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Performance-oriented Architecture and the Spatial and Material Organisation Complex

Rethinking the Definition, Role and Performative Capacity of the Spatial and Material Boundaries of the Built Environment

Abstract

This article is based on the proposition that performance-oriented design is characterised by four domains of 'active agency': the human subject, the spatial and material organisation complex and the environment (Hensel, 2010). While these four domains are seen to be interdependent and interacting with one another, it is nevertheless necessary to examine each in its own right. However, the spatial and material organisation complex contains both the spatial and material domains, which are interdependent to such a degree that these need to be examined in relation to one another and also in relation to the specific environment they are set within and interacting with. To explore this combined domain within the context of performance-oriented design is the aim of this article, in particularly in relation to the question of the definition and performative capacity of spatial and material boundaries. The various sections are accompanied by research by design efforts undertaken in specified academic contexts, which are intended as examples of modes and areas of inquiry relative to the purpose of this article.

Keywords: performative capacity, material boundaries, spatial boundaries, spatial and material organisation complex.

Preamble. Extended Spatial and Material Boundaries as (Regions of) Action

This article sets out to examine the potential role of material and spatial organisation in performance-oriented architectural design, with a particular focus on the role of material and spatial boundaries. This is done in accordance with Chris Luebkeman's proposition:

> Performance-based design is really about going back to basics and to first principles, taking into account the experience one has gained over time as well as field and laboratory observations about the non-linear behaviour of elements and components. It is the combination of first principles with experience and observations that is the fundamental potential of the design philosophy. It places the design imperative back in the hands of the designer. And, more importantly, it also places responsibility and accountability back into the designer's hands in a very obvious way. One can no longer hide behind building codes. (Luebkeman, 2003: 284-285)

Consequently, the aim is to challenge entrenched preconceptions, to commence from first principles and to utilise the empirical production of knowledge based on a combination of theoretical reflection and research by design. In so doing, the argument presented here is based on a number of propositions as to what might be thought to constitute key characteristics of performance-oriented architecture.

These include first and foremost that 'performance as a paradigm enables the study of nature and the built environment as active agents, rather than as passive context' (Hensel, 2010: 41), and that active agency is a fundamental characteristic of 'four interrelated domains [...]: the human subject, the environment and the complex of spatial and material organisation' (Hensel, 2010: 38). Moreover, performance-oriented architecture entails that 'form and function are not separately treated, and neither follows the other; instead, both are interrelated and interdependent', as are 'different ways of organising and modulating space' (Hensel, 2010: 48). The latter refers both to spatial partitioning by means of material boundaries and to micro-climatic gradients and modulation that arise from the interaction of a system and its surroundings over time. Consequently, these two modes of spatial organisation are inseparable.

If the above indicates that architecture or its product, the built environment, can be viewed as a domain of active agency, it would be interesting to pursue this proposition in greater detail in one of the core areas of architectural production: spatial and material organisation. This pursuit requires an elaboration of increasingly complex relations and processes. This article commences therefore from material organisation and its interrelation with a specific environment, proceeding to material systems and, subsequently, to a discussion of spatial architectural boundaries. This discussion includes walls to envelopes, and delineating singular boundary conditions to ones that are extended over a region of space and that operate in a dynamic manner over time. This approach implies that boundaries might be understood as (regions of) action. The intended synthesis of the various scales and their complex interactions is termed the *spatial and material organisation complex* here.

Wherever suitable, the potential contribution of biological systems is discussed. The inquiry presented below is in large part driven by and illustrated with examples of research by design in architecture and architectural and biological systems analysis. The intention of this process is to contribute to the development of a theoretical framework for performance-oriented architecture.

Context of this Research

Research by design carried out by the author and his team of collaborators and students constitutes the various findings that underlie the article. These efforts are rooted in the educational field and were undertaken with diploma and master-level students in various schools of architecture in Europe, the Americas and Australia, and are currently being undertaken by the author at the Oslo School of Architecture and Design. This research focused on the articulation of the architectural boundary, resulted in scaled and full-scale material systems and the spatial and environmental provisions associated with these systems and culminated in a series of publications (e.g. Hensel & Menges, 2008; Hensel & Menges, 2006).

Initial questions about the role of materials and material systems as potential active agents have been discussed in various articles and papers (e.g. Hensel, 2009). Questions about spatial organisation and, thereby, also questions about the role of spatial boundaries, were chiefly pursued in an anthology of selected seminal essays by architects and theoreticians for the last fifty years (Hensel et al., 2009).

The cumulative research has led to the formulation of specific research areas focusing on questions of the articulated architectural threshold and auxiliary architectures, with the aim of raising the complexity of architectural inquiry (Hensel and Sunguroğlu Hensel, 2010a, b, and c). While the work undertaken to date is extensive, it is in mainly basic research. At this stage, it requires a detailed, overarching theoretical framework with the aims of grounding the findings and further pursuing and developing the proposed definition of performance-oriented architecture in detail. This necessitates research in the four proposed domains of active agency. This article is, thus, an attempt to tackle the domain of the *spatial and material organization complex*, based on the research and theoretical reflection undertaken to date.

Rethinking Material Boundaries

Approaching Performance-Related Concepts of Boundaries and Thresholds

In the discipline of architecture, the concept of 'boundary' is commonly understood as a material division, floor, wall or ceiling that separates an interior from an exterior, or, likewise, two adjacent spaces or rooms. In this context, a 'threshold' is a demarcation line, like a doorstep, that needs to be crossed to enter from one space into another; it connects and divides at the same time. However, throughout architectural history and across different climate zones, there existed different understandings as to what the exact functional assignment of an architectural boundary ought to be, varying also in the related understanding of how open or closed such a boundary should be.

Yet, since the late 1960s, interior climate conditioning through electrical-mechanical equipment and related stringent requirements for the conditioning of interiors have led to a much more hermetic separation of spaces and a likewise material articulation of the architectural boundary. In general this constitutes today's predominant understanding across all climate zones. This understanding has not been fundamentally challenged in spite of critical questions with regards to the impact of the homogenisation of the built environment and questions of sustainability. Instead, and under the mantle of the latter, all efforts are invested in improving the capability of the architectural boundary to separate (spatially, acoustically, thermally, etc.), as well as into lowering, the energy consumption of the electrical-mechanical equipment that re-orchestrates the carefully modulated exchange between the interior and exterior, or between adjacent spaces; in short, the zero-energy building. The predominant understanding of zero-energy buildings does not necessarily imply a preference for passive means, but instead a continued use of technology combined with clean energy sources. In order to facilitate this approach, the architectural boundary continues to be a dividing element.

The American scholars Addington and Schodek offered a fundamentally different approach to the problem at hand:

> For physicists … the boundary is not a thing, but an action. Environments are understood as energy fields, and the boundary operates as a transitional zone between different states of an energy field. As such, it is a place of change as an environment's energy field transitions from a high-energy to low-energy state or from one form of energy to another. Boundaries are, therefore, by definition, active zones of mediation rather than of delineation. (Addington and Schodek, 2005: 7)

In the context of thermodynamics, a boundary determines the relation between a thermodynamic system and its surroundings. Principally thermodynamic systems are defined by their boundary, but the exchange with their environment can be varied. An open system can exchange heat, work and matter with its surroundings. A closed system can still exchange heat and work, but not matter. Only isolated systems can exchange none, but these are only theoretical constructs (Atkins, 2010: 2). More specifically, thermodynamic boundaries can be described as adiabatic, isothermal, diathermal, insulating, permeable or semi-permeable. These characteristics describe the specificity of the flow of heat, mass or work across thermodynamic boundaries. This makes clear that thermodynamic boundaries range over a much broader pallet of different exchanges than simply being entirely open or closed. If we consider all degrees of open and closed systems, it becomes apparent that the interaction between the surroundings and system will affect a spatial region to a greater or lesser extent. This type of exchange underlies the emergence of specific microclimates. Rosenberg et al. described this as follows:

> Microclimate is the climate near the ground, that is, the climate in which plants and animals live. It differs from the macroclimate, which prevails above the first few meters over the ground, primarily in the rate at which changes occur with elevation and with time. Whether the surface is bare or vegetated, the greatest diurnal range in temperature experienced at any level occurs there. Temperature changes drastically in the first few tens of millimetres from the surface into the soil or into the air. Changes in humidity with elevation are greatest near the surface. Very large quantities of energy are exchanged at the surface in the processes of

> evaporation and condensation. Wind speed decreases markedly as the surface is approached and its momentum is transferred to it. Thus it is the great range in environmental conditions near the surface and the rate of these changes with time and elevation that makes the microclimate so different from the climate just a few metres above, where atmospheric mixing processes are much more active and the climate is both more moderate and more stable. (Rosenberg, Blad, & Verma, 1983: 1)

However, the production of microclimates in architecture today is mostly accidental. The built environment's accumulative micro-climatic effects are, thus, often unintentional (see, for instance, urban heat islands). This impact requires careful reconsideration.

