptualisation are linked with those related to further development, engineering, manufacturing and completion.

Keywords: Dynamic simulation; agent-based; BIM; form-finding.

1. Introduction. Cartesian vs. topological

The vocabulary of architecture includes terms such as slab, column, beam, wall, window, façade, roof, staircase, room and corridor, being some of the discrete elements appointed to resolve form, spatial articulation and structure. Such terms are virtually reflected onto any architectural edifice being analysed to its constituents. In fact, since early Twentieth century modernism, one of the main aspirations of the building industry in reforming its practices has been to fully embrace Cartesian geometry as a reference to rationalise and to resolve design and construction (Le Corbusier, 1923). Such an aim would be achieved by taking full advantage of the new materials and the fabrication techniques, as for example those related to reinforced concrete, steel frame and compound construction. Soon after their first introduction, these innovations were crystallized into architecture’s modern language,
likewise shaping a new attitude about the building seen as a fully industrialized product. Ideally, design in architecture would be conceived, organised, circumscribed and manufactured by a set of controlled, finite and repetitive operations, valued in terms of cost and return on investment (Migayrou, 2002).

Notwithstanding the obvious benefits of Cartesian geometry in setting modern architecture’s vocabulary as one being remarkably efficient in resolving design and construction, in several other instances the related approaches have not always been suitable in describing the plurality of effects produced by more dynamic approaches of formal exploration also seen as ones of less aesthetic control. Setting aside Cartesian references has often led employing ones of organic origin, in support of more seamless comprehension of the parts making the whole. In response to its perceived limitations, geometric regularity and the instruments associated to it have been replaced by topological logic capable of carrying through design’s dynamic nature especially during the early stages of data gathering, also schematic and formal exploration.

This paper first traces historically the above incongruity by also projecting it onto enduring assumptions about design, the instruments and the main references in support of aesthetic-driven processes particularly those associated with Cartesian logic; then, it examines current versions of BIM software with regards to Cartesian definitions of architectural elements, in order to point out that along with the apparent facilitations and efficiencies they have provided in managing a project, meanwhile unquestioned adaptations of Cartesianism have averted from dynamic engaging of influences that would affect form in more challenging, also direct therefore more original tropes. This paper proposes that future BIM software may support extended data inputs since the early stages of the design process, setting a non-Cartesian basis to define architectural form as a topological continuum.

2. The modern paradigm. Cartesian geometry making machines for living

Modern architecture has widely adopted Cartesian geometry as a theme of great validity and respect borrowed from Renaissance. A key figure to modernism’s related endeavours has been Le Corbusier, whose schemes known as *Dom-in-o* and *Architecture’s Five Points* presented in 1914 and 1925, reinforced a connecting thread between the engineering ideology, the emerging modes of production and construction, the new materials and the new aesthetics. These studies were perhaps ones of the most succinct propositions in representing the modern style as one being true and consistent, mainly due to the fact that it echoed no apparent resemblance with anything else ever built before, despite the fact that it was profoundly linked to geometric rules and tools for making drawings inherited from the Western tradition. Several attempts on similar themes were developed often being more complete and exhaustingly analytical (Mumford, 1999), such as *The Minimum Dwelling* in 1927 and Ernst Neufert’s seminal book *Architect’s Data* in 1936. In view of society’s changing principles, modern architecture was identified as a system in which “geometrism” and measure constituted the autonomous and univalent domain of a new dogma (Migayrou, 2002). Elements setting the architectural vocabulary were effectively reduced to pure volumetric prisms. Cartesian geometry was resourced in representing the rational style, in alignment with modernism’s primary objective to describe the architectural edifice and the house being its primary symbol as an assembly of repetitive also geometrically standardised parts making better “machines for living” (Le Corbusier, 1923) (Figure 1).
However, the desire towards extended geometric rationalization would not necessarily act contrary to adjusting the design to individual needs. As Migayrou (2002) comments, the use of standardised elements and identical materials in different constructions would authorise a fortunate architectonic combination of maximum standardization with maximum variety. Such a task could be actualised by a view of the edifice made of same often prefabricated pieces, also by the idea of the open space and mainly the plan that would be adapted to the particularities of each case. Both of these directions have sprung from the presupposition of limitless “geometrising.” By combining repetition with openness, geometric resolution would serve as a way to maximise the economics of design and construction without major compromises on modernism’s socially sensitive principles translated to higher living standards for the masses, manifested in numerous propositions about the modern house. It is therefore important to address Cartesian geometry as a critical and practical means employed in order to reach and to resolve the total set of new often contradictory aims associated with modernism’s founding proclamations.
3. The organic as an alternative scheme

