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Performance-oriented Architecture

Towards a Biological Paradigm for Architectural Design and the Built Environment

Abstract

This paper introduces and elaborates a specific approach to architectural design entitled 'performance-oriented architecture' based on a redefinition of the concept of 'performance' in relation to the discipline of architecture and set within a biological paradigm. The concept of 'performance' evolved out of a series of intellectual efforts that had broad consequences, bringing about a paradigm shift in the humanities referred to as the 'performative turn'. These efforts commenced in the 1940s and 1950s and had significant impact also on the sciences, deriving what is referred to as the 'performative idiom'. Here the question is raised as to what 'performance' in the context of architecture may entail. The approach introduced contrasts previous ones that focused either on questions of representation and meaning in architecture, or, alternatively that have treated performance as synonymous to function placed in the context of post-design functional optimisation. Contrasting these previous efforts performance is here reformulated as a driving concept for design that helps re-consolidate form and function into a synergetic relation with the dynamics of natural, cultural and social environments, and in so doing, locate performative capacity - 'active agency' - in the spatial and material organisation of architecture, in the human subject and the environment through the dynamic interaction between these four domains. In pursuing this approach the potential of a close disciplinary affiliation between architecture and biology is examined, so as to locate a suitable paradigm for performance in the discipline of biology and its various sub-disciplines, in its various foci and modes of inquiry, and, moreover, in biological systems.

Keywords: performance, agency, material organisation, spatial organisation, subject, environment, form, function, biological paradigm, biological systems, complexity, systems-theory

Preamble: The Task at Hand

The altered environmental conditions of today can no longer be mastered with the architectural resources of the past ... Though architecture today does not fulfil its task, it is nevertheless the only decidedly peaceful profession in which synthetic thinking can be exercised on a large project without hindrance The relationship between biology and building is now in need of clarification due to real and practical exigencies. The problem of environment has never before been such a threat to existence. In effect, it is a biological problem (Otto, 1971: 7).

In the above quote Frei Otto ardently points towards the ineptitude of current approaches to architectural design in tackling today's design problems relative to questions and problems of the environment. (For the purpose of this paper 'environment' is understood here in a broad sense.) In order to pursue the problem, it is now over four decades since Otto effectively proposed a rethinking of the disciplinary affiliation between architecture and biology and stated the core of our contemporary condition as a biological problem. The question arises as to what has happened in the interim that might have brought about an instrumental disciplinary adjacency between architecture and biology.

Two principal themes underlie this paper and the research that precedes and follows it: a specific take on the notion of 'performance, and a revised approach to a potential biological paradigm for the former to play itself out within. Neither of these two themes is in actuality new to architectural discourse. However, previous attempts have had their explicit shortfalls. The discourse of 'performance' in architecture first arrived in the form of the discourse of 'representation' and 'meaning' which was limited to be of consequence for the problem at hand. Its second manifestation is a more recent one in which performance is by and large synonymous with 'function' and chiefly entails some kind of post-design optimisation with regards to functional criteria often related to structural or environmental engineering. This approach reinforces the division of form and function with all the related ramifications that this entails. First, the architect exercises aesthetic predilection, personal idiosyncrasy or 'signature'. Subsequently, the design is adjusted to fulfil functional targets that were not intended to be addressed when the design took place. In doing so, this approach merely redressed a conventional design approach in new terminology. In these instances, as a biological paradigm is concerned, buildings might end up in the metaphorical, or more directly, formal realm of 'biomorphism' without ever acquiring any truly new capacities. The accumulative ramifications for the (built) environment are even more unsettling. One may ask, then, what the repercussions of moving both functional and aesthetic consideration to the very onset of the design process might be and how a suitable paradigm may be located in the discipline of biology?

Previous approaches to a biological paradigm either exhausted themselves in metaphors or mere formal resemblances, so called biomorphism, or in the better case employed predominantly analogical modes to translate functional principles in biological systems into surface effects and articulations, thermal modulation, mechanical solutions to engineering problems, etc. The approach employed here takes a broader view of biology as a discipline by means of establishing characteristics of biological systems that may be deployed in design. It examines modes of inquiry in the discipline of biology and the questions asked by its various sub-disciplines. It also looks into various modes of analysis and visualisation of complex biological systems and relations. It is only possible to discuss all this briefly in the context of this article.

In order to tackle these problems the author initiated and developed over the last decade an approach to design, research by design and design education that has begun to point towards a synergetic theoretical and methodological approach to architectural design and its potential disciplinary affiliation with biology. This paper tries for the first time to collect the different traits that combine to this particular take on performance-oriented architecture. This research is projective and interdisciplinary in character and rooted in systems- and complexity theory. The latter is necessary to tackle the relational dynamics between the four domains attributed here with performative capacity or 'active agency': the (heterogeneous) spatial and the material organisation that actualises architectural works, the subject and the environment (in the broadest sense) [Fig. 1]. This interrelation requires an 'open systems' approach in order to find an instrumental inroad to tackling the involved complex dynamic interrelations.

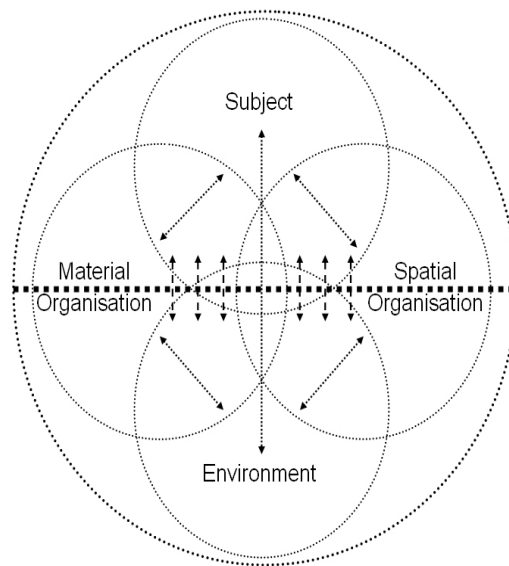


Fig.1 The approach to performance-oriented architecture proposes four interrelated domains of 'active agency': the subject (inhabitant), the environment and the complex of spatial and material organisation. It is through the complex of spatial and material organisation that architects generally operate and through which complex interaction between all four domains of active agency can be enabled. (Diagram by Michael Hensel 2008).

The development of this research proceeds through architectural theory advancements and design experiments and their collation into a coherent theoretical framework grounded within both, a critical theory discourse and a scientific discourse. In moving from the collation of the findings into a coherent theoretical framework new questions arise that suggest further empirical modes of knowledge production by means of design experiments. The perpetual movement between these modes of inquiry and production of knowledge serves to distil a clearly defined research area. It is this particular instrumental approach and the presence of design experiments that indicate a viable mode for research by design that becomes increasingly articulated and specific within a larger pluralistic field of already existing and emergent approaches. The motivation is then to distil an approach to architectural design that is capable of addressing the complexity of current design problems in an effective manner.