Also of significance is the relation between micro-climatic layers close to material surfaces and adjacent climatic layers. Oke elaborated on the climatic strata upwards in scale: [i] the laminar *boundary layer*, 'which is in direct contact with the surface(s) … the non-turbulent layer, at most a few millimetres thick, that adheres to all surfaces and establishes a buffer between the surface and the more freely diffusive environment above'; [ii] the *roughness layer* that extends above the surface and objects 1 to 3 times their height or spacing and that is 'highly irregular being strongly affected by the nature of the individual roughness features'; [iii] the *turbulent surface layer*, up to 50 metres high, that features 'intense small-scale turbulence generated by the surface roughness and convection' (Oke, 1987: 6). Moreover, the vertical extent of these strata is dynamically affected by the atmospheric boundary layer that is characterised by turbulences 'generated by frictional drag as the atmosphere moves across the rough and rigid surface of the Earth, and the 'bubbling-up' of air parcels from the heated surface' (Oke, 1987: 4-5). As Oke points out, the height of the boundary layer can vary substantially due to the intensity of 'surface-generated mixing'. During the daytime when the sun heats the surface of the Earth, heat is transferred upwards into the atmosphere and, as a result, extends the boundary layer by up to 1 or even 2 kilo-metres. With the surface of the Earth cooling at a faster rate than the atmosphere at night, the mixing gets reduced due to the downward transfer of heat. This implies that the boundary layer might be reduced to less than 100 metres. Large-scale weather systems can have an additionally considerable effect on the thickness of the boundary layer (Oke, 1987: 4-5).

There is great potential in considering the production of a microclimate and its interactions with strata upward in scale as an integral part of the architectural design and the potential of the architectural boundary with regards to the interaction between the spatial and material organisation complex and the climatic environment. Yet, what transpires is that the extent to which the spatially extended dynamic boundary is defined in each case depends on the scale and complexity of interaction that is deemed of significance in each case. A great level of consideration and care is required in defining this extent in a case-by-case manner.

Addington and Schodek argue that the understanding of a boundary can no longer be reduced to the material surface alone. Instead, it must be expanded into a spatial and dynamic zone characterised by 'multiple energy environments fluidly interacting with the moving body' (Addington & Schodek, 2005: 8). They go on to argue, therefore, that 'smart materials' are of interest, with regards to 'their transient behaviour and ability to respond to energy stimuli', as they 'may eventually enable selective creation and design of an individual's sensory experiences' (Addington & Schodek, 2005: 8). In so doing, Addington and Schodek point in a very promising direction with regards to an instrumental redefinition of the concept of boundary. They do so with the aim of arguing for the development of smart materials that can respond in carefully calibrated ways to extrinsic stimuli. The first question that arises from this intent and proposition is whether current materials lack the capacity to be used in the proposed way or whether there is perhaps an underlying inherited industrial prejudice that prevents another approach. This issue shall be discussed in the following part.

In addition, there is also a more explicit proposition that architects are currently not able to operate on the basis of a redefined and spatially and dynamically extended concept of boundary, although Addington and Schodek are careful to point out interesting possibilities that arise from research in other disciplines (physics, biology, neurology) (Addington & Schodek, 2005: 8). The overarching aim of the research into performance-oriented design is to challenge this preconception and to provide a workable paradigm. Part and parcel to this is to show that currently unrecognized or undervalued potential can be found in pre-industrial architectures, in the redefinition of the architectural boundary, in the revision of the relation between interior and exterior, in the specific utilization of materials and so on. This implies that a great number of preconceptions that prevent different views and approaches must be challenged, partly from within architectural discourse and research and partly by looking for alternative paradigms in different disciplines as proposed by Addington and Schodek. Therefore, after having considered the definition of thermodynamic systems and boundaries as regions of active agency, it is useful to examine biological models for the purpose at hand. To commence this inquiry, it is necessary, however, to consider material boundaries and behaviour more generally.

Repositioning Material Boundaries and Material Behaviour

Materials are characterized by their composition and structure from which their properties arise. The latter include mechanical, thermal, chemical, electrical, magnetic, acoustic, optical and environmental properties, each with their own specific sub-categories. While some properties may be relatively constant, others may vary as a function of the impact of independent variables, such as temperature, ambient humidity, etc. Material properties can either be intrinsic; that is, resulting from a material's micro-structure – its chemical composition and atomic and molecular structure – or extrinsic; that is, defined by a material's macro-structure. Some properties are 'dependent upon the energy fields of their environment' (Addington & Schodek, 2005: 39). Addington and Schodek continued that 'all material properties … are indicative of the energy stimuli that every material must respond to', that 'all energy stimuli are the result of 'difference' and that 'properties are what mediate that difference' (Addington & Schodek, 2005: 39).

The properties of a material can either be directionally dependent (anisotropic) or homogenous (isotropic), depending on the specific structure of a material. This is of great importance for utilizing material behaviour. Material properties, together with the specific environment within which a material is placed, yield material behaviour, i.e. dimensional variability due to temperature changes or changes in ambient humidity, while in turn also affecting its surroundings or microclimate, as discussed above. In general, material behaviour is deemed negative in the industrial tradition, as a result of standardization, tight tolerances and associated liability. It is therefore typical for architects to prefer materials with as minimal behaviour as possible, to prevent material behaviour in some way by altering its properties or to neutralize the impact of material behaviour by means of mechanical solutions. This development is directly related to the increasing replacement of a systems theory-related approach by standardisation, with tremendous repercussions in the understanding and use of materials, structures (for elaboration of the related repercussions, see, for instance, Polóny, 1997), spatial and programmatic organisation of buildings and interior environments; in other words, the entire remit of aspects pertaining to the articulation of the built environment. This then constitutes the fundamental need to critically re-examine this development as suggested above by Chris Luebkeman (Luebkeman, 2003).

In general, this needs to include the critical revision of the prevailing approach, which requires the material constituents of the built environment to be chiefly in stabile equilibrium. Continuing this approach would obviously be in fundamental contradiction to the notion of spatial and material organisation characterised by 'active agency' and requires a repositioning towards the dynamic condition of 'stabile disequilibria' (a fundamental notion proposed for the understanding of ecological systems by Reichholf, 2008). For the instrumentalisation of the material constituents, this requires that material behaviour is understood as based 'on energy stimuli that every material must respond to' (Addington & Schodek, 2005: 39).