Besides modernism’s preference to Cartesian geometry, there is considerable body of nineteenth century work enabled by the same new-at-that-time technologies in design and production, seeking geometric diversification through dynamic methods of formal exploration. An example may be found in the studies of Eugène Emmanuel Viollet-le-Duc. In explaining his work, Viollet-le-Duc turned to models of physiology also with reference to Gothic architecture, and so he presented the organic relationships and the shared functions of the parts as connected anatomical organs, as opposed to mere results of pure geometric juxtaposition (Vinegar, 1998). Viollet-le-Duc favoured selective techniques of representation that would disclose information about the design only partially and in subjective manners, such as analytical separation and perspective applied in medical and plant anatomy, rather than abstract geometric shapes projected orthogonally onto drawings such as plans, elevations and sections (Vinegar, 1998). For him, graphic representation in physiological models was a critical process rather than one being neutral, specifically with regards to cutting, separating, and exposing of organs for display at the expense of others, even though the results of such actions would still be accepted as scientific evidence. Viollet-le-Duc favoured a dialectical style, both aesthetic and structural, by which to subjugate the forces of nature and those of culture (Bressani, 1989). By inscribing the anatomical metaphor onto architecture, he filtered the viewer’s conception sponsoring more organic interpretation about the total and its parts shaped by their influences, rather than being autonomous. His “anatomical” approach sought ways to transcribe those forces onto form. The geometries emerging from these interactions set adaptive modes of association as opposed to rigid rules about repetition, producing an architectural language that is intrinsically conditioned by processes of topological mutation, resonating operations that are essentially organic (Figure 2).

Figure 2: Eugène Emmanuel Viollet-le-Duc, Concert Hall, 1864.
Similar resolutions were offered alongside modernism’s regulatory scope as alternative pathways to better represent life’s lively patterns not carried out efficiently by geometric shape primitives. To this direction, Hugo Häring preferred organic interpretations that were also compatible with the semantics of modernism such as order, efficiency, economy and performance; however, within the framing he proposed, such terms were unrestricted to modern fixations about form such as functional purity and simplification. In effect, in 1924 Häring envisions the edifice as an organic structure that evolves along with the activities and the people it serves, with design being an approximation of biological processes, as opposed to ones of Cartesian aesthetics. Rather than understanding the building as an optimised solution with reference to a frozen instance in space and time, Häring describes it as a singular event emerging out of the particularities of place, program, material, and culture. The building is not a passive container being indifferent to its content, but an active response to the individuality of various conditions. Architecture sets the standards of the desired conditions with regards to its various meanings being interested in dynamic patterns of change. In 1932, Häring underpins architecture’s further relevance to organic structures, “bred” out of “form arising out of work performance,” looked upon as “man’s second skin,” hence as a body organ. Series of external and internal factors as “functions” that extended that notion’s significance compared to modernism’s dedicated view on functionalism would indicate a degree of fluctuation proposed towards the conception of the building also establishing its dynamic connections with the geo-political site. A great variety of palpable data would actively be involved in producing variable outputs about the total form and its parts reinforcing dynamic integration with the setting, load-sharing and role-distribution. A closer look at architectural studies developed during interwar and the post-war era reveals a recurring appeal towards biological and organic themes, most importantly to the transformative operations due to systemic interactions (Poole & Shvartzberg, 2015). A shift in thinking may be noted, specifically from a focus on form-making to the processes of form-finding, the dynamic constitutive systems and ecologies and also to techniques, building blocks and modules as modes of diversity and evolution (Doxiadis, 1963; Pyla 2002; Mertins, 2009; Aish, 2013) (Figure 3). This shift has caused revisiting the technologies and the phases of production related to the building industry in bio-logistic terms, across scales and across media.