Context of the research

A series of preceding research efforts by the author and his team of collaborators deliver the foundations of the approach discussed here within. Questions of spatial organisation and the contemporary preference of leading architects and researchers into heterogeneous space is traced in an anthology of selected seminal essays by architects and theoreticians chiefly over the last fifty years (Hensel, et al. 2009). Similarly, questions of material organisation were pursued. However, this took shape in the form of basic research into materials, material systems and material behaviour and exchange with the environment. These efforts were located in the educational field and were undertaken with diploma and master-level students in various schools of architecture in Europe, the Americas and Australia, culminating in a series of publications (see e.g. Hensel & Menges 2006, Hensel & Menges 2008).

The coalesced and revised research has led to the formulation of a number of specific research areas focusing on questions of the architectural threshold and auxiliary architectures that can alter the existing built environment (Hensel and Sunguroglu Hensel 2010a, b, and c). This stage of the research also investigates the potential of migratory inhabitation modes, involving questions of the subject in relation to the interaction between spatial and material

organisation and their dynamic interaction with local climate and environment. The work to date is extensive. It increasingly requires a detailed overarching theoretical framework. This is to ground the research, to distil further more specific research efforts, and to increase the necessary complexity of the argument and of the critical experiments that characterise this research by design effort. The following is an attempt to draft an overarching approach to a performance-oriented and biology-rooted paradigm for architecture and the built environment.

Approaching the Concept of Performance

The 'Performative Turn' and the Subject as Active Agent

As discussed above, previous approaches to the relation between architecture and the concept of performance were in one way or another deficient with regards to providing a longer lasting theoretical and methodological framework for research by design and to addressing the increasingly complex demands towards architecture that itself is becoming increasingly reduced in its relevance vis-à-vis the making of the built environment at large. If architecture is thought to deliver more than mere formal styling, we need to start anew in approaching the development of the notion of performance to identify a different potential for its relation to architectural design.

The notion of 'performative turn' identifies a paradigm shift in the humanities and social sciences, which focused on theorizing 'performance' as a social and, moreover, cultural category. Two related historical developments originated in what is today referred to as the 'performative turn'. This was initiated by intellectual efforts that commenced in the 1940s and 1950s.

The first development is related to the work of a number of people that pursued the development of a specific take on a dramaturgical paradigm to be applied to culture at large, most notably: [i] the American literary theorist and philosopher Kenneth Duva Burke, who developed a 'dramatistic approach' to the analysis of communicative actions; [ii] the cultural anthropologist Victor Witter Turner and his works in symbolic and interpretative anthropology and cultural expression in staged theatre and ritual; and [iii], the Canadian sociologist Erving Goffman and his works on symbolic interaction. Goffman emphasised the significant link between social life and performance (Goffman, 1956). This opened the concept of performance to a significantly larger and public arena and proposed a dramaturgical paradigm in which all culture can be viewed as performance.

The second development originated in the work of the British Philosopher of language John Langshaw Austin (1911-1960). Austin posited that speech is not a passive practice, but, instead, constitutes a form of 'self-referential' action, an active practice that can affect and transform realities (Austin, 1962). In pursuing this proposition he coined the phrase that 'to say something is to do something' (Austin, 1962: 12). As a result, performance today is a frequently alluded to as a concept that serves as a heuristic approach to understanding human behaviour. It is rooted in the hypothesis that all human practices are 'performed' as an act of public staging of the self.

Erika Fischer-Lichte has shown that these developments also affected a 'performative turn' in the arts. In this turn, fine arts, music, literature and theatre all 'tend to realise themselves through acts (performances)', thus shifting the emphasis from 'works' to 'events' that increasingly involve the 'recipients, listeners, spectators' (Fischer-Lichte, 2004: 29). Furthermore, Fischer-Lichte proposed that Austin's notion of the 'performative' is not only applicable to speech, but that it can also be applied to corporeal acts. Thus the concept of 'performance' evolved in the context of 'performance arts', referring to a situation-specific, action emphasising and ephemeral artistic presentation of a performer, which can incorporate a range of art forms. This implies that performance in the context of performance art is a concept that incorporates difference. Acclaimed theorists of performance art, like Marvin

Carlson, state that there cannot be a singular generalised definition of the central character of performance in performance arts (Carlson, 2003). In this context, performance is thus pluralistic in character; it may be seen to entail a somewhat elusive concept and related discourse that is hard to pin down. This, however, is not inevitably the case.

In drawing up his seminal approach to semiology, Umberto Eco characterised a kind of work that invests part of the action in the spectator (Eco, 1989). Such 'open work' is characterised by a deliberate ambiguity of meaning. According to Eco, 'open works' must leave the arrangement of some of their constituents to the public or to chance, thus giving these works a field of possible orders rather than a single definite one. The subject can move freely within this field of possibilities, which serves to avoid conventional forms of expression and prescribed interpretation. At the same time, Eco points out that this does not entail a total *laissez-faire* approach and amorphousness. Rather, there must be a guiding directive from the designer that structures the field of possibilities in some way or another for the subject (Eco, 1989).

This understanding has direct relevance for architecture as it indicates that performance in architecture can be approached by charging a context with meaning, but also by charging it with multiplicitous meaning, or, more significantly, by the exact opposite, the orchestrated reduction of meaning, by abstraction. Of significance here too is that the subject becomes an active agent that needs to structure a possible order from a field of possibilities. Thus 'subject' entails 'active agent', as evidently an 'open work' would not unfold into a structured order until, and unless, this movement is 'performed' by the subject.

Environment as Active Agent and the Emergence of the Culture of Environment

The concept of 'performativity' has also been utilised in science and technology studies, as well as in economic science. Andrew Pickering observed a shift from a 'representational idiom' in science to a 'performative one'. He argued that 'within an expanded conception of scientific culture, however - one that goes beyond science-as-knowledge, to include material, social and temporal dimensions of science - it becomes possible to imagine that science is not just about representation' (Pickering, 1995: 5-6). Pickering argued that:

One can start from the idea that the world is filled not, in the first instance with facts and observations, but with *agency*. The world, I want to say, is continually *doing things*, things that bear upon us not as observation statements upon disembodied intellects but as forces upon material beings. Think of the weather. Winds, storms, droughts, floods, heat and cold - all of these engage with our bodies as well as our minds ... Much of everyday life, I would say, has this character of coping with material agency, agency that comes at us from outside the human realm and that cannot be reduced to anything within that realm. My suggestion is that we should see science (and, of course technology) as a continuation and extension of this business of coping with material agency.... These remarks, then, sketch out a basis for a performative image of science, in which science is regarded a field of powers, capacities, and performances, situated in machinic captures of material agency. And my aim ... is to understand scientific practice within such a performative idiom (Pickering, 1995: 6-7).

The proposition that 'practice effects associations between multiple and often heterogeneous cultural elements' (Pickering, 1995: 95) may also turn the attention not only to the object of study (i.e. 'biological systems'), but also to scientific practice (i.e. criteria and methods for biological systems analysis). Through this practice there operates the production of knowledge and scientific practice as a means of 'doing things', which has a transformative impact on multiple and heterogeneous contexts, for instance, through potential paradigms through which other disciplines, activities and agencies are transformed.

Moreover, 'performance' as a paradigm enables the study of nature and the built environment as active agents, rather than as passive context. It is this understanding and critical evaluation that must precede an instrumental approach to the concept of performance in relation to the built environment. This may commence by embracing the 'active' status of the built environment much more broadly, and, thus, make it the focal point of inquiry.

