THE BIOLOGICAL MODEL AND THE BIO-TYPE

Dynamic simulation tools defining architectural components

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Abstract. Architecture has shown a recurring interest on themes of biological origin, especially since the early days of modernism. With the advent of computation, the related discourse has been enriched with new analogies, in particular when biological systems are described by algorithmic formulas and their parametric functions are inspected with the assistance of simulation tools. An understanding of the architectural object with reference to biology offers breaking from typological preconceptions about form in favour of its operational character supporting organic behaviour, so to speak. In reflection, the present paper puts under scrutiny architectural components such as façade, wall, window, opening, support structure and circulation viewed as topological references also in analogy to biological notions such as skin, membrane, cell, bone structure, energy flows and the nervous system. Form becomes the dynamic effect of forces; a system that manages energy trades being the primary cause of its own shape.

Keywords. System; parametricism; type; topology; bio-structuralism.

1. Introduction

The present paper draws upon architecture’s analogies with biology in order to discuss main architectural components such as façade, wall, opening, support structure and circulation. Biological themes presenting dynamic behaviour have often been appointed in studying architecture’s relevance to parametric thinking also under a comprehensive view of the architectural object as a system that is integrated with its surroundings and the multiplicity of agents setting broader ecologies. Architectural components may be defined and designed in response to the systemic operations they perform. As a result, their presumed conforming to archetypes of Cartesian
geometry along with their resolution as rigid solids supported by conventional (analogue and/or digital) techniques is being contested. In effect, this paper revisits the notion of type in architecture described as a topological entity informed by dynamic interactions also in relation to parametricism and the bio-type. Types may adapt to systemic change even be blended together offering increasingly complex variations, hybridisations and mixtures. Consequently, derivative notions such as typology and archetype may also respond to systemic fluctuations and be treated as “soft” entities. In the last part, this paper proposes some prototype models of architectural components formed through active parametric agents. Architectural components are being defined by their shared tasks and reunited under a “smooth total” that is impossible to break apart.

2. Parametricism and the bio-type

References transferred from biology to architecture, when not limited to mere visual resemblance, may reveal design’s dynamic character. The analogies may be summarized as: first, an understanding of the architectural object as an organic entity that relates parts, functions and qualities into its structure; second, its conception as a metabolic entity forming systemic interactions and exchanges with the environment; third, the generative aspect of design seen as a process, endowed with the task to register and translate the set of factors making a system into physical space and form (Hensel and Menges, 2007). The interest in biology has significantly advanced since various digital software and working platforms have been introduced in the design process to assist in testing the dynamic associations among elements, data and other related influences. Digital technology, more than a mere facilitator to design – or, better stated, precisely because of the enormous facilitations tools associated with the digital have brought into design – has helped to understand the architectural project as the result of information exchanges among various, human and technical, agents (Carpo, 2013). As Hight and Perry (2006) have observed, digital technology’s potential to transform hitherto prevailing modes of design practice may even be more radical in its implications. Collaboration, participatory authorship and collective decision-making are some of the terms used to describe architecture’s agent-based nature, profoundly linking it with parametricism.

Parametricism in architectural practice may be described as a sophisticated strategy that engages all stages of design from the preliminary ones until completion aiming to bring various systems together via increasingly complex processes and institutions (Schumacher, 2009). Early versions of parametricism may be viewed in shared platforms facilitating communication
among different expertise, such as those offered by Building Information Modelling software known as BIM, fostering documentation and data exchanges among the stakeholders that take part in building, construction management and cost control. More recently, and as design computing has expanded beyond representation, it has become possible to foresee a future in which BIM will evolve to a complete parametric tool for design and construction. In these forthcoming versions, BIM may also provide with tools for analysis, simulation and physical object making, as more realistic ways of introducing new organizations being necessary to contend with increasingly mixed programs and building types, promising to revolutionize design practice (Garber, 2009). Advanced design software currently includes highly sophisticated techniques capable of manipulating complex data and their interactions. As such, they assist different stages of design such as data importing and comparing, ideation strategies, conceptualization, schematic development, resolution, refinement and final fabrication. These additions to the making process have allowed architects to better forge their ideas and manage how these will be realized, meanwhile challenging traditional delivery and construction methods with more innovative ones. In consequence, it has been possible to envision an all-encompassing view of architectural practice as a multi-agent approach that reflects the aforementioned advancements along with the project’s behaviour and overall performance as an optimized answer to a set of outlined aims. The integration of parametricism in architecture may virtually end when the sum of agents describing a project will be joined together, guiding the architectural components toward finding their final shape, relative positioning and role and so defining form as an extended system. Parametric logic would suffice to address the total range of relationships among the parts and the broader system under inclusive also competent solutions.