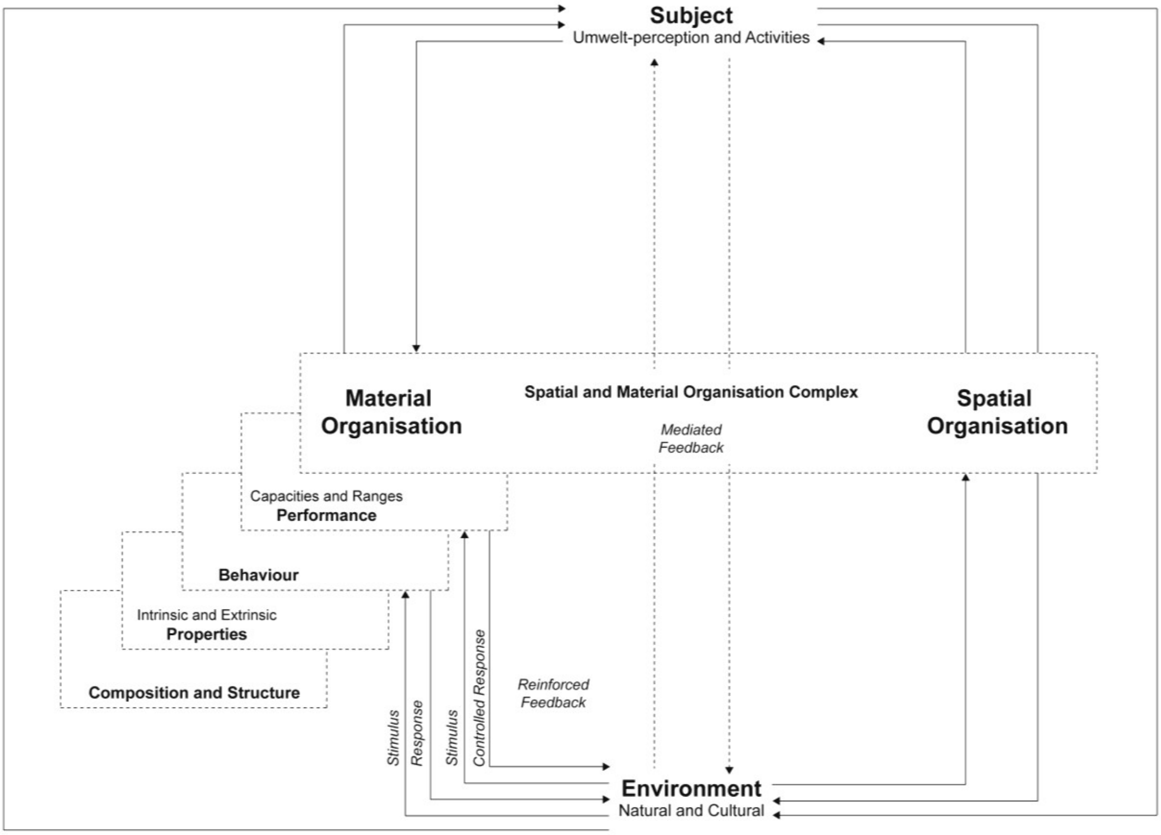

Fig.1. Performance-oriented architecture concerns the dynamic interrelation between four domains of 'active agency': the human subject, the environment and the spatial and material organisation complex. In order to derive an instrumental approach to the material constituent as an 'active agent', material behaviour needs to be positively regarded and fully embedded in architectural design. It is therefore necessary to approach material properties and their potential range changes due to independent environmental variables in a different way and with main emphasis on deploying the resulting behaviour (i.e. dimensional variability). Material behaviour can, thus, be instrumentalised as performative capacity. This entails reinforcing a nuanced feedback between material properties and independent variables and a fundamental repositioning towards the material constituents that make up the built environment. Illustration: Michael Hensel, 2010.

This repositioning must commence with the understanding of material in relation to surroundings. This must commence from material composition in relation to environmental conditions (i.e. the specific structure of wood resulting from the specific environmental conditions affecting its growth; see, for instance, Schweingruber, 2007), and must furthermore be based on the interrelation between material properties and environmental conditions, which then determine material behaviour. The harnessing of material behaviour towards active agency constitutes the basis for the instrumentalisation of material behaviour as performative capacity.

With regards to the internal makeup of a material, this entails a positive repositioning towards a greater amount of differentiation (see, for instance, Wagenführ, 2008 with regards to the anisotropic structure of wood). This is required in order to utilise a greater scope of performance ranges and a much more finely nuanced use of material behaviour.

It is also of importance that the findings are not primarily geared towards further standardisation, but rather towards the central question of processes of interaction between systems. Consequently, this also requires a renewed interest in systems thinking towards the articulation of the built environment, and in design and research by design (Sevaldson, 2010). The need for the production of reliable empirical data is immense and potentially costly. However, if it is made the subject matter of dedicated research conducted within academic contexts and embedded in teaching syllabi, it may well be very affordable. The following is an example of dedicated research geared towards a repositioning of material behaviour based on the production of empirical data.

In the context of the master-level Wood Studio at the Oslo School of Architecture and Design, the master student Linn Tale Haugen challenged the fact that the moisture content-related warping of timber laminates is negative per se. Timber laminates are generally composed of an odd number of layers since this stabilises the laminate and prevents it from warping due to its hygroscopic behaviour. Hygroscopy characterises the ability of a material to absorb water from the environment: wood is hygroscopic and can therefore absorb moisture from the environment or yield it back, ‘thereby attaining a moisture-content which is in equilibrium with the water vapour pressure of the surrounding atmosphere’ (Dinwoodie, 2000:49). Hygroscopy coupled with anisotropy leads to dimensional variability of the material. In other words, the material can swell or shrink in response to the level of relative humidity of the environment. In a typical laminate consisting of an odd number of layers, the layers are rotated so as to utilize the fibre direction to stabilize the laminate. Likewise, in a laminate with an even number of layers, the fibre direction of the various layers can be utilized to warp the laminate in a controlled way. ingle or double curvature can be attained with a specific fibre direction in the different layers and with the related directions caused by the swelling and shrinkage from the moisturizing and drying of the wood. It is then no longer necessary to derive such curved elements by means of machining, such as routing, which results in a large amount of off-cuts or sawdust, or, on the other hand, the costly production of moulds.

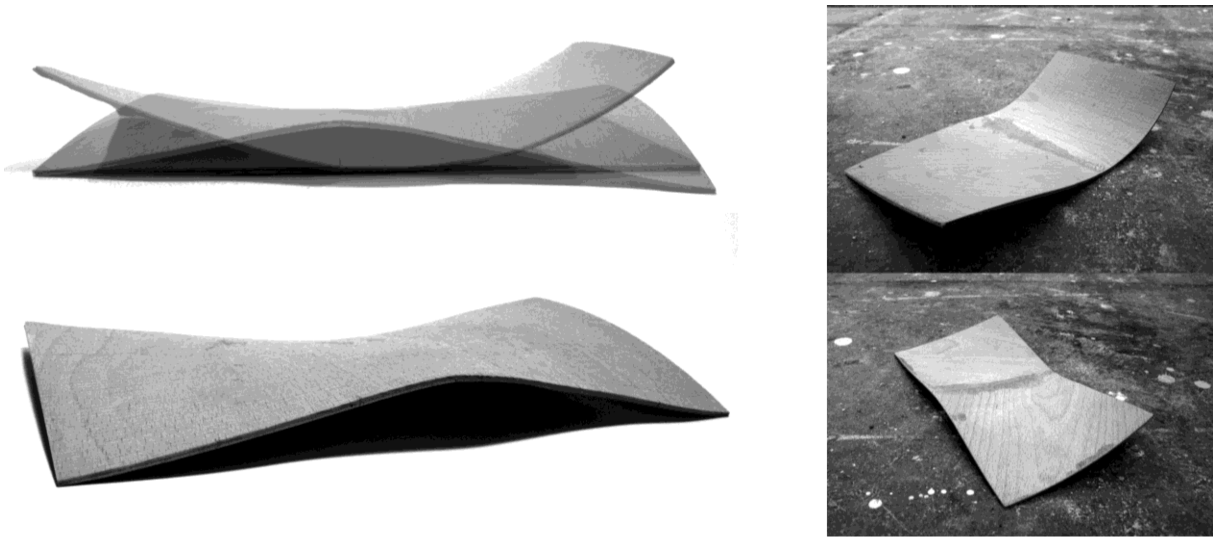

Fig.2. Various examples of an instrumental utilisation of the hygroscopic behaviour of wood for the purpose of ‘self-shaping’ laminates. In the context of the Wood Studio at the Oslo School of Architecture and Design, master student Linn Tale Haugen conducted extensive research on the production of empirical data regarding the production of single- and double-curved laminates with a pre-determined geometry. The principle was derived from the analysis of the layered fibre direction of the seedpod of a Flamboyant tree, as discussed below. Photos: Linn Tale Haugen, 2009.

Linn Tale Haugen used beech veneer due to its elasticity and related ability to warp without cracking and undertook a large number of experiments to be able to eventually accomplish pre-specified curvatures of the laminate. In doing so, the material behaviour was harnessed in a process of shaping that is more sustainable than existing methods for the production of specifically shaped elements. This process is to some extent reversible when the material remains untreated, or it can be made irreversible by sealing the surface. The reversible option is based on and maintains a dynamic exchange with its surrounding by virtue of its hygroscopic behaviour. This may be useful if a non-form-stable material element or assembly is required.

Furthermore, it is necessary to consider the material system made from specific material elements. Various parameters are crucial to the utilisation of the behaviour of a material system, which is also evident in its definition: the fabrication and resultant characteristic of the material elements with regards to tools and treatment, the logic of connecting elements into larger assemblies and the resultant performative capacities of such systems. This raises questions about dimensions, positions and the orientation of material elements into a larger assembly.

This requires consideration of the various critical thresholds in which a material system acquires additional properties, behaviours and capacities. Given the complexity of interdependent variables and parameters in a material system, this aspect will require detailed examination in a separate paper. In the following sections this discussion is therefore omitted for the sake of focus on the architectural aspects of the material boundary and spatial organisation.

While the importance of the principal approach to utilising material behaviour is increasingly becoming evident, a lot more research needs to be done to provide reliable empirical data for design. And while first steps have been taken, it is also necessary to look for a suitable paradigm to locate this approach within. This may well be found in the relationship of biological systems to their specific environments.