In this context, it is not intended that we rehearse non-representational theory with regards to how practices of non-human formations are performed. Instead, focus is placed on how such formations can 'perform' in a more literal way, thus lending the outcome of the inquiry to a more direct use in the design and evaluation of the built environment. Moreover, the question arises as to what performance may affect. With regards to the broader implication of the 'performative turn', one may argue that it is culture that is affected and that architecture belongs to, and that it is always already shaped by and in turn shapes culture, environment and, further, is shaped increasingly by what might be called 'culture of environment'.

To this end it is important to emphasize that today's culture is entangled in questions and concerns regarding the environment, in general, and the role and impact of the built environment onto the social, cultural and natural environment, in particular. With regard to the latter, Nobel-prize laureate and chemist Paul Crutzen posited that our geological time period ought to be considered as the 'Anthropocene', implying 'that human activity is now affecting the Earth so profoundly that we are entering into a new epoch'. (Holmes, 2009: 32) This take and a whole host of more detailed indicators imply that culture and environment can no longer be thought of as separable.

Significantly, as Peter Sloterdijk proposes, architecture's aim and ability to create 'environment' preceded the actual conception of the term in theoretical biology:

Only gradually did nineteenth-century minds grasp the paradigmatic significance of constructing glass houses. Such edifices took into account that organisms and climate zones reference each other as it were a priori and that the random uprooting of organisms to plant them elsewhere could only occur if the climatic conditions were transposed along with them.... Following the initial breakthroughs in devising an elaborate system for harbouring plants alien to the local climate, it was to be another two or three generations before theoretical biology responded at the conceptual level to the new practices of uprooting plants. It bears considering that it was the afore-mentioned exercise of granting plants hospitality that first created the conditions under which it became possible to formulate a concept of environment. I can of course forgo providing any detailed explanation of how and why the concept of 'environment' as coined by biologist Jacob von Uexküll in 1909 (in his book *Umwelt und Innenwelt der Tiere*, second edition, 1921) was one of those twentieth-century innovations in logic that was to have the greatest impact. Not only do large stretches of modern biology depend on it but also both ecology as a whole and systems theory. If post-Uexküll the talk was of 'environment', then this meant thinking not just of the natural habitat of exotic animals and plants but also of the procedures for the technical reproduction of that habitat in alien surroundings (Sloterdijk, 2005: 944-945).

This suggests that the 'performative capacity' of specific architectural interventions can be actualised in various ways, including the production of environment, and, ultimately the production of a 'culture of environment', one that evidently relates the spatial and material organisation complex to affecting the environment. What is still missing from the discussion of the interrelation and interaction of the four domains of active agency is the more direct relation between the subject and the environment above and beyond the intermittent agency of technology. At any rate, a discussion of environment would be incomplete without considering the Estonian biologist Jacob von Uexkuell's 'Umwelttheory', as indicated above by Sloterdijk. (Umwelt is the German word for environment.) Uexkuell coined the notion of

Umwelt, in which he posited that while environments are shared, it is the experience of environments that is different between organisms due to their sensory and affective networks. Organisms thus create and reshape their reality by interacting with the world. Uexkuell's notion of *Umwelt* suggests that space may be understood as a reflexively produced and immanent condition of subjective experience and therefore contrasts both with objective ideas of space and with phenomenological and post-modern concepts that understand it as constructed by the subject:

Objects, equipped with all the possible sensory characteristics always remain products of the human subject; they are not things that have an existence independent of the subject. They become 'things' in front of us only when they have become covered by all the sensory envelopes that the island of the senses can give them.

What they were before that, before they became covered, is something we will never find out. In this state they are of interest to the biologist only as a cause of stimuli that by their action on the sensory organs make these generate characteristic properties. The purpose of the sensory organs is always to transform stimuli into properties (von Uexkuell, 2009 [1936]: 146).

This realisation need not, however, lead to an impasse by way of extrapolating from the above that the problem of subjectivity in the creation of *Umwelt* may entail the impossibility of an *objective* in the production of environment. On the contrary, all that is required to begin with is the realisation of the need to understand environment always already as heterogeneous. The implication, therefore, is the need to relinquish the prevailing preference for homogenised (interior) environments, since this the latter constitutes a contradiction vis-à-vis Uexkuell's *Umweltheory*. The approach to performance-oriented architecture introduced here therefore embraces Uexkuell's proposition and operates on a preference of heterogeneous space. In doing so, the interrelation between all four domains of 'active agency' have been generally addressed in relation to the question of environment and a general position has been accomplished from which to discuss particular inadequacies of current architectural design.

An instrumental Approach towards Performance in Architecture ***Disassociation of 'Form' and 'Function' – Background and Ramifications***

In order to develop instrumental approaches to architectural design, architects invariably operate on a set of categorical items that allows them to break complex and often dynamic relations into smaller subsets, so as to be able to make them intelligible and instrumental. In itself this constitutes no problem as long as categorisation as an intellectual tool is not mistaken as anything other than artificial dichotomy for the sake of intelligibility - an entirely known and yet often uncared for fact. Therefore the need to categorise often ends up reinforcing entrenched dogmas.

One iconic, artificial dichotomy that has fuelled architectural discourse over the better part of a century now is the one that divides 'form' and 'function'. This debate has led to an acceleration of increasingly divided positions between those that give primacy to 'form' and promote its divorce from any other underlying logic so as to gain complete freedom of expression unconstrained by other concerns, and those that promote an increasing emphasis on synthesis and seek for models and modes that enable this pursuit.

In doing so, the disassociation of form and function has brought with it the most profound differences in architectural theory and practice. This is by no means a new realisation. It has been debated at great length time and again. Yet, the search continues as to how the disassociation of 'form' and 'function' shall be tackled. With this the question arises as to why, when and how 'form' and 'function' came to be disassociated.

A key moment that brought about a distinction of function as a driving concept for the articulation of built form occurred in the writings of the American sculptor Horatio Greenough, who defined 'beauty as the promise of function; action as the presence of function, [and] character as the record of function' (Greenough, 1947 [1852]: 71). Thus 'function' takes thus on a predominant role in Greenough's approach. It holds sway over the other characteristics by being their pre-requisite. 'Function' has thus come to the fore. However, Greenough takes a particular position with regards to architecture:

Instead of forcing the functions of every sort of building into one general form, adopting an outward shape for the sake of the eye or association, without reference to an inner distribution, let us begin from the nucleus, and work outward. The most convenient size and arrangement of the rooms that are to constitute the building being fixed, the access of the light that may, or the air that must be wanted, being provided for, we have the skeleton of our building. Nay, we have all excepting the dress. The connection and order of parts, juxtaposed for convenience, cannot fail to speak of relation and uses ... the unflinching adaptation of a building to its position and use gives, as a sure product of that adaptation, character and expression (Greenough, 1947 [1852]: 61-62).

The prominence of function in the writings of Greenough resonate in an article written in 1896 by the American architect Louis Sullivan, entitled 'The Tall Office Building Artistically Considered', in which he posited 'that form ever follows function' (Sullivan, 1896).