The above description reinforces the production of variations in analogy to biology, as adaptations of architecture’s parametric logic into changing contexts, from which different types may occur. In biology, variety may indicate discrepancies in an organism’s vital functions with reference to environmental constraints, which are given parametric significance (Thompson, 1917). Evolution, the process of defining new species as different phenotypes, becomes an effect of generating and updating the genotype due to limitations that have emerged during an organism’s systemic associations with external influences. Variations of the phenotype generally result from the interaction between the genetic code making the genotype and data flows as energy exchanges with the environment. The notion of bio-type may be suitable to outline schemes driven by intensive and extensive operations of recursion and mutual feedback between an organism and its environment, link-
ing the genotype and the phenotype into an ever-ending process of adaptation, mutation and updating.

There are operative similarities as well as differences between the bio-type and common uses of the type in architecture, being evident in the ways that type is inherently linked with form’s functioning and defining, but may only partially respond to agents and dynamic inputs. Instead, the architectural project may be described as the manifestation of a generic type about a system whose articulations support the parametric connections of multiple subsystems. Its organizing logic may join together elements at various sizes from interior to architectural to urban scale interacting with one another, the result being their interference and compromise. Such an updated view of the type is necessary in order to accommodate within it the dynamic processes of conception and formation about architecture and its components as a total system that is holding, defining and defined by its parts.

The proposed view on type affects derivative notions such as typology and archetype. References to typology would be appointed so that an organizational problem about architectural space be somehow converted to one of Cartesian geometry, that is, a problem of finite resolution addressed by classic aesthetics. Rowe (1947) for example explores the geometric analogies between Le Corbusier’s Villas and those of Palladio over Renaissance and so he uncovers a grid system as an organizing mode that is also critically adapted in order to meet the particularities of each case. Additionally, Le Corbusier’s Modulor system describes geometric relations based on variable ratios of the human body with reference to proportional systems describing beauty during Renaissance. The same systemic approach is carried throughout the design, whereby the fabricated typologies are produced under regulating scope and then used as guidelines for producing architectural space through the relative positioning of its components such as walls, openings, columns, roofs and slabs.

There are apparent variations in the produced results, reflected in the descriptions of the grid and other geometry-defined references supporting architectural form. These, however, still produce static morphological transformations of autonomous architectural components (Lynn, 1993) being parts of the total composition, rather than bringing into the project any of the aesthetic effects of the interactions among the agents that have influenced decision making, to the point that they could incite continuous adaptation and updating. Rigidity and permanency about architectural components reinforced by the inert behaviour of materials commonly used in construction further align with the idea that the architectural composition is practically fixed in space and time. The assumption is that architectural form does not need to fully acknowledge its formative causes, mainly due to restrictions
related to standardization and cost, also due to the expressed view that architecture provides its own vocabulary and syntax (Alexander et all, 1977).