Potential of Biological Materials and Membranes

Biological membranes, such as cell walls, are selective barriers that both contain and facilitate exchange between the contained and the surroundings. Their importance is not to be underestimated, as biological membranes facilitate one of the essential criteria for life, which is called inherent unity. In 1971, the Hungarian chemical engineer and biologist Tibor Gánti posited a series of life criteria (Gánti, 1971) Gánti distinguished between real and potential life criteria, the former being necessary for an organism to be in a living state, while the latter are necessary for an organism's survival in the living world. Gánti included inherent unity, metabolism, inherent stability (homeostasis), information-carrying subsystems and program control among real life criteria (Gánti, 1971: 76-78), while growth and reproduction, capability of hereditary change and evolution, as well as mortality are posited as potential life criteria (Gánti, 1971: 78-80).

Since Gánti's *Principles of Life*, many revisions, as well as abbreviated ones, to life criteria have been proposed to identify, characterise and facilitate the quest for artificial life. Be this as it may, inherent unity has remained a key criterion for life in all the various attempts to define and list such criteria. For the purpose of discussing a biological paradigm for architectural design, it is, thus, of interest to understand what biological membranes are and how they function in order to discuss their potential value as a way of rethinking and redesigning the characteristics of man-made material and material boundaries.

Among the key features of biological membranes is their ability for selective permeability and filtration of material through the membrane and their role in energetic processes, such as the partitioning of metabolism. Packer posited that 'membrane bioenergetics represent one of the most sophisticated specialisations of the living world, as biological membranes make possible the controlled channelling of energy into different modalities' (Packer, 1974: 211). Yet, Packer also pointed out that a more detailed understanding of the 'basis of energy transduction in membranes remains one of the … unsolved current problems in biology' (Packer, 1974: 211), although some considerable progress has been made since. Another fundamental difficulty according to Packer is the wrong assumption that the 'structural organisation of membranes is stable in time'; instead, he claims, 'membrane components are astonishingly mobile' and can therefore at best be described as 'time-averaged membrane structures' (Packer, 1974: 145). Thus, the direct utilisation of biological membranes as a model for architectural boundaries will, for some time, remain elusive, not the least because the production of biology-inspired intelligent membranes is currently constrained to very small sizes mainly for the purpose of controlled filtering in pharmaceutics.

It is interesting to note, however, that in order to fulfil their functions associated with the necessary continuous control of chemical processes, living cells must possess the ability to sense chemical concentrations, to translate sensors' responses and transmit related signals to an actuator that drives the response. This relates directly to Philip Ball's definition of smart materials as 'materials that replace machines – in other words, materials that can carry out tasks not as consequences of signals or impulses passed from one component to another […] but as a result of their intrinsic properties' (Ball, 1997: 103). Ball continues to posit that the specific value of natural materials is to be found in 'their potential to serve as models for the advanced materials of the future' (Ball, 1997: 144). The question, though, is whether the functionality of sensing, transmitting and actuation is solved in a mechanical manner and through technological equipment, as is the current approach in architecture, or whether it is affected by the intrinsic properties of the material as Ball, as well as Addington and Schodek, suggest. Moreover, the question is whether this requires that smart materials must be specifically designed and manufactured or if materials presently not considered smart can be generally utilised by foregrounding their characteristic property-defined material behaviour and performative capacity.

Could materials be re-described from a biological perspective? The English pioneer of biomimetics Julian Vincent states,

> There is a general move towards the production of biomimetic and intelligent materials. This involves developing new ideas for synthesis of materials to take control of morphology and chemistry closer to the molecular level at which the cell works, and understanding more about the mechanisms of control. This understanding will inevitably feed back to biology. (Vincent, 1990: ix)

The primary issue that needs to be tackled in this regard is the degree to which a material must be active in the currently understood manner and definition of smart materials: [i] as specific singular items and elements that respond in a controlled manner to some defined type and scale of stimulus; or [ii], whether this still constitutes a more mechanistic understanding that is merely analogically aligned to biological materials, systems and behaviour. If, in general, materials are considered and utilised with regards to their behaviour in a much greater scope of interdependencies and stimuli, it is perhaps exactly this understanding, which could be more directly extracted from biological systems. We can therefore propose a model in which perhaps the analogical mode is not the predominant one, and a more literal approach may be required. In this area of inquiry, a great deal of thinking and research will be necessary.

While such studies into biological materials have been the subject matter for scientific inquiry in the field of biomimetics, this kind of research is new to general architectural education. The 'Biological Systems Analysis' course in the master program of the Oslo School of Architecture and Design focuses on such detailed studies. One example is the study of the fibre orientation in wooden plant parts and their resultant hygroscopic behaviour. The related research findings are then explored in the research by the design-based 'performance-oriented design' studio. For instance, the detailed study of a Flamboyant tree seed pod was utilised in Linn Tale Haugen's research into the self-shaping of even-layered beech veneer laminates, as discussed above. Further studies of conifer cones show how dimensional instability is utilised for the reversible process of opening and closing the cone for the purpose of proliferation of the respective species. Obviously, questions of scaling must be carefully considered when trying to instrumentalise the relationship between material objects and physics.

Fig.3. Analysis of the fibre direction of the different layers of the seedpod of a Flamboyant tree undertaken in the 'Biological Systems Analysis Course' at the Oslo School of Architecture and Design. The angle of rotation of the fibres in the layers and the thickness of the layers determine the degree of warping of the two parts of the seedpod as a result of moisture loss-induced shrinkage. The warping serves the purpose of separating the two parts of the seedpod and releasing the seeds. The cones of conifers show a similar principle at work, yet a reversible one, which facilitates the cones' opening and closing in response to the level of ambient humidity in the environment. Photos: Michael Hensel, 2005.

Rethinking Spatial Boundaries in Architecture

Problematising Walls and Envelopes

Architects typically use walls and building envelopes as material boundaries and as a means of organising space through partitioning and delineation. However, it was the advent of mechanical-electrical interior climate modulation, paralleled and enhanced by the attempt to devise closed ecological systems for spaceflight programmes and the design of Cold War bunkers at their height in the 1960s, that accelerated the material boundary towards a quasi-hermetic division between the exterior and interior or between different enclosed spaces. The repercussions of these developments for contemporary architecture is evidenced and enhanced by a diagram of a tent in Rayner Banham's seminal 'The Architecture of the Well-tempered Environment' (Banham, 1984 [1969]: 18). While Banham's proposal that 'technology, human needs and environmental concerns must be considered an integral part of architecture' (Banham, 1984 [1969]: back-cover) is in line with the argument pursued here, the diagram of the tent promotes, alas, a view of the tent membrane as a hermetic division: it 'deflects' moisture, airflow or thermal radiation. The diagram exclusively foregrounds that which is 'deflected' and gives no evidence of the conditions that arise out of the permeability of the

tent membrane and the connections and gradients facilitated by it. This is so because Banham wished to promote the technology of 'power-operated solutions' as that which ought to re-orchestrate the exchange between the exterior and interior and as that which 'creates the opportunity for new spatial-social organisations' (Hight, 2007).
While this seminal book constitutes in some way the fundamental theorisation of the 'power-operated solution', Banham is certainly not singlehandedly responsible for the developments that have ensued since then. Various developments have led up to this moment, which cannot be enumerated in the context of this paper, although some shall be more closely examined below. However, the combined repercussions fundamentally changed the appearance and processes of today's built environment.

In sum, today's fundamental necessity to consider all architectural interventions from environmental, social and cultural sustainability aspects has not yet led to a broad critical re-examination of the prevalence of the ultimate architectural division between the exterior and interior and the electrical-mechanical reconnection between the two, but instead only to a refinement of active technology and passive materiality (i.e. in the form of thermal insulation). The development to this point has neither been linear nor singular. The following part focuses on selected approaches and critiques in this development in order to then seek alternative ways of understanding architectural boundaries and thresholds.

The late Robin Evans examined the role of the wall and types of spatial organisation in relation to social formations at length in his seminal writings (Evans, 1997a and 1997b).
He elaborated on the role of the wall in two ways: first, as the means to enable retreat from an exterior to a private, secure place, and, second, as the prison wall, the means of exclusion by way of punishment. In both cases, the wall acquires the role of quasi-hermetic division. Evans concluded that

> Of all the means of shutting out experience … the wall is clearly the most adaptable. Yet, the history of the wall as a means of moral, aesthetic and social exclusion … is unwritten … One cannot help but feel that retreat is to us a more acceptable, gentler and altogether more lovely realisation of the current resurgence of existential despair than the crude Procrustean surgery of exclusion, but both could be considered, in a certain sense, as defeats. So maybe what we have seen emerging in the past few years is not so much the budding vision of a young paradise, as the birth of a new technic of human failure. The desire of sanctuary is with us once more.' (Evans, 1997a: 50-51)

Evans evidently took a negative stance towards the role of the wall that he perceived. Yet, his critique does not extend to a proposition as to how to remedy the fundamental problem he stated, nor does his essay implicitly point towards any particular alternative.