Sullivan, who developed the tall office building in the late 19th century, wished to break with the styles of the past as he viewed them as inappropriate for the new design problems at hand. If thus precedent was inappropriate, the question arose as to what should inform a design. Sullivan was clear in his article: 'form ever follows function'. However, Sullivan did not associate with this statement the relinquishing of aesthetic expression by means of ornamentation. He did indeed use ornamentation in his designs. It was not before 1908 when Adolf Loos published his seminal book 'Ornament and Crime' (Loos, 1908) that the real disassociation was ushered in. The 1932 exhibition 'The International Style: Architecture since 1922' at the Museum of Modern Art in New York, curated by Henry Russell Hitchcock and Philip Johnson, cemented the magnitude of what came to be known as functionalism.

Over time the dogma of 'form follows function' fostered radical positions and counterreactions. Instead they either made the latter a secondary concern or completed the disassociation so that only a concern for form remained, as can be seen in the works of Peter Eisenman, Frank Gehry, and others. In time and in consequence a more recent school of thought emerged in the architectural avant-garde of the US, that does not only postulate the comprehensive divorce of form from function and the divorce of form from structural logic, but also the latent divorce of form from material logic. This development constitutes the exact counter-position to the argument pursued in this paper.

Aldo Rossi's critique of functionalism pursued a different point of view, namely that architecture cannot assert control over how spaces are used over time (Rossi 1982). In parallel to Rossi's critique the architect Bernard Tschumi pursued a body of work from the early 1970s onwards that focused on the relationship between space and its use. Tschumi stated that:

There is no architecture without program, without action, without event. ... architecture is never autonomous, never pure form, and, similarly, ... architecture is not a matter of style and cannot be reduced to a language ... [the aim is] to reinstate the term function and, more particularly, to re-inscribe the movement of bodies in space, together with the actions and events that take place within the social and political realm of architecture [and to] refuse the

simplistic relation by which form follows function, or use, or socioeconomics ... in contemporary urban society, any cause-and-effect relationship between form, use, function, and socioeconomic structure has become both impossible and obsolete (Tschumi 1994: 3-4).

... there is no cause-and-effect relationship between the concept of space and the experience of space, or between buildings and their uses, or space and the movement of bodies within it... (Tschumi 1994: 16) ... Architecture's inherent confrontation of space and use and the inevitable disjunction of the two terms means that architecture is constantly unstable, constantly on the verge of change (Tschumi 1994: 19).

Operating on this perceived 'disjunction' of the relation between space and its use, Tschumi juxtaposed spaces and uses in a collage-like manner. However, this argument, if followed through, eradicates entirely any possibilities for questioning the relation of space and its use in a different manner. Nonetheless, Tschumi did raise explicitly the notion of 'event' and in result inherently the importance of time and not only of space.

The importance notion of 'event' can be located in the effort of the French philosopher Henri Bergson to provide a philosophical response to Albert Einstein's special theory of relativity, which required in Bergson's view a radical shift in relation to viewing the nature of time (Bergson, 1999 [1922]). The importance and impact of Bergsonian philosophy cannot be overstated. It set the stage for seminal writings such as by Alfred Norton Whitehead's 'The Concept of Nature' (Whitehead 1964 [1919]), the works of the influential French philosophers Michel Foucault and Gilles Deleuze, and so on. A detailed elaboration and analysis of this matter would entirely go beyond the scope of this paper. However, it is of use to briefly consider the related writings of the American writer Sanford Kwinter (2001). Kwinter stated that:

Thus the object – be it a building, a compound site, or an entire urban matrix, insofar as such unities continue to exist at all as functional terms – would be defined now *not by how it appears, but rather by practices*: those it partakes of and those that take place within (Kwinter, 2001: 14).

As design practice and thought are deflected away from the traditional and largely 'aesthetically' constituted object and simultaneously reoriented toward a dynamic macro- and microscopic field of interaction, an entirely new field opens itself to the designer, theorist, or artist (Kwinter, 2001: 21).

...it may be said that any truly great body of work – literary or otherwise – derives its unique power ... from the global universe of relations it expresses (actualises, in the perpetual and dynamic sense), not the meaning it manifests. The totality of these virtual relations – the universe expressed – determines, in a purely pragmatic sense, what one can call the capacities of a work, that is, what it is capable of affecting, transforming, or doing in the world (Kwinter, 2001: 215).

Kwinter grounds the proposed shift from a static work held fixed in space and saturated by 'local' meaning to one that is perpetually 'actualised' in the Bergsonian notions of 'duration', 'simultaneity' and 'event'. In so doing Kwinter draws a relation to systems- and complexity theory, foregrounding that the relation of a system to time emphasises the significance of transformation based on complex interaction and nonlinear behaviour (Kwinter, 2001: 23). Kwinter's approach thus delivers a useful inroad to the Bergsonian notion of 'event' in relation to the emergence of novelty and an understanding of the role of time vis-à-vis specific creative work.

Subject and Architecture as interacting Agents

In relation to Kwinter's argument and in order to approach the question of the relation between architecture and the subject, it is useful to recall that Eco's notion of 'Open Works' in which the subject 'structures' a field of possibilities provided by a (literary, architectural, or other) work (Eco 1989). This corresponds with Roberto Mangabeira Unger and Jeff Kipnis notions of 'blankness' and 'pointing' (Unger, 1993 and Kipnis, 1993). 'Blankness' implies 'the suppression of quotation or reference through the erasure of decoration and ornament to include canonic form and type. By avoiding formal or figurative reference, architecture can engage in unexpected formal and semiotic affiliations without entering into fixed alignments' (Kipnis 1993: 43). Pointing implies that "architecture must be projective, i.e., it must point to the emergence of new social arrangements and to the construction of new institutional forms. In order to accomplish this, the building must have a point, i.e., project a transformation of a prevailing political context" (Kipnis 1993: 43). Kipnis went on to elaborate that pointing is not synonymous to signifying.

What is interesting about the combination of 'blankness' and 'pointing' is that it extends Eco's notion of the open work. It does so by suggesting the possibility of embedding the characteristics that entice the individual or collective subject to 'structure the field of possibilities' towards the 'emergence of new social arrangements' and 'institutional form' in the built environment and that architecture can provide such stimuli. If this can be accomplished, the interaction between architecture and the beholder/inhabitant can be described as a performative one that locates 'active agency' in both.

In synthesising the various approaches discussed above Leatherbarrow concludes his initial observations about architecture's performance by proposing that there are

... two kinds of understanding in the theory of architectural performance: the kind that can be exact and unailing in its predictions of outcomes, and the kind that anticipates what is likely, given the circumstantial contingencies of built work. The first sort is technical and productive, the second contextual and projective. There is no need to rank these two in a theory of architectural performance; important instead is grasping their reciprocity and joint necessity (Leatherbarrow 2005: 18).