Instead, more dynamic views on the type may translate it in ways that it becomes responsive to the agents about a project seen as generative ones; or in analogy to bio-type. In respect, Lynn (1993) suggests viewing the type as a flexible reference, so that it stays indicative of form’s own structure, meanwhile accepting form’s discontinuous development through interactions with its formative causes. Architecture may still be defined through systemic modes of influence, this time however by also questioning the applicability of rigid geometric references in defining form. Architecture is proposed as a total scheme joining its components together and consequently, any of the graphic abstractions that have traditionally assisted in bringing the various elements together, is introduced as dynamic entities that may interact with the design agents. Some of these elements were formerly considered as being autonomous and also unrelated to, or barely affecting, each other, but within the presented working platform they may be manipulated as systemic parts of a larger whole. Integration through heterogeneity is the product of intensity describing the local – i.e. inner – connections between the parts, along with the dynamic incorporation of external influences causing transformations. The type should be able to expand or contract, extend or bend, even be combined to offer hybrid compounds, constantly internalizing external influences and forces within its limits supporting new affiliations. These features challenge a long-term tradition, helping to understand and effectively use the type as a point of departure in studying form, rather than an idealized reference to which design must always return and compromise.

Accordingly, attention may shift from form’s geometric characteristics to its propensity to represent data being activated to produce variations. Rather than assuming it to be the output of aesthetic-driven manipulation, form is seen as a system that may be managed indirectly through data tweaks concerning the forces that are set to generate and influence it, having an effect on its external appearance and internal structure. Form becomes a mixture of elements defined by shared tectonic functions. Tectonic in this case describes a condition whereby the architectural components transcend their utilitarian aspect (Lim, 2009) and through synergetic interaction reveal compound meaning. This has happened along with recent updates in perceptions of the physical world from classical definitions of harmony, proportion and order to ones stressing out exchange, mutation, transformation and movement. Cartesian geometry has given its place to topology and mathematics, so that form may not be defined by applying geometric rules, but instead it may be calculated (Cache, 1995). Design has become process-driven as opposed to object-driven and beauty is pursued with reference to the organiza-
tion and making, further attained through the dynamic aesthetics of process, as opposed to the traditional aesthetics of object (Lim, 2009). Success is measured in relation to the degree that different elements are integrated in the composition. Performance-based criteria are gradually replacing ones based on representation predominantly assuming architectural form an aesthetic object. Optimizing standards are approximated and refined in simulations running onto abstractions of concepts during form-finding and carrying them onto next levels of refinement as more information gradually enters the design scene (Garber, 2009). The produced models may be viewed as advanced versions of BIM in a broader sense, capable of linking data of various kinds. Recent theories have embraced this paradigm shift, whereby system-oriented thinking is increasingly informed by biological themes and parametric modes of data management assuming design the organic output of progressively refined functions. In effect, new opportunities have emerged for BIM software to integrate dynamic form-finding with pragmatic management and tools of construction in driving design towards its physical manifestation.

3. Redefining architectural components: the bio-structural model

Next, the above discussion is implemented onto main architectural components specifically with regards to dynamic processes of formation, offering solutions that are not defined by geometric regularity. Components such as walls, openings, rooms, slabs, columns, staircases and corridors have set the main architectural vocabulary during many centuries of architectural production. Especially during modernism, these elements were defined with reference to Cartesian primitives, aiming for standardization, profoundly linking the building industry with techno-economic factors. Compliance with Cartesian geometry has been reinforced by a variety of tools for drawing such as the ruler, the orthogonal triangle and the T-square, further supported by elements used in miniature model-making such as cardboard sheets and wood sticks representing slabs, roofs, columns and beams. It is worth noting that the same geometric logic has been transferred into the mainstream digital design tools. Design software such as Sketchup and FormZ and also ArchiCAD and Revit based on BIM are set to describe entities with reference to Cartesian primitives such as planes, cubes, spheres and cylinders. These packages, due to a point-based logic, satisfy demands related to accuracy and so they are better in supporting geometric regularity; however, they present limitations in handling complex geometries, not being suitable for relating dynamic data inputs with form’s outlook. This restriction has given room for software that can handle geometric transformations more efficiently, also
with reference to behaviours due to a number of programmed factors. In effect, designers often resort to software initially developed for purposes being foreign to architecture, such as Maya Autodesk and Rhinoceros with its parametric plug-ins. With this software, an instance on the screen is a topological entity defined by its inner structure, properties and behaviours. The available tools also provide with capabilities for simulating the effects of forces, fields and other dynamic instances onto form, even in real time. Such a dynamic approach may further be aligned with bio-systemic views describing the different stages of the production process, setting the basis for extended versions of BIM software.