Figure 3: Bio-systemic definitions of architecture and urban settlements (Doxiadis, 1963).
Since modernism, architecture’s main aims have often departed from its designated focus. Topological geometry has been offered as an alternative way to perceive, to calculate, to refine and eventually to construct living entities as integrated compounds of dynamically linked parts. Simple geometric routines may not suffice to describe life’s complex, changing and unexpected experiences, often being without precedent. Although existing typologies generally offer reliable solutions to known problems, they still acknowledge a limited sample of users, being also attached to a specific moment; even more, their function as absolute references to design resolution is virtually incompatible with an equal need for extended flexibility. In effect, dynamic models may be more suitable to simulate the intertwining of activities, their fluctuation in space and time and their potential influences in design in organic terms. Related observations have caused to redefine architectural elements as ones charged by their interaction with contextual factors. In 1984, Paul Virilio, extending the studies he performed together with Claude Parent in the 1960s on the “oblique function” (Parent, 1996), proposed to update the notion of the urban wall, which has given way to an infinity of openings and ruptured enclosures. Its surface-boundary has become an osmotic membrane and a common interface, adapting to facilitate, to impede even to participate in the exchanges between two worlds. Later definitions have proposed the wall as a dynamic element that interacts with the activities of the space it defines, even in real-time. With their built prototype for the project Aegis Hyposurface, the group deCOi (Goulthorpe, Burry & Dunlop, 2001) have set the wall as an elastic structure that holds information about the activities performed around it. Sensors capture the sound and send it to a highly performative control system that recodifies it into dynamic forms. The constructed space has become the result of a nonstop multiplying of effects, affecting – and affected by – their environment, not adequately described by a finite composition. The ongoing research may be seen as the continuation of modernism’s sporadic attempts, this time with the assistance of great computational power. Advanced techniques for modelling and dynamic simulation have been developed and refined testing the dynamic mixtures that occur as the parts interact with the associative agents of design (Garber, 2009). These studies vary significantly in their references and aims, but they all present a common interest in themes such as continuity, mutation, amplified responsiveness and augmented interrelation of “soft” elements making “smooth” totals perceived as aberrations of the norm (Cache, 1995) produced through recursive processes (Lynn, 1993; Spuybroek, 2008) described in relation to evolutionary ones found in biology (Frazer, 1995).

Evolution has become a question of updating a biological structure (Kirschner, 2009) with reference to rules interacting and influenced by external and internal constraints. Simple geometric shapes may only act as malleable starting points, rather than ones design must return to. The emerging models incorporate feedback and employ techniques that are inherently destabilizing. Idealised typologies have given way to topological idioms (Lynn, 1993). Seen as a topological entity, the type acts like a dynamic system acquiring more intelligence as it responds to increasingly complex inputs (Zavoleas, 2016). Moreover, customised manufacturing also under fully digitised therefore reliable procedures invokes questioning the necessity of geometric uniformity for fabrication. Full-scale 3D printing even of whole buildings, combined with research on compound materials and dynamic structures has set the basis for a complete re-evaluation of construction, forcing to rethink whether analysis of an architectural edifice to its parts will soon be relevant, or if these may be conceived, designed and resolved by agent-based simulations as one seamless body (Figure 4). Computers are an asset to such attempts, no longer limited to represent instantaneous ideas, or to carry out age-old tasks, offering instead their potential for dynamic interactivity between data, the designer and the user (Rahim, 2009). Optimization may no longer end when geometric harmony is achieved, but when complexity has reached the highest level of collective sophistication in meeting the design goals.
4. Revolutionising BIM

Developing software has focused in meeting the above goals, specifically in supporting extended levels of interaction among data and users involved since the beginning of a project. Traditional methods of design, refinement and delivery have been linear, built upon clear specialisations, mostly isolated phases and autonomous technologies; these have tended to frame the time reserved for design and to restrict the impact of the architect in later decisions (Garber, 2014), potentially having a negative impact on the project’s delivery. An answer to this may be software that promotes participatory modes of production such as BIM, whose idea is to offer extended workflow management with regards to collaboration and information-sharing also across various stakeholders. BIM aims towards integrated project management and to elements connected with real-time databases and shared models, wherein the design team can iterate and test the design prior to on-site execution. It follows that BIM refers to how decisions about design and construction are dynamically connected and affected by various agents; an idea that is only partially carried through by the existing platforms.