While the argument above tackles the question of reduction of meaning as a powerful means to promote the emergence of new social arrangements and institutional form, it is also necessary to analyse buildings as repositories of embodied knowledge, as well as spatial organisation as embodied social formation and arrangement intent. The late Robin Evans delivered a seminal argument to this end (Evans 1997). Evans based his succinct analysis on comparing paintings and architectural plans to gain insights into the relation between spatial organisation and social arrangements and formations. He distinguished between the Italian medieval matrix of connected spaces and a social context based on closeness, carnality and accidental social encounter and the British corridor and cellular room model and a social context based on privacy, distance and segregation. He completes his accomplished discourse with the question as to why the corridor model today still prevails as the predominant spatial organisation and questions its relevance vis-à-vis today's prevailing social pattern. However, what is remarkably obvious is that Evans' analysis is based on an articulation of the wall characterised by a substantial and opaque materiality, a spatial divider only interrupted by a door. If this were to be changed, say, by introducing transparency or numerous additional openings of different sizes and purposes into this wall, the entire situation would change. The argument could not be had or upheld under the circumstances of critical changes in the articulation of the wall as a material threshold. What becomes clear, then, is that Evans' argument about the possible relation spatial organisation and social formation needs to be extended to encompass a directly related and interdependent condition of materiality and

material performance. This is one that entails 'active agency' emanating from material organisation as a means of facilitating specific modes of spatial organisation and, moreover, various preferential forms of social formation and inhabitation provision. This warrants a more detailed discussion in the following part.

In order to wrap up the current argument it is of interest to note that the arguments of Eco, Ungers, Kipnis and Evans reflect in different yet complementary ways upon the relation between built form and spatial organisation. They also have bearing on the subject as agents that require the presence of each other to 'perform' in an effect/affect relation that unfolds architecture and the built environment through active agency.

Material Capacities and Performance from a Material Perspective

The discipline of architecture, among other things, is also a material practice that transforms the human environment through material and environmental interventions. Material responds to stimuli and can thus be utilised strategically in the orchestration between material and energetic exchanges. This can be exemplified through a simple reference. Wood, for instance, displays dimensional variability through its hygroscopic characteristics. It can take up water from the environment and give it off again in response to changes in relative humidity. Material responds to a great variety of stimuli. Gravity has been the most obvious one throughout the history of human construction. Materials organised into structures are to be able to bear numerous loads, ranging from self-weight to horizontal loads. Dynamic loads resulting from various kinds of movements and dynamics add to the gamut. Over recent history architects such as Frei Otto developed a method known as 'form-finding' to establish structural form in response to external stimuli. This method is based on utilising the self-organisational characteristics of materials and material systems in response to extrinsic influences. Antoni Gaudi used this method to 'form-find' the catenary arches of the Guell church in an additive quasi bottom-up manner, while Frei Otto mostly utilised the method to establish the overall form of gridshells, membrane roofs and so on, whether these were used in an additive manner or not.

What is striking, however, is that this method has not been developed subsequently to incorporate an increasing number of variables. There is therefore great potential in the form-finding approach that has its correspondences in the pattern formation in many natural systems, whether non-living or living. Frei Otto and his collaborators realised this early in their research and dedicated a considerable research effort into basic research geared to analyse and wherever possible utilise such self-organisational processes for the purpose of deriving optimal light-weight structural form or, alternatively adaptable architectures or in some way 'optimal' settlement pattern.

Much more remains to be done, both in the domains of basic and applied research. Material capacities and behaviour, their organisation in space and time in relation to a dynamic extrinsic milieu, lie at the core of a performance-oriented architecture. This approach may also fundamentally change the way in which materials may be viewed in the future. The material stratum may then not be primarily understood as the means to provide thresholds, that is divisions between an inside and outside for example, but, instead, serve as an 'active agent' in the orchestration of flows, energetic or otherwise, that generate dynamic gradients of conditions as a way of modulating space in a heterogeneous and motile way. (For an initial elaboration of the topic see Hensel et al., 2009).

Architecture and Environment as Interacting Agents

David Leatherbarrow argued that:

... to see how the building itself operates, technological and aesthetic explanations must be temporarily suspended ... [as] the continued dedication to a technical interpretation to a technical interpretation of performance will lead to nothing more than an uncritical reaffirmation of old style functionalist thinking (Leatherbarrow 2005: 7).

Affirming that 'old style' functional thinking disallows the advancement of a more promising argument of performance, Leatherbarrow pursues a series of different approaches.

He refers to his first approach as the 'device paradigm', in which the action of the building is located in mechanically moveable parts to enable adjustment. In this case, the range of adjustability is key to "... the modification and mediation of the environment in its widest sense, from climate to human behaviour" (Leatherbarrow 2005: 12). Secondly, Leatherbarrow proposes a 'topography paradigm' in which not a position of a part of a building but its state becomes the register of performance, i.e. of the interaction of material and climate leading to weathering of the material. Since the specific impact of a dynamic climate is unforeseeable, as are the events that may take place within the building, Leatherbarrow posits that 'the true measure of a building's preparation is their capacity to respond to both foreseen and unforeseen developments' (Leatherbarrow 2005: 15-16). He infers from this that buildings cannot be seen as separate from environment in the wider sense, as it is the interaction between the two that constitutes the basis for performance.

Discussion on the relations between architecture and environment are of course not a new; however, a significant shift occurred when the possibility of enhancing architecture with electrical and mechanical devices became broadly available and feasible. In the late 1960s the accumulation of developments in architectural theory and practice coincided with research into the possibility of the entirely contained, 'closed', interior environments and ecological systems of space flight and cold war bunker developments to facilitate survival in case of a nuclear war. Into this time falls the let Reyner Banham's seminal book *The Architecture of the Well-tempered Environment* (Banham 1969) in which he distinguished between two traditions of organising space:

Cultures whose members organise their environments by means of massive structures tend to visualise space as they have lived in it, that is bounded and contained, limited by walls, floors and ceilings Against this, societies who do not built substantial structures tend to group their activities around some central focus – a water hole, a shade tree, a fire, a great teacher – and inhabit a space whose external boundaries are vague, adjustable according to functional need, and rarely regular. The output of heat and light from a campfire is effectively zoned in concentric rings, brightest and hottest close to the fire, coolest and darkest away from it ... but at the same time, the distribution of heat is biased by the wind ... so that the concentric zoning is interrupted by other considerations of comfort or need (Banham, 1969: 19-20).

The question that arises from this proposition is whether the separation of the two modes of organising space is valid. A first, and more general, objection may be made with regards to the 'environmental' effects of partitioning space, assigned to the first tradition. In tandem with this argument, Banham uses a diagram which was as wrong as it was of consequence: a diagram of a tent the skin of which seals hermetically the interior from the exterior. The fallacy of this diagram is that it supported the argument towards the desirability and usefulness of entirely sealed interior environments and help push technical climatization of interiors into the state of a status symbol and over the course of the 1970s to replace a great wealth of strategies of passive modulation with air-conditioning in large parts of the world.

And yet an entirely different path remained available to those who were not so fortunate to afford the new technology and, instead, had to rely on the continued use of traditional means of passive means of micro-environmental modulation, for example, Islamic screen-walls so called *mashrabīyas*. *Mashrabīyas* are multi-functional elements that control light penetration, airflow, privacy and views, while operating on a synergetic relation between ornamental pattern and material distribution. The latter secures the necessary embedded complex functionality of the screen-walls. The late Hassan Fathy provided a detailed analysis of the *mashrabīya* that today remains unfortunately overlooked (Fathy, 1986). Such screen-walls integrate ornamental attributes with functional properties and capacities. Form and function are not separately treated, and neither follows the other; instead, both are interrelated and interdependent. The distribution of material satisfies both formal and functional criteria in an integral manner for as long as both operate within correlated dimensional ranges.