The above view is applied to produce prototypes of architectural components created under the notion of Bio-structuralism. Components are translated as open systems interacting with different agents set as generative forces. Various outputs emerge from homogenized strategies supported by advanced operations. These strategies incorporate the parameters of design, whose influences are simulated to interact with other ones also with form. Parameters such as social factors, economy and function have been included in digital-assisted approaches dating since the late-1990s (MVRDV, 1999), exceeding, however, this paper’s scope. An updating of the semantics about architectural components is proposed by examining the dynamic effects of various agents acting onto “soft” primitives, whose behaviour is defined by their inner logic.

Biological themes such as skins, cells, bone structures, energy flows and the nervous system are borrowed to interact with agents influencing spatial phenomena. Interactions include applying forces onto materials and evolving generic elements to generate self-sustaining also proliferating systems, as the output geometries become increasingly complex. These experiments produce bone-like supports such as advanced three-dimensional scaffolding multiplied at varying directions and sizes (Figures 1); stratified skin shells taking different shapes in response to external forces and internal resistances (Figures 2); ground and slab structures converting to beams, columns, platforms and roofs (Figure 3); ground platforms, slabs and beams forming aggregates of smooth transitioning and expansion (Figure 4), and façade walls translated to flexible membranes offering fluidity between the interior and the exterior and efficiency in weight support (Figure 5). Form is conceived as a topological entity subdivided and programmed to follow changing data inputs. As a result, the simulation of the interactions between form and the agents creates sequences of variable outputs whose parts are immersed into a system logic.


Figure 3. Bio-Structuralism (Zavoleas, with Michelis and Tzemou, 2013-14). Ground and slab structure converting to beams, columns, platforms and roofs.
Figure 4. Bio-Structuralism (Zavoleas, 2014). Ground platforms, slabs and beams forming aggregates of smooth transitioning and expansion.

Figure 5. Bio-Structuralism (Zavoleas, 2014). Façade wall transformed to flexible membrane offering fluidity between interior and exterior and efficiency in weight support.

Future BIM software will handle unique compounds, being fully customized, calculated and fabricated under total control. At any phase of the process, production systems will support back-and-forth testing between data tweaks and variable schemes. Detailed resolution will be instant, as long as every bit of information is digitized. Until then, the software industry must strive continuously to align with the pioneering minds in the field, providing tools that better respond to the increasing expectations of design.

4. Conclusion

The prototypes presented above aim at updating definitions of commonly used architectural components through their interaction with the design agents during form-finding. Each one shows potential for further study, along with the influences it has been programmed to undergo at micro and
macro level. A discussion on the dynamic comprehension of architectural components has led to questions on the type in architecture. Its adaptations may be set in analogy to biological models and the bio-type, also alongside theories that touch upon architecture’s parametric character. It is suggested viewing the type as a topological reference of a systemic logic, one that can be manipulated and transformed according to parameters that are addressed to have an impact upon form. Moreover, with significant advancements in construction technology, restrictions referring to product standardization may no longer be relevant. In effect, references to Cartesian geometry may reflect aesthetic criteria and not to necessities of construction.

As an alternative to aesthetics, this paper advocates extensive data management reinforced by experimentation from the initial phases towards completion. Dynamic simulation tools appointed for testing architectural object’s systemic behaviour may be suitable for linking the data from analysis with the design choices. The biological theme is an aid in identifying the relationships among the agents of design and conveying them into the general logic, the organizing schemes and the strategies of resolution. Further to this endeavour, advanced simulation tools incorporated into future BIM software may be added to the list of means including drawings and models describing the process of making, as ones also fostering creativity.

References