In his second seminal essay, 'Figures, Doors and Passages' (Evans, 1997b), Evans pursues a similar critique in which he described how a spatial organisation called the 'medieval matrix of interconnected rooms' was supplanted in seventeenth-century England by the model of the corridor with rooms opening into it. In this essay, Evans connected and correlated social formation with spatial organisation in the plan, discussing the medieval matrix in relation to the more or less accidental social encounters between those who passed through these rooms and those who inhabited them. According to Evans, the matrix of inter-connected rooms belonged to a culture of the carnal, touch, immediacy and co-habitation. Evans went on to describe that the shift towards the corridor model originated from the need of the landed gentry to uncouple the space inhabited and the circulation space of the landlords from that of the servants. Social encounters became controlled, and proximity turned into social division, perhaps even exclusion.

In summing up, Evans asked why the corridor model still prevails today as a predominant spatial organisation, when the social arrangement that brought it into being is perhaps no longer significant. In doing so, he alerts the reader to the need to rethink spatial organisation via the arrangement of material boundary and strategic connections and thresholds and their possible combined provisions an implications for social formation. Again, the essay constitutes a call for a critical approach to the topic at hand without pointing towards a particular alternative. It might then be useful to first point out the unchallenged preconditions of the argument.

In both cases of spatial organisation, the 'matrix of interconnected spaces' and the corridor and cellular room model, the dividing wall is clearly assumed to be solid and opaque. A wall with many openings and/or transparency would not fulfil the basic criteria of division that underlies both the function of the wall and its critique as pursued by Evans. What, then, are the ramifications of changing these basic criteria? What if the architectural boundary is not entirely solid and opaque? There are numerous suitable examples throughout architectural history that lend themselves to a detailed analysis.

Screen-walls and Louvered Walls

As part of his research into the environmental modulation capacity of vernacular architecture in hot arid climates, the late Hassan Fathy analysed Islamic screen-walls, or so-called *mashrabīyas*, that consist of wooden latticeworks, frequently used in projecting oriel windows that are enclosed by such latticework (Fathy, 1986). These screen-walls are characterised by multiple functionalities. They regulate, in a nuanced manner, the passage of light, air flow, temperature and humidity, as well as visual access from the inside and protection from the outside. All this is accomplished through the careful calibration of the size of the balusters that make up the latticework and the interstices between them. Different parts of these screen-walls cater to different hierarchies of the integrated functions. If, for instance, interstices need to be smaller at seating or standing height to reduce glare, the resultant reduction in airflow would be compensated for by larger interstices higher up in the latticework. While fulfilling their various functions in a nuanced and interrelated manner, the actual formal articulation of the pattern of the balusters can absorb very different aesthetic preferences. Examples include expressive floral patterns and abstract geometric patterns. These screen-walls are compelling demonstrations as to how formal and multi-functional requirements can be integrally solved instead of being disentangled into separate single-function building elements. Perhaps the most sophisticated function is the modulation of the humidity of the air current for the purpose of cooling by means of utilising the hygroscopic behaviour of wood:

> Wind passing through the interstices of the porous-wooden *mashrabīya* will give up some of its humidity to the wooden balusters if they are cool at night. When the *mashrabīya* is directly heated by sunlight, this humidity is released into any air that may be flowing through the interstices… The balusters and interstices of the *mashrabīya* have optimal absolute and relative sizes that are based on the area of the surfaces exposed to the air and the rate at which the air passes through. Thus if the surface area is increased by increasing baluster size, the cooling and humidification are increased. Furthermore, a larger baluster has not only more surface area to absorb water vapour and to serve as a surface for evaporation but also more volume, which means that it has more capacity and will therefore release the water for evaporation over a longer period of time.' (Fathy, 1986: 48-49)

Clearly, the orientation and positioning of the *mashrabīya* relative to the spatial and material organisation of a building and in relation to the local environment is of key importance. It is, thus, necessary to understand the interaction between the spatial and material organisation complex and a specific environment. This is not sufficiently addressed as a series of one-way causal relations, all separately dealt with through a set of mechanical models that focus on single functional criteria and material characteristics. Instead, it is necessary to conceive this as feedback-based exchanges that require behavioural models as the means of instrumentalisation: the local environment affects the spatial and material organisation complex and vice versa.

These screen-walls were used throughout history in all parts of the Islamic world, from Mogul architecture in India to Morocco. Many contemporary architects have indeed taken interest and recognise their potential without necessarily re-theorising these elements for the contemporary built environment. The Behlings, for example, posited that 'the dream of the Mogul architects was to create the ultimate diaphanous wall', in this case carved from white marble or other stone, and 'the Mogul screens are far more sophisticated than modern devices for creating shade. The filigree designs and the dramatic play of light and shadow create virtual spaces within room … the screens filter the light and allow cross-ventilation' (Behling & Behling, 2000: 117).

Islamic screen-walls have been in continued use, especially in North African context, in spite of the fact that electro-mechanical interior climate conditioning has, since the 1970s, all but eradicated a great wealth of sophisticated passive means throughout the world. What makes things worse is the fact that air conditioning has become a status symbol of the affluent, and the increasingly reduced prizes of equipment ensured that eventually all households, except the ones of the poorest, are now air-conditioned too. Nonetheless, screen-walls have had a new lease on life outside of architecture for the poor, gained through certain works of modernist sculpture and architecture.

In a chapter of his seminal book *Architecture oriented otherwise*, David Leatherbarrow discussed different variants of louver walls designed by modernist architects, arguing that this building element has great potential for performative architecture (Leatherbarrow, 2009). Leatherbarrow foregrounded the role of orientation, stating that 'because buildings occupy sites, they must "find their bearings" with respect to their environment. Because they accommodate uses, they must cover their volumes with suitable surfaces' (Leatherbarrow, 2009: 9). In the following detailed analysis, Leatherbarrow selects a particular type of surface, a louvered wall that he calls a 'breathing wall'. Leatherbarrow continues by quoting Alan Colquhoun, stating that the sun breaker, an external louvered wall, 'was more than a technical device; it introduced a new architectural element in the form of a thick permeable wall' (Colquhoun, 1989: 187). It is the interaction between this type of building element and the specific environment that is set within what Leatherbarrow calls 'productive, because its settings supply what the given location is unable to supply on its own' (Leatherbarrow, 2009: 33), and, moreover:

> Certainly the building's elements are passive – they do not move or change position – but they can also be seen to be active if their 'behaviour' is seen to result in the creation of qualities the world lacks. This is to say, architectural elements are *passively active*. Seemingly at rest, they are secretly at work. The key is this: in their labour, architectural elements fuse themselves into the latencies of the ambient environment, adopting their capacity for change or movement. (Leatherbarrow, 2009: 37-38)

Given these realisations, it would be necessary to take stock of permeable building elements in different climate zones (ranging from light textile membranes to porous materials with considerable mass) and to analyse their capacity to fulfil multiple functional requirements while being capable of absorbing formal preferences that may relate to specifically intended cultural and combined social and spatial agendas.

Likewise, it is necessary to develop these elements for different ranges of functional requirements and for different environmental contexts. This line of research commenced in 2000 and took place in various academic contexts (see, for instance, Hensel and Sunguroglu Hensel, 2010c; Hensel and Menges, 2006 and 2008). An example of a variation on the theme of the screen-wall is a design experiment carried out by master students Joseph Kellner and David Newton in the context of the Proto-Architecture Studio at the Rice School of Archi tecture in 2004. The screen-wall consists of uniformly shaped and sized thin plywood elements that are mounted onto larger sheets of equally thin plywood. The smaller elements are attached to the larger ones in two diagonally opposing corners and pushed away from the larger sheet in the remaining opposing corners by means of metal bolts. This results in the warping of the smaller patches, which then also affect the warping of the larger sheets. The curvature of both the smaller patches and the larger sheets can be calibrated by means of the metal bolts. Numerous sheets were mounted to one another to form a 10-meter-long and two-meter-high wall. This wall was initially mounted flat without any warping induced by the bolts. After complete assembly, the bolts were used to incrementally induce the warping in all small patches and larger sheets until the entire wall assumed double-curvature. The addition of perforation to the larger sheets exposed upon warping of the patches enables light transmission and ventilation between the two sides of the screen-wall. In addition to the functionality of traditional Islamic screen-walls, the specific curvature of the entire wall facilitates its capacity to bear its own load.