Moreover, Banham's distinction of the two traditions of organising spaces collapses vis-à-vis this example. Thus, neither form nor function are separable, nor are the different ways of organising and modulating space. Moreover, Fathy's argument is not restricted to historical architecture or architectural elements. A similar take resonates in Leatherbarrow's statement:

I would like to show that a building's performances are the means by which it simultaneously accomplishes practical purposes and gives them legible articulation. Put differently, the appearance and meaning of an architectural work are essentially tied to the operations performed by its several elements. Representational content is not something added to the shaping of settings in response to life's "bare necessities", as suggested by arguments within the functionalist tradition, but is something intrinsic to the response to those necessities (Leatherbarrow, 2009: 26).

With regards to the intrinsic nature of representational content, as suggested by Leatherbarrow, we may recall the Eco/Unger/Kipnis argument elaborated above, which indicates that the deliberate reduction of meaning and representational content constitutes a valid approach to the question of yielding 'agency' and thus performance. However, one may ask to which extend environmental performance has become in some way the representational content of today's mainstream architecture labelled as 'sustainable' and thus pre-empted and prevented from yielding alternative approaches to this entirely relevant topic. This discussion, however, exceeds the scope of this paper, although it is implicitly contained within it. More careful attention shall be given to this aspect in a different context.

A Systems Approach to Performance in Design

The question arises then as to how the synergies discussed above might be accomplished by design. A promising first inroad to this question can be found in Christopher Alexander's seminal book *Notes on the Synthesis of Form* (1964). Although the book is based on positions that are being challenged by this paper, namely the form-function dichotomy, the use of the concept of 'performance' as synonymous to 'function', and the continuation of a form follows function argument ('physical things which display new physical order, organisation, form, in response to function' (Alexander, 1964: 1)), it provides nevertheless an interesting systemic approach that might be of use for the purpose at hand. Quoting D'Arcy Thompson's notion of form as a 'diagram of forces' (Thompson, 1992 [1942]), Alexander pursues a systematic analysis of how a multiplicity of 'forces' or requirements may yield a particular formal response. He thus went on to claim:

We ought always to design with a number of nested, overlapped form-context boundaries in mind. Indeed, the form itself relies on its own inner organisation and on the internal fitness

between the pieces it is made of to control its fit as a whole to the context outside (Alexander, 1964: 18).

The choice of terms, such as 'fitness', may suggest that Alexander's references and concepts originate in evolutionary biology (although this proposition requires further analysis). His methodological approach which he went on to elaborate has its origin in Systems Theory, which itself originated in the 1920s to tackle the need of explaining the interrelatedness of organisms in ecosystems.

In pursuing a design method based on Systems Theory, Alexander proposed to establish a way of breaking complex design problems down into sub-systems and the variables that specifically relate to each subsystem. On the level of the variables, Alexander promotes an analysis of inter-variable correlations that is based on causal relations between them, while on the other hand requiring independence between the subsystems:

... the variables of such a system can be adjusted to meet the specified conditions in a reasonable time only if the subsystems are adjusted independently of one another. A subsystem, roughly speaking, is one of the obvious components of the system ... the designer is faced with all the variables simultaneously ... if he tries to manipulate them all at once he will not manage to find a well-fitting form in a reasonable time (Alexander, 1964: 64-65).

Alexander thus stated two conditions with regards to accomplishing a time-restricted design. Firstly, the subsystems of a system need to be independent. Secondly, the sub-system specific variables ought not to be manipulated simultaneously. Careful examination leads to the question as to whether the extrinsic constraint of time required for deriving a design should have primacy, or, instead, whether a more integral relation between the subsystems should be sought first? In any case, the question of what is resolvable in a given time pertains to processing quantities of data. The problem stated by Alexander does not posit a problem of incompatibility, but rather one of 'computational' capacity.

With regards to the afore-mentioned Islamic screen walls, Alexander would have argued that these evolved out of an unselfconscious process of minor adjustments over generations of skilled craftsmen in a specific climate and culture. In this case, the resolution arises over small 'computational steps' over time that result in an integral 'form-context' relation. However, as Alexander stated, the self-conscious process of design in architecture revolves around a different, in fact contrary, logic, in which the originality of a design is the designer's primary concern. In this case all design must take place in a very short time. From this several key questions arise. Is it possible to emulate the logic of the unselfconscious process within a self-conscious one? Is it therefore possible to 'compute' an intensively integral relation between all sub-systems and variables? To overcome the apparent contradiction in instrumentalising unselfconscious and self-conscious design processes, algorithmic procedures have been utilised by the author and others that are geared towards 'evolving' designs out of the structuring and manipulation of a generative process, 'structuring a field of possibilities' (Eco 1989) without predetermining a singular result or a narrow scope of 'design options'. Suitable 'computational' approaches are the subject of intense research and are becoming increasingly available. The interrelation of large numbers of variables is both a question of processing capacity, as well as suitable ways of setting up relational models. So-called associative (relational) models that are parametrically defined can increasingly serve the purpose.

Pursuing the above will require an empirical mode of production of knowledge through design experiments. This requirement will have implication for the conceptualisation and realization of 'research by design'. In realising this need Alexander raised the following problem:

The experiment of putting a prototype form in the context itself is the real criterion for fit. A complete unitary description of the demands made by the context is the only fully adequate non-experimental criterion. The first is too expensive, the second is impossible: so what shall we do? (Alexander 1964: 21).

There are two approaches towards gaining empirical knowledge that are otherwise not directly accessible. The first issue is arrived at by a careful and detailed analysis of empirical knowledge embedded in 'objects' that, to use Alexander's words, evolve from unselfconscious processes. In other words, architectures and the built environment may be viewed, as indicated earlier, as a repository of embedded and embodied knowledge, i.e. in the form of buildings, or what is more, a repository of potentials within biological systems. In order to make this knowledge available, particularly where the tradition of passing on knowledge from master to apprentice is interrupted and literature is not available, extensive re-examination and analysis is required. Much of this is still required today and it may take place by means of an interdisciplinary approach and various modes of analysis that deploy state-of-the-art technology. In fact, the author and his collaborators have initiated just such a research project, which comprises the detailed analysis of 50 pre-industrial buildings on a case-by-case basis. The latter entails that a quasi-forensic study first tackles the problem of establishing criteria for analysis for each case to account for its time and context-specificity. In other words, the first aim of the analysis is not a comparative mode in which criteria for analysis are pre-established for all cases, since such an approach might miss out entirely on various domains and levels of 'agency' as established above.