In consequence, BIM is challenged by an all-encompassing idea about production, which, apart from tectonic resolution, may also handle information, choices and assessments during all phases of design. Future BIM may contain extended data inputs such as constraints and references about the project and its parts from the beginning of the process, conveying a more organic character to the result. New tools and virtual techniques may hold influences together also with regards to formal exploration. Having dealt with different sorts of input since the early stages, it will be possible to seamlessly unite the components into compounds being linked back to data. This process may be supported by advanced simulation tools translating components and compounds virtually to actual buildings and supervising construction (Garber, 2014). As such, it will be possible to completely merge the phases of creation and management about a project including generative actions, simulation of influences and behaviors among the design agents, calculations related to construction and material and final fabrication via CNC (Computer, Numerically Controlled) operations. Updates similar to those outlined above will set the new workflow supported by shared platforms and across-specialisation information exchange (Zavoleas, 2008). Future design tools will allow extended parametric control of databases also with versatile content, accessed mutually and refined dynamically during the design process, by also taking full advantage of the graphics, the memory and the storage capacity of the computer. The digital file will hold encoded data in the form of inherently built intelligence, having become a witness of a more collaborative approach among various scales, phases and expertise (van Berkel & Bos, 1999). The formed relationships across design, engineering and construction may eventually be crystallized in novel organisations, updated efficiencies and a new course for practice (Lynn & Leach, 2004; Garber, 2014).
Apparently, there is greater potential for optimisation in the earlier stages of the design process, compared to the current standards set by existing BIM software. In fact, design has often employed dynamic simulation software such as Maya Autodesk and Rhinoceros with its plug-ins initially developed for scopes outside architecture to manage advanced parametric entries. The practical difference between these tools and current BIM is that an instance on the screen is described and codified as a topological entity with its inner structure and dynamic properties, as opposed to a Cartesian prism and a set of point coordinates being significantly rigid and so the design is empowered with far greater possibilities for formal manipulation due to increased flexibility. Furthermore, these tools provide with capabilities for simulating effects of forces, fields and other inputs even in real time, in support of design’s early phases in dynamic manners. Related operations have been used in design research to fill the aforementioned gap since the early 1990s, and so it is expected that similar ones will eventually be incorporated into mainstream BIM platforms. As such, BIM will allow for new ways of integration between design theory and research with design practice, which is still underexplored. It will embrace design’s multi-faceted open-ended character, by extending optimisation and customisation with regards to multiple effects, as opposed to latent management capabilities.

5. Conclusion. Holistic design via BIM

So far, this paper has drawn upon earlier adaptations of organic references around the modern era, reinforcing topological definitions about form. The related studies were often overshadowed by modernism’s practice; nevertheless they have heralded more recent approaches that employ dynamic production modes to define form as a continuum. These modes differ radically in their scope, assuming design to be the result of interaction of various agents with form’s dynamic properties, rather than an aesthetic-driven process. It is claimed that such differences portray two different ideologies about design, invested in the tools and their operational performance during the production process.

On the one hand, the traditional one focuses on form’s descriptive properties as the effect of the geometric relationships among the elements and the whole. This approach is supported by the common instruments for drawing such as the ruler, the orthogonal triangle and the T-square. These instruments serve orthogonal layouts, wherein an element and its relative positioning are determined according to Cartesian references, such as straight lines, parallel and perpendicular ones. It is worth noting that the same logic has been transferred from the analogue drawing board to the toolbars and the common operations of the first generation of CAD and BIM software (Figure 5). The main idea is that the elements are created as point-based Cartesian shapes and prisms such as planes, cylinders, cubes and spheres, also that the drawing expresses order in relating them via rectilinear systems (grids, orthogonal snaps); however, this system is limited in handling large point clouds and complex geometries.

On the other hand, design is approached by generative also performative actions since the early phases of production. It is suggested that such a prospect will inform the next generation of CAD and BIM software. In analogy to dynamic simulation and parametric input software currently employed to resolve advanced design tasks, the proposed tools will operate beyond descriptive modes of geometric representation. Form will be addressed as an open system and a dynamic effect, translated to malleable formations as densifications of points whose coordinates are defined and updated via codified expressions and parametric values. Design will be a totality made possible due to the fact that data of all phases will be included and linked together in the digital file. In effect, form will not conform to aesthetic rules based on Cartesian geometry, but instead it will be topological; its intensive properties will reflect the organic relationships of agents about the forces, the fields of action, the assigned
behaviours, the appointed logic, the occurring schemes and the strategies of resolution. Recursive feedback of form-finding will result in non-standard transformations, increasingly complex geometries and variable outputs, in so doing establishing a common thread that connects all stages and decisions related to the production stream.

Figure 5: Analogue instruments used to geometrically regulate the drawing, compared to mainstream CAD tools defining architectural components as Cartesian primitives organised by grid layouts.

While examining architecture’s modes of production, this paper has compared established notions about architectural practice currently represented into mainstream design software. Several analogue and digital approaches of dynamic exploration alternative to those based on descriptive modes and Cartesian references have been revisited, in an attempt to point at the profound influences of the production tools and techniques upon the result. In responding to the perceived limitations of aesthetic-driven operations in supporting design’s dynamic character especially during the early phases associated with creativity in architecture, form is proposed as the outcome of real-time data inputs and agent-based simulations producing topological compounds that are impossible to break apart. In effect, architectural components’ shape and other properties are entirely directed by the shared influences and functions they perform with regards to the design problem whose complexity is invested onto the final form. It is hoped that such an aim presents an alternative direction to update common BIM platforms, so that they represent more holistic views about design.

References