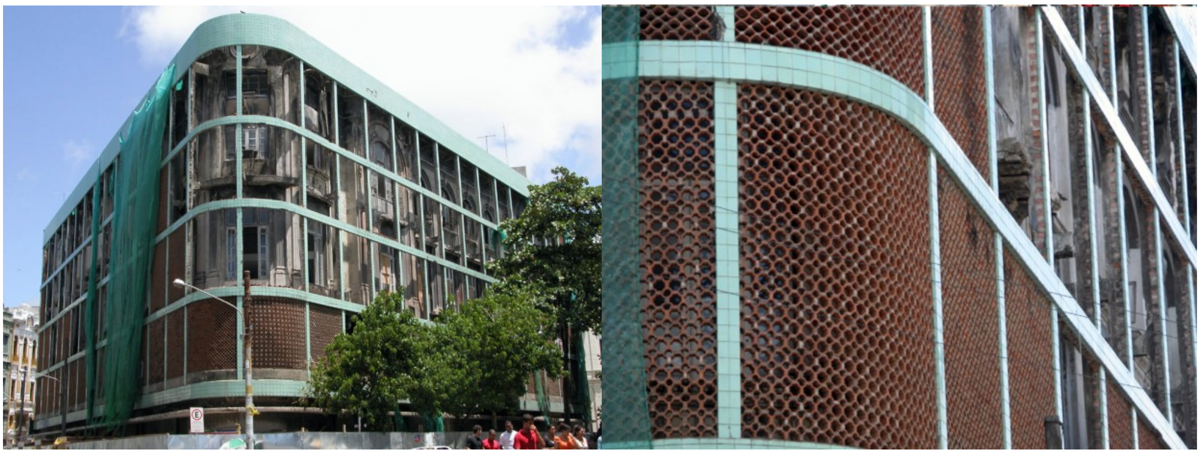

Fig.4. The Brazilian *Cobogó* is a contemporary façade element commonly made from ceramics or concrete and assembled into a screen-wall that serves the purpose of ventilation, shading and the regulation of visual access. The name of this element is an acronym that derives from the names of three Brazilian architects and engineers who invented the Cobogó during the first half of the 20th century: Coimbra, Boeckmann and Góis. The Brazilian architect Delfim Amorim used the *Cobogó* as a screen-wall in the 1959 redesign of the Luciano Costa house, an eclectic building from the 1910s located in Recife. A tiled concrete framework supports the ceramic Cobogó infill. Photos: Defne Sunguroğlu Hensel, 2006.

Unlike the flat Islamic screen-wall, this variant can stand by itself, given sufficient curvature. Moreover, the curvature of various parts of the wall can be used for better orientation towards the sun or prevailing wind. However, the mechanical effort required in shaping the screen-wall or modifying its shape subsequently seems out of proportion. This may be remedied by utilising the research by Linn Tale Haugen described above, which focused on the self-shaping capacity of laminates consisting of even layers with a consideration of fibre direction per layer and a wetting and drying process to affect the controlled warping. In order to maintain sufficient curvature so as to sustain structural capacity, selected areas of the wall could be sealed to accomplish irreversibility, while other areas may remain shape-reversible due to hygroscopic behaviour. In doing so, the project shows how the 'active agency' of an architectural boundary may be informed by historical examples, while being broadened in scope by research of design efforts. This approach is also not without historical precedent. Traditional wooden hay barns in northern Germany utilised the hygroscopic behaviour of timber shingles to keep the hay dry to prevent it from rotting. This was accomplished by fixing the timber shingles only along one edge and by not sealing the wood surface. In this way, the material can take up and give off moisture from the environment. When swelling due to the timber taking up water, the shingles warp and increase the size of the opening, increasing airflow. The enhanced airflow keeps the hay dry. When the ambient humidity of the surroundings falls below the moisture content of the timber shingles, hygroscopic behaviour tends towards equalisation of moisture content, and the shingles dry out and return to their flat shape. The level of interaction present in these examples demonstrates how one can develop the instrumentalisation of the active material and architectural boundary.

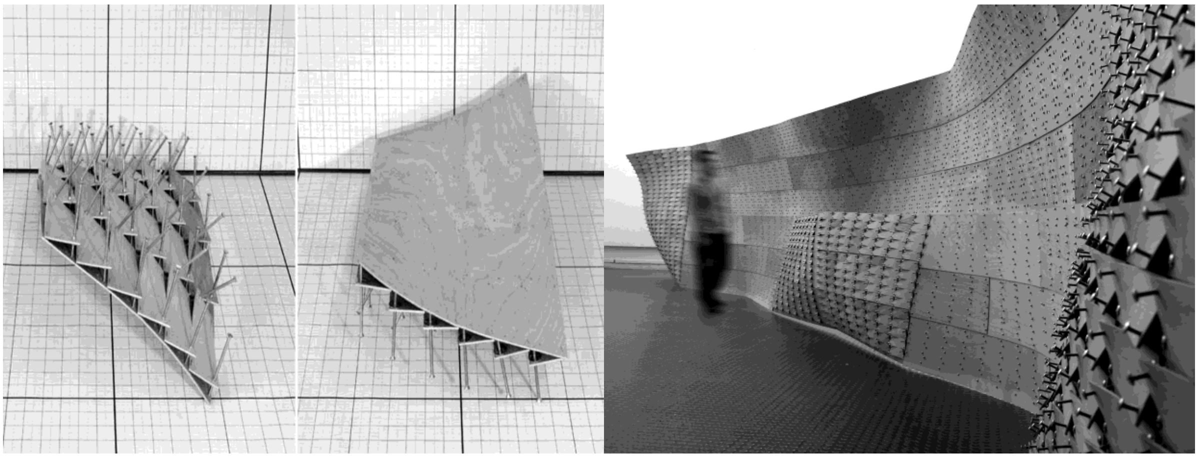

Fig.5. Screen-wall variant experiment by master students Joseph Kellner and David Newton at Rice School of Architecture in 2004. The design utilised the controlled warping of plywood elements to induce curvature in the assembly, which adds structural capacity and the possibility for differentiated orientation, as well as possible shape adaptation to the scope of multi-functionality of traditional Islamic screen-walls. Photos: Joe Kellner and David Newton, 2004.

Transitional Inhabitable Spaces

When the architectural boundary begins to acquire sufficient space for inhabitation, it furthers the performative capacities of architecture, as well as the possibility of entirely repositioning the relation between the inside and outside. This is not a new thought. The history of architecture is rich with examples, including the versatile use of arcades and loggias. The transitional zone between the inside and outside introduced by such elements can facilitate the sophisticated climatic modulation of the respective building and provide spaces for versatile use by the inhabitants. The articulated inhabitable envelope is, thus clearly in direct opposition to the flat and often spatially featureless enclosure of the age of electrical-mechanical interior climatization. The former was, thus, deemed aesthetically old-fashioned, indicative of a time of lesser comfort and unnecessarily costly in initial expenditure.

David Leatherbarrow claimed that modern architecture did not eradicate the architectural boundary as a separation between the inside and outside. Instead, modernist architecture made this separation more subtle in his view, as ‘boundaries between spatial interiors and exteriors are not overcome with the adoption of the structural frame, but thickened’ (Leatherbarrow, 2009: 34) One may wonder, then, whether the arcaded space of the Renaissance, for instance, did not predate the modernist louvered wall as a thickened boundary. Such a comparison may, however, be based on an error in category. The louvered wall, just like the screen-wall is a building element characterised by, for lack of a better term, a second-degree space, one that serves various sophisticated purposes, yet not intended for direct inhabitation. The confusion arises from the ambiguous use of terminology by different writers. Behling and Behling, for instance, refer to the arcaded space of Italian Renaissance architecture as ‘the wall [that] becomes habitable shade’ (Behling & Behling, 2000: 120).

Whether it is correct to argue that the arcaded space derives from the design evolution of the wall is not of essential concern to the argument pursued here; instead, the importance lies with the hierarchical structuring of complex interaction for the purpose of its instrumentalisation for performance-oriented architecture. Thus, it is useful for the purpose at hand to distinguish between building elements and habitable spaces in a clear manner.
Therefore, in returning to David Leatherbarrow's comment on the thickened border of the louvered wall, it is necessary to examine whether some traits of modernist works developed equivalents to inhabitable transitional spaces between the inside and outside.