Alexander's second concern, regarding a 'complete unitary description of the demands by the context', will remain an unsolvable problem, as much as any encyclopaedic approach will never be complete. This is a problem that requires a different approach via a hierarchical structuring of key criteria and related variables that are flexible enough to be reconfigured, as a first inroad to addressing this specific problem. It is in relation to this problem that a systems-oriented approach may become useful again, one that tackles relations between different inherently dynamic domains, that possess 'active agency'. Some promising approaches begin to emerge from the educational and research work of Prof. Birger Sevaldson at the Oslo School of Architecture and Design, in particular with regards to methods of extended relational mapping. In any case, a promising approach must be characterised not by separation but by interrelation, by foregrounding dynamics and change, or in the words of Sanford Kwinter 'movement', that is set within an open systems paradigm.

For the sake of an expanded notion of performance, it is necessary to extend the above by identifying other repositories of embedded performative capacity that could serve as experimentation-fields for deriving alternative and more complex models for the built environment. The specific hypothesis here is that such repositories can be found in biological systems, in which 'active agency' is a precondition from which emanate processes of self-organisation and emergence that operate on the notion of 'event' as an occurrence in a particular understanding of time. Sanford Kwinter elaborated this as follows:

Morphogenesis occurs either as a mechanical process of translations fixed once and for all and external to the specific morphogenetic moment-event, with its highly particular and unreproducible conditions – or else, it is the very principle of life, that is, perpetual instability and therefore creation itself, and wedded to the ever-evolving particularities of time ... (Kwinter 2001: 10).

Consequently, the above amounts to an extensive need for basic research in design and a fundamentally different take on design education. First and foremost as indicated above, this

includes a foregrounding of the role of time and dynamics in complex systems and a fundamental understanding of the latter. This can be accomplished both through a direct intellectual approach of researching and teaching underlying principles, but also in a more tacit manner through (material) experiments and towards the production of empirical knowledge. The author has developed a specific combination of these means with research and translational focus on buildings as repositories of embedded knowledge and biological systems as potential repositories of milieu-specific 'active agency', and, moreover, the role of the environment or milieu as 'active agency'. In addition, the role of the subject needs to be considered within the context established by the above. This research took place over nearly a decade and is set within an educational context, while at the same time remaining extensively connected to past and current practices.

In order to pursue the argument further, it is now necessary to turn the attention to a particular approach to biology as a paradigm for performance-oriented architecture. For a while now research into biological systems has taken place in a number of dedicated research centres, as evidenced by Frei Otto's work and the activities of the former Institute of Light-weight Structures in Stuttgart and the special research area SFB 230 in Stuttgart for instance, or the educational activities of the author. However, the latter differs from the former in the specific approach to placing the research within a series of intents larger than, for instance, the concerns of deriving light-weight structures or other such attempts that focus on more singular domains of 'function', as opposed to the approach elaborated here within. The following will begin to outline the premises for the approach to biology pursued relative to the research programme of the author.

A Biological Paradigm for Architecture

Master-builders and architects have always taken interest in nature as a source for design, whether in a direct, metaphorical or analogical way. The interest in biology as a discipline is, however, a more recent phenomenon. Here too approaches may be literal, analogical, and, more often than not, metaphorical or superficially formal. The approach I advance, which is interested in performance, will look at biology and more specifically ecology in a systems-based mode that takes interest in how organisms and environments interact.

Complexity and Dynamics of Biological Systems

Both the term and concept of modern 'biology', the science of 'life', originated in the beginning of the 19th century through the individual efforts of Karl Friedrich Burdach, Gottfried Reinhold Trevianus und Jean Baptiste de Lamarck. At the same time as the modern concept of biology emerged, another neologism appeared namely that of 'morphology'. It was coined both by Goethe (ca. 1796) in the context of his botanical studies, as well as by Karl Friedrich Burdach (ca. 1800). Several early 'biologists' laid the cornerstones for what was to come. George Cuvier contributed, among many other major aspects, key advancements in comparative anatomy (ca. 1798), while Goethe sought to come to terms with the dynamics of formation and the temporality of material form of living systems (Goethe, 1988 [1807]). Morphology thus became one of the early sub-disciplines of biology, together with taxonomy and embryology. It concerned itself with structure and form of organisms and the comparison of different types and species. This brought up the question as to what might inform, govern or modulate the formation process. Darwin's evolutionary theory established one way of addressing this question. Another way of addressing it was put forth by the Scottish biologist and mathematician D'Arcy Wentworth Thompson in his seminal work *On Growth of Form* (Thompson, 1992 [1942]). Moving away from evolution as the singular driver of morphogenesis, Thompson assigned a much greater role to laws of physics, emphasising the correlation between mechanical influences and biological form.

Before long there evolved two competing approaches to morphology. These shared the understanding that the structure of organisms is not the result of arbitrary aggregation of parts, but instead constitutes an organised system. These approaches differ, however, in the question as to how the structure of organisms is to be understood. One of the approaches is based on the assumption that the parts of the body of an organism are related in a functional sense, while the second posits that the build of the body follows an underlying plan or schema and that the parts of the body are not functionally, but, instead, structurally organised. Walter Bock and Günther Wahlert, eminent supporters of the functional approach, point out that a part of a body can display more than one functional potential, and that it therefore constitutes a form-function-complex characterised by specific capacities than can, but must not necessarily be used (Bock & Wahlert, 1965). An organism can in the context of functional morphological approaches not plainly be seen as a functionally organised system only, but as a layer in a hierarchy of functional systems (Hertler, 2005).

It is not common practice to understand such complex relations and dynamics in architecture. With regards to interaction of agents in a performance based approach to design in architecture a lot could be gained from this understanding. Likewise, biological systems are articulated in an integral manner over a larger range of levels of magnitude, often over eight levels ranging from the macrostructure to the molecular. Architecture operates on the meter to millimetre scale, often neglecting a better understanding of the inherent material characteristics that originate from the internal characteristics in the micrometer to nanometer scales. There is plenty of repositioning and empirical study necessary to tap into the potential of material capacities at a much greater level as has been done thus far, learning much more from the capacities of the material makeup of biological systems.

Therefore the question arises as to how a biological system might be analysed. Robert Cummins proposed an interesting approach that bears obvious resemblances to Alexander's approach elaborated above. Cummins stated that an analysis of the biological important capacities of an organism may be approached through a decomposition of the organism into a series of systems, such as cardio-vascular system, nervous systems, etc, each of which displays specific abilities. These in turn can be subdivided into organs and structures until the capacities of interest are accessible (Cummins 1975). Cummins elaborated, however, that the purpose of such analysis is not a perfect description of the entire complexity of the functioning of the system as a whole, but instead, to utilise mechanistic explanations of only such subsystems or system components that are of key importance to enable an understanding of the system based on relevant internal processes.

The above leaves us with two problems, first the form-function division in morphological studies, and second, the need for reductivism in the analysis of systems. To address the latter first, reductivism cannot be avoided, but the question of relating criteria in a hierarchical manner and enabling a change of hierarchy for experimental purposes through 'weighting' has already been addressed above. A useful approach is contained in Robert Brandon's and Alex Rosenberg's explanation:

To call something a wing, a feather, a tissue, a cell, an organelle, a gene is to describe it, at least implicitly, in terms of its function, i.e. the purpose it serves in the behavioural economy of some larger system. It must be kept in mind that biological structures can also be identified independently of their current function. Indeed, the possibility of such identification is required for one of the central concepts of evolutionary biology – that of homology (Brandon & Rosenberg, 2000: 148-149).