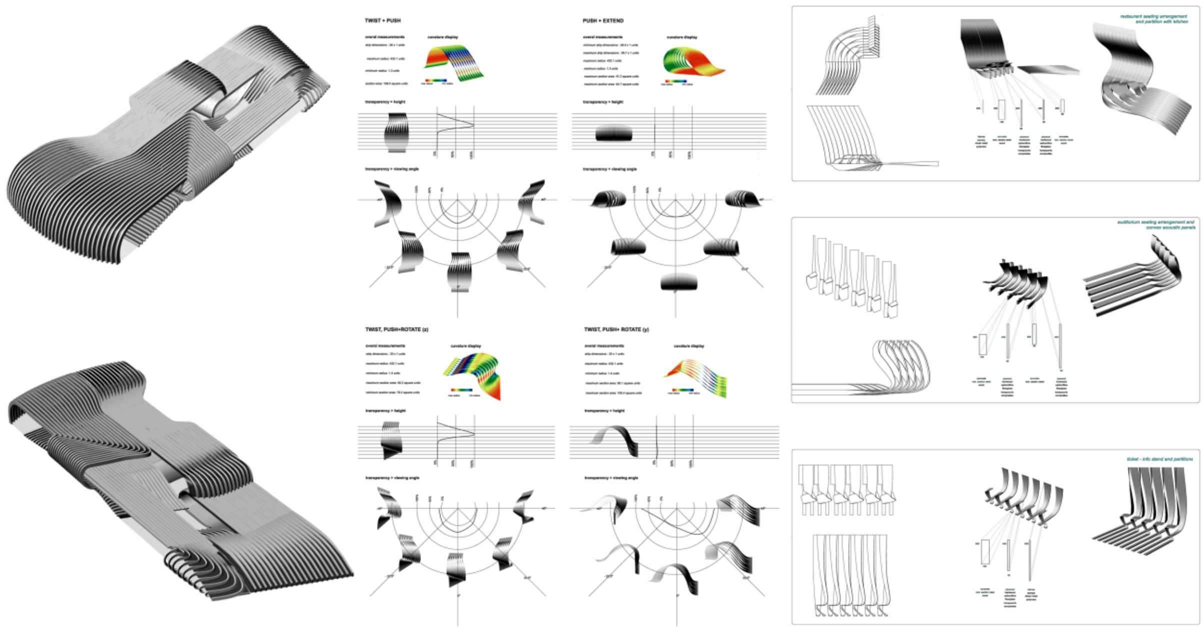

Fig.6. In the context of Diploma Unit 4 at the Architectural Association, directed by Michael Hensel and Ludo Grooteman (1999-2003), the extension and spatialisation of the architectural boundary was the subject of extensive research by design. For their entry to the Copenhagen Playhouse Competition, Copenhagen, Denmark, 2001-02 diploma students Nasrin Kalbasi and Dimitrios Tsigos pursued decisive transitions from closed surfaces to the striated organisation of the building envelope and a semi-burrowed, multiple-ground configuration engendered by the continuous surface. This design was based on a detailed geometric study of striation density, orientation and curvature and the resultant viewpoint-dependent visual transparency of the envelope. The gradual transitions of the striated envelope and its smooth transformation into a furniture and ergonomics-related scale made the envelope also part of the furnishing and the articulation of the ground, thus thickening the envelope into an inhabitable space. The approach to a striated tectonic owes to the works of Iranian architect Bahram Shirdel and the sculptural works of Raimo Utriainen. Illustrations: Nasrin Kalbasi and Dimitri Tsigos, 2001-02.

The work of the second-generation German modernist architect Egon Eiermann is characterised by an extensive use of so-called 'wrap-around galleries' (Hoebel, 2004). These are elements that do not fulfil the purpose of inhabitation, but, instead, that of maintenance and cleaning of the exterior, as well as structural support and spatial distribution of elements for passive environmental modulation such as shading. They constitute, according to Friederike Hoebel, 'constructive and tectonic elements of the three-dimensional façade' (Hoebel, 2004: 79). Interesting for our purpose is that Eiermann advocated that 'one should always be careful to examine whether in our climate it is really worth installing so-called air conditioning, or whether one could achieve equally good results by making special provisions in the construction and use of simple ventilation systems' (Eiermann, 1973: 518).

Yet, while Eiermann's view seems to suggest a shared interest in various historical examples discussed above, he expressed clearly that architects should not concern themselves with the study of the history of architecture. As the latter continues to be organised around questions of style and type, it would have been interesting to know whether Eiermann would have subscribed to an architectural history focused on questions of performance.

Between 1999 and 2003 Diploma Unit 4 at the Architectural Association undertook research into alternative articulations of the architectural boundary, one that could be described as the synthesis between screen-walls or louvered walls with that of an inhabitable boundary, yet extended into the design of entire buildings. This resulted in spatial arrangements that were entirely transitional, with spatial characteristics of 'matrixes of interconnected spaces' as well as multi-functional and environmental modulation characteristics of screen-walls or louvered walls. However, these studies remained somewhat elusive with regards to the synthesis of spatial and material resolution. What was missing was a careful analysis of suitable precedents that needed to be examined from this new perspective.

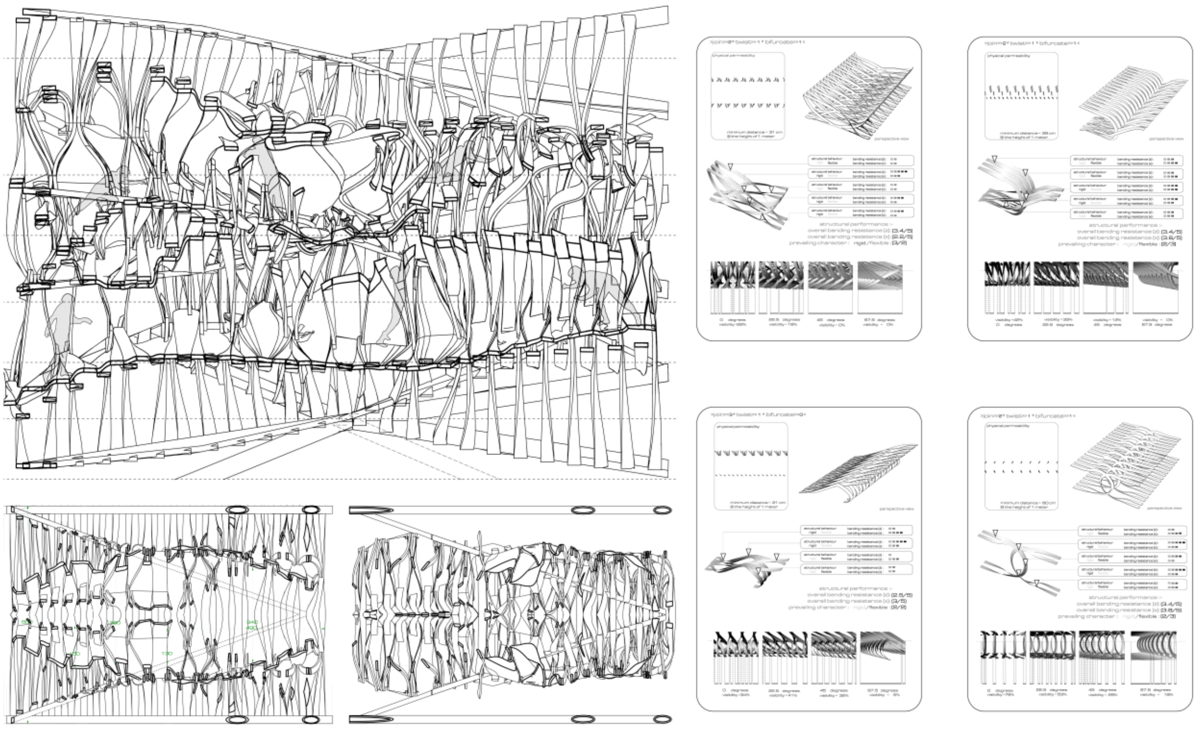

Fig.7. In the context of Diploma Unit 4 at the Architectural Association, diploma students Dimitrios Tsigos and Hani Fallaha pursued a study of a housing unit based on a striated articulation of the architectural boundary, which articulates an inhabitable deep louver wall. The geometric articulation of the material strips relates to ergonomics, visual access and thermal and luminous parameters. The longitudinal section and the plans clearly display the striated tectonic scheme of the project. Material experiments served to compile an extensive catalogue of geometric manipulations of the material strips and the resulting arrays of elements that were analysed, systematised and deployed in relation to the stated functional criteria. Illustrations: Dimitri Tsigos and Hani Fallaha, 2003.

Architectural history is without a doubt very rich in examples of spatial and inhabitable architectural boundaries that are characterised by an integral relation between spatial and material resolution and its interaction with a specific environment. These are not simply generic elements attached to an exterior wall, but rather an intentional extension and spatialisation of the latter for the benefit of a more heterogeneous space and varied environment that provides for dynamic inhabitation. The detailed study of these historical examples, with a focus on performance, has recently started at the Oslo School of Arch-itecture and Design and will culminate in a book of specific case studies.

Research fellow Defne Sunguroğlu Hensel, one of the key researchers involved in this project, currently investigates the spatial organisation and environmental performance of the Ottoman Baghdad kiosk (*Bağdad Köşkü*) (1638-39), a small building located at the Forth Courtyard of Topkapı Palace in Istanbul that was used mainly as a summer or winter recreational residence (Hensel and Sunguroglu Hensel, 2010b). This double-storey building is organised on an octagonal footprint with four of the faces recessed, resulting in a meandering envelope thickened by an arcaded space. The meandering spatial and material organisation results in different exterior spaces that are set back and shaded by the protruding roof. It also positions the windows in the protruding corners in a more exposed location to gain light for the interior. Moreover, it results in areas of different climatic exposure in the interior, which it organises into four apses, which are occupied by diwans. These provide diverse choices of locations for specific activities relative to the time-specific comfort requirements of the inhabitants. The arcades could either be fully exposed or covered by hanging carpets and textile draping, transforming the upper level into exposed or private zones. Textile draping can provide visual protection, shading and ventilation. What is surprising is the ratio between the transitional arcaded space and the interior space, both of which are equal in area. Clearly, the transitional space was neither deemed wasteful nor secondary.

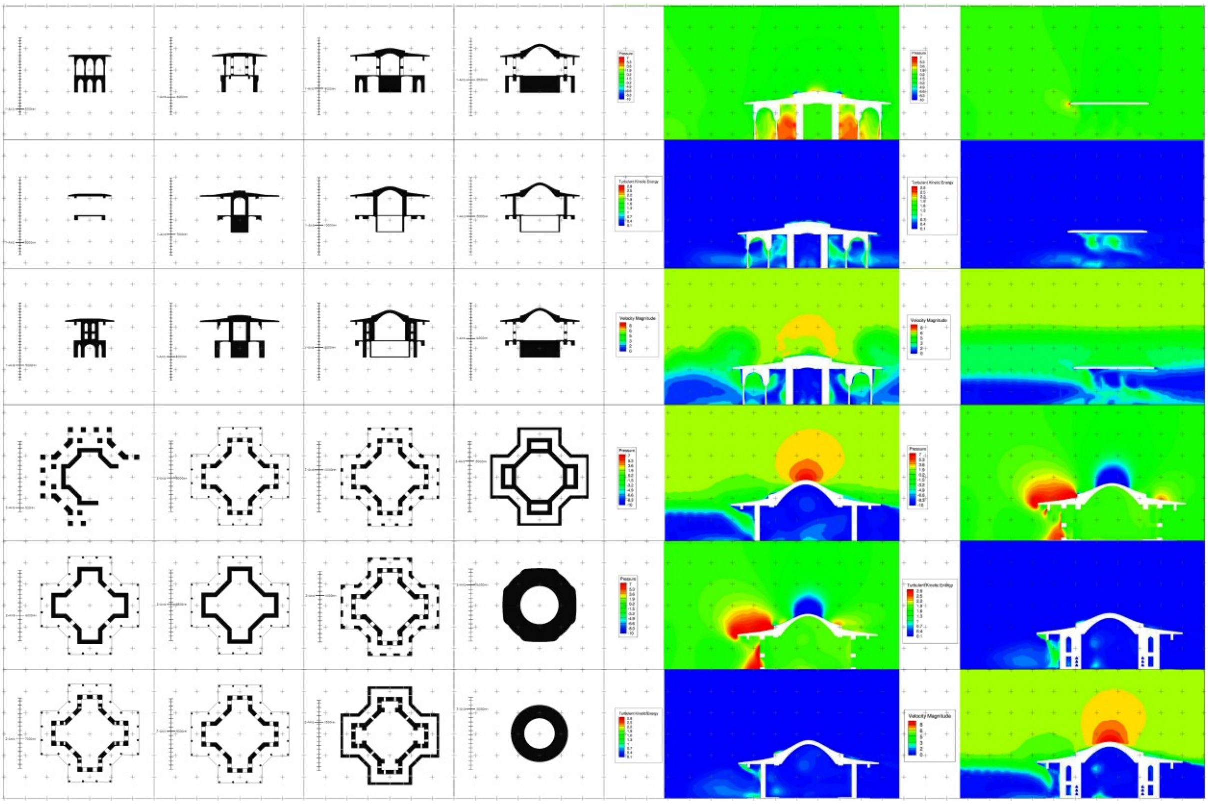

Fig.8 Defne Sunguroğlu Hensel research undertaken at the Oslo School of Architecture and Design focuses on the interrelation between the spatial articulation and environmental performance of the Baghdad kiosk (*Bağdad Köşkü*) (1638-39) at the Topkapı Palace in Istanbul, Turkey. The spatial organization analysis involves the production of models and the vertical and horizontal sectional sequences, which indicate the intricate articulation and variation of the combined spatial and material envelope of the kiosk. The environmental analysis involves Computational Fluid Dynamics (CFD) analysis of airflow velocities, pressure zones, and turbulent kinetic energy, thus extending the question of the spatial and material organisation of the building threshold to its exchange with the local environment. This part of the research is undertaken in collaboration with Dr. Øyvind Andreassen and Emma M. M. Wingstedt at FFI – the Norwegian Defense Research Establishment, 2010. Illustrations: Defne Sunguroğlu Hensel, 2010.

In a research meeting in 2000, Andrew Hall, at the time the director of Arup Façades, pointed out two directions of future research for building envelopes. Hall termed the first approach an engineer's approach, which focuses on the development of a thin material envelope that is multi-functional and takes care of all environmental requirements of the building. Hall termed the second approach the architect's approach, which focuses on utilising multiple material layers with inhabitable spaces located between them. This second approach has clearly historical precedents as discussed above. While evidently the first approach prevails, as discussed above, it would be incorrect to exclusively attribute this fact to the constraints of current standards, expectations or affordability. This assessment would not reflect the situation accurately enough. It would be necessary to take into account that a fully developed alternative is not readily at hand; yet, it could arise from the synthesis of the redefinition of the material and spatial boundary within the paradigm of performance-oriented architecture.

Conclusion: The Spatial and Material Organisation Complex

This article aimed to elaborate on the various interrelated elements that are necessary to facilitate a synergetic approach that brings all of the above into an integral model for a spatial and material organisation complex towards a performance-oriented architecture. This consists of: [i] the material constituent, from the microstructure to material properties, their modulation by a specific surrounding, the resulting material behaviour in interaction with a specific environment and, thus, its performative capacity; [ii] the multi-functionality of material systems and assemblages and the building systems made from those in interaction with their specific environment; and, [iii] the spatial organisation of architectural boundaries as extended areas of transition from the outside to the inside, again in interaction with a specific environment, as well as [iv] the resulting heterogeneous space and the provisions for choice of type and location of activities that arise from that.

To accomplish this task, much more research and research by design is required, which needs to focus on each of these four areas and on the overlaps between them. This will require the production of reliable empirical data and detailed insights into processes of active agency and interaction, a renewed interest in systems thinking and often the search for an increased complexity for which biology might provide a suitable paradigm.

This article has attempted to draw together the various constituents of what is termed here the spatial and material organisation complex. Above and beyond the further research into this domain, as outlined above, the subsequent effort in developing the framework for performance-oriented architecture will need to focus on the other domains of active agency, the human subject and the environment. Moreover, it will be necessary to discuss and develop an appropriate methodological framework and a repositioning of the notion of sustainability vis-à-vis the overarching approach to performance-oriented architecture.

Follow-up articles need to focus on the elaboration of the definition and role of material systems, the intermediary stage between the material and spatial boundary or between material behaviour and the architectural boundary as a mode of spatial organisation. Subsequently, a number of articles need to focus on suitable definitions of the environment and its role in relation to the spatial and material organisation complex and the human subject. And, finally, it will be necessary to discuss the need for a differentiated and heterogeneous built environment in relation to the human subject and its desynchronised evolution vis-à-vis the man-made acceleration of the transformation of the environment.

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