The insight gained is that the analysis of any (biological) system ought to be based in a variety of different categories and at different levels of hierarchies. With regards to any category it is necessary to consider levels upwards and downwards in the hierarchy of

systems, from the element to 'the overall behavioural economy' of the larger system. This involves then also the relations between a system and its context.

The problem becomes more complex when the inquiry does not only include the morphology of an individual organism in relation to what causes its particular expression and transformation over time, but when it also involves questions of evolution over time. The Danish botanist, plant physiologist and geneticist Wilhelm Johannsen contributed tremendously to the understanding of evolution by proposing first the notion of 'gene' and later the notions of 'genotype' and 'phenotype' (Johannsen, 1903). An organism's 'genotype' is the complete inherited information embedded within its genetic code, while its 'phenotype' unfolds from the interaction between the genotype, environmental factors and random variation. The resulting phenotypic variation is a key process in evolution by natural selection. 'Phenotypic plasticity' constitutes the extent to which the genotype determines an organism's phenotype. High phenotypic plasticity entails a greater environmental influence on the development of the phenotype, while low plasticity entails a greater influence of the genotype.

For the purpose of performance-oriented architecture driven by an evolutionary process, this suggests that the 'weighting' of the relation between the data that might constitute 'the genotype' of a system in relation to the wider environmental influences, the level of the 'phenotypic plasticity' of the system, can be a powerful method to integrate, interrelate and alter multiple parameters and variables that were selected for the 'design' process. The relevant system inherent information can be established empirically through design experiments and analysis focusing on properties and stimulus-response based system behaviours.

If we seek to enhance the active aspect of 'environment' beyond established modes of utilizing the concept of performance vis-à-vis architectural design and towards an expanded and instrumental take on performance-oriented architecture, biology can provide a paradigm through its various sub-disciplines of morphology, physiology, evolution and ecology and their interaction. Philosophers of biology and biologists are of course far from having exhausted questions in each sub-disciplines, let alone their integration. This, however, constitutes no hindrance in approaching a much greater disciplinary adjacency between architecture and biology, as can be learned from new disciplines such as Bionics or Biomimetics, in which technical biology constitutes an approach that utilises state-of-the-art technology to analyse the characteristics and behaviour of biological systems. Architecture has much to benefit from such research, both with regards to the understanding of biological systems and also the development of analytical methods that can be translated into generative methods.

A Brief Comment on Problems of Visualisation of Complex Systems in Biology and Architecture

If we examine the relation of the discipline of architecture to the discipline of biology since its inception, we can see that questions of form (architecture) and morphology (biology) as in *Gestalt*, offers the most comfortable ground for architects to relate to biology, since architects utilise material arrangements as the means of organising space, etc. This is given by a combined intellectual and visualisation problem and results unfortunately mostly in superficial formal resemblances between buildings and organisms, an approach known as 'biomorphism' in architecture.

The visualisation problem is not unfamiliar to biologists. In many a case understanding was hampered by insufficient visualisation skills. When some promising approaches occurred they were often overlooked until the visualisation problem moved more succinctly into the centre of attention. For instance, Maria Sibylla Merian, the naturalist and

illustrator who took interest in the metamorphosis of insects, researched the latter and illustrated two seminal books (*Der Raupen wunderbare Verwandlung und sonderbare Blummennahrung*, 1679 and *Metamorphosis Insectorum Surinamensium*, 1705) that showed the different stages of insect development and the related food plants and natural enemies together in one illustration. These illustrations were as unique at the time as they were rejected by the scientists for being too 'artistic' and the artists for being too 'scientific'.

This evaluation drew attention away from what were essentially some of the first relational illustrations. Instead, and in spite of Goethe's realization of the development of organisms over time and Darwin's and Haeckel's evolutionary trees, which constitute a type of diagram of the development of species over evolutionary time, the main focus of biological illustrations remained on (comparative) anatomy and morphology. This had intellectual consequences by way of focusing on form, even though the discourse of morphogenesis, metamorphosis, metabolism, evolution, genetics, biochemistry, etc required very different kind of illustrations. Notably and more often than not when major advancements were made in biology these came hand in hand with novel ways of illustrating the processes of interest.

The complex illustrations prepared today to visualize and elaborate matters concerning ecology are close to impossible for architects to 'read', let alone to instrumentalise for the purpose of architectural design. It is therefore of importance not only to consider what biological systems or methods of analysis in biology have to offer to a performance-oriented architecture, but also which types of illustrations are needed to help structure thought process and inquiry. At any rate this will require re-skilling and re-tooling of architects on a much more fundamental level than the argument heretofore may have suggested.

Towards Performance-oriented Architecture

From the above we have gained insights into the possibility that architecture, environment and inhabitant all 'perform', that all can be seen to possess in an interrelated way 'active agency', and that all interact with one another yielding perpetually complex behaviour. This makes it clear that a synergetic understanding and approach is required to unlock these complex interactions for the purpose of an instrumental approach to architectural design. It is evident that the articulation of architectures and the built environment can absorb and satisfy multi-functional and aesthetic criteria and preferences and that partitioning of space and modulation of environment are both consequences of material practice. In addition to these elements, we have seen that intentional abstraction can prompt the inhabitant to become an active part in 'structuring a field of possibilities' and that architecture can thus be 'blank', but also 'pointing' towards the possibility of 'new social formations and institutional form'.

In this way, David Leatherbarrow's requirement towards a reciprocal relation between the technical and productive and the contextual and projective can be satisfied. Given this synthesis, it is possible to think of social, cultural and environmental performance in an integral manner. This too delivers a new way of thinking about sustainability along the coordinated statement of performance requirements, quite unlike the currently predominant mode in which performance is seen as synonymous to functionality and different modes of sustainability are elaborated separately.

Research by design efforts can then focus on:

1. a detailed performance analysis of pre-industrial buildings unconstrained by interrelated issues of standardisation, tolerances and liability
2. an examination and develop of suitable already existing design methods such as form-finding
3. greater effort in basing design on material capacities and behaviour

4. careful examination and furthering of architecture theoretical efforts, and,
5. a disciplinary adjacency to biology, not only with regards to the understanding of living systems, but also with regards to the particular methods of biology as a discipline and also the philosophy of biology. In particular the field of ecology should provide valuable insights.

When aiming to synthesise a large number of parameters and variables it is necessary to adopt a systematic approach rooted in Systems Theory. Modes of analysis of complex biological systems may serve this purpose directly, considering the behaviour of various levels of subsystems, as well as the contribution to the 'behavioural economy of some larger system'. It is therefore of use to study both method and subject of biological systems analysis. For this a relational model is required for which ecology may serve as a field of study, as well as a generative mode, for which evolutionary biology may serve as a field of study.

It may be noted that many of the suppositions are as of yet only partly tested, that a higher level of integration has not yet been fully established and that related projects based on the proposed paradigm are yet to be constructed. However, the cornerstones of the theoretical and methodological framework have been established by the author and his team of collaborators and considerable work pertaining to the questions above is already under development. At any rate research efforts need now to be directed towards an overarching, consistent, and synergetic approach.

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