Architecture as an Information Machine

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> There is an ecology of ideas, just as there is an ecology of weeds.
> Gregory Bateson, 1972[1]

> It is much more beautiful to know something about everything than to know everything about something.
> Blaise Pascal, 1974[2]

It is said that Newton revealed the depths of human ignorance with the immensity of his discoveries. Nowadays, health and environmental crises express not only our current inability to respond when such crises occur but essentially our abyssal ignorance of the complexity of the world we live in. The old paradigms used to study phenomena and to develop strategies based on separate issues and approaches no longer seem efficient. Our traditional and mainstream nature/culture dichotomy is being called into question, day after day, by the entangled challenges of knowledge, acting and designing. Cities, built environments, social interactions, territorial governance policies and environmental agendas are bringing crucial questions to architecture as a discipline, ones that may completely recast its foundations. Problems of high complexity in architecture and urban planning cannot be addressed by the usual 'design' approach anymore. These problems involve speculation on the past, present and future of the built environment as an *œkoumène* intertwining various interdependent dimensions and scales, as well as on new paradigms and new theoretical and practical tools that make it possible to share questions, bring together disciplines and participate in forging an object of knowledge to help us think, act and design relationally. With this in mind, this essay I propose ways of connecting fields of reality that all too often have been considered in isolation. I therefore seek to identify opportunities to better facilitate the understandability of territorial systems and to engage in singular relationships with things and beings.

Architecture and complexity

The intuition that the territory is a complex reality is certainly an almost banal observation today. Indeed, this was the argument advanced by the postmoderns in the last century in order to disqualify the modern project, considered disembodied and simplistic. However, postmodern ideology generally contented itself with simply stating this complexity, far from revealing the system organising it along with its constitutive heterogeneous elements and the contingent and necessary relations that bind it. The most frequently used leitmotif is that of language.[3] Thus, complexity was no more than an ambiguous collection of disparate and equivalent signs provided by history or the production of the time. Among the works exploring more analytical or systematic approaches, there were those of Kevin Lynch, Christian Norberg-Schulz or even Aldo Rossi and Tendenza. While these approaches placed the question of form and its requirements at the centre of their concerns, neither the phenomenological and gestaltist approaches of the first two, nor the typological rationalism of the latter succeeded in

exposing the complex system of forms, its evolutions or transformations, nor how to achieve it.

Thus, the complexity described by architectural theory and practice fascinated, frightened or stupefied in equal measure. Furthermore, whether out of cynicism or catastrophism, a disillusioned postmodern relativism took hold. Only micro-narratives, micro-structures, micro-organisations and other such concepts were regarded as relevant. In response to this complexity, some architects and planners experimented with functional programmatic strategies and abstract geometric manipulations, which were therefore repeated indefinitely here and elsewhere as fragments emerging from unhistorical entities. In this same period, as well as more recently, other visions advocated the 'local project', spontaneous processes, tactical town planning, and so on, as if to say that the territory is only a sum and an accumulation of small and flexible interventions without any planning, or a result of very local specific conditions identified a priori as being at the appropriate scale and the core issue. One of the predicaments of deconstruction today is to locate the answer to the complexity problem in architecture at the level of computational machines and algorithmic processes.[4] Here, the complexity of architectural forms is usually considered – rarely that of the territory – but only in their physical and structural conformations as pointed out by Sanford Kwinter.[5] It is primarily invoked metaphorically or through borrowed mathematical models belonging to other fields of knowledge to design new algorithmic-generated forms.[6] It is rarely used to analyse existing forms and their irreducible enclosed multiple dimensions. Today's machine and digital practices are conducive more to making shapes than understanding forms. Is this situation integral to the machine and the tools with which architects and planners continue to work? Is there a machine that could be seen and characterised as a tool to reveal the inherent formal complexity of the territory and built environment, and to make it effectively available for designing and empowering action?

Architectural machines

The use of the word 'machine' is quite common among architects, theorists and architectural historians. This is true not only in the modern era and in the wake of the Industrial Revolution or today in the post-industrial age, but also in antiquity.[7] In Book I, Chapter III, Vitruvius assigns to the architect not only the task of knowing how to build buildings, but also machines: gnomons, clocks and engines used for architecture and war.[8] However, once one looks beyond the more or less metaphorical discourses with pejorative or meliorative connotations (that is, Le Corbusier and his detractors) and attempts to transpose machinic processes or imaginaries – whether mechanical or electronic and digital) – to architecture (buildings, urban proposals, conceptual models and generative algorithms), nagging questions remain. They continue to be heard in the background despite the agitation of theorising exegetes, classifying historians or avant-garde analysts. Why should architecture be a machine? And if we do consider it as a machine, does this apply only to the building or also the discipline and the profession? How can the architect become – or remain, as Vitruvius wanted – a machine builder? What is the machine today?

Without going into lengthy subtle explanations to distinguish the definitions of words such as machine, tool, mechanism, automaton and so on, we can limit ourselves here to following and simplifying the history or the evolution of what are commonly referred to as machines and their properties.[9] Thus, historically we can notice that we have three kind of machines: simple machines, motorised machines and 'information machines'. Simple machines include levers, winches, pulleys, polyspasts, clocks, lathes, mills and other more or less complicated mechanical devices involving the force/displacement ratio. The motorised machines characteristic of the nineteenth century such as fire engines, steam engines, gas engines, and the like were based on the principles and findings of thermodynamics, where one type of energy (thermal,

pressure, kinetic, potential, and so on) transforms into another. Finally, the information machines developed in the twentieth century are, above all, machines for transmitting or receiving information, whether natural or artificial.[10]

Invented in the 1940s, cybernetics, as founded and named by Norbert Wiener, is the science of information machines. It studies the transmission of messages, their speed of propagation, their probability, their redundancy, the quantity of information they contain, and so on. It is therefore the study of messages and, in particular, the effective control of messages that characterise 'self-governed' systems. They are information and control machines driven by information. Cybernetics imagined these machines that inform each other and inform themselves, doing away with the boundary between automatic machines and living beings. However, as science journalist Pierre de Latil anticipated from early on, today we increasingly observe these machines in the general system of nature. Cybernetics was well prepared for this since, as Wiener put it, 'the world [is] made up of *models'* (patterns).[11] A model is 'essentially an arrangement. It is characterised by the order of the elements of which it is made rather than by the intrinsic nature of these elements.' And he adds that 'it then becomes easy, without risk of confusion, to use a *model* in which several subsidiary *models* are placed one above the other, then to separate them so as to find themselves placed side by side'.[12] Cybernetics can therefore be understood as proposing formal conceptualisations that would allow approximate constructions and general explanations.

From the manufacture of 'fact machines' – simple or motorised machines – we have moved on to the construction of 'theory machines' or 'sign machines'. Any model becomes, in law, a machine to inform, but also to reason. And, as John von Neumann noted very early on, the complexity of physical objects and phenomena calls for a complexity of theoretical constructions and models.[13] Generalisations, constructs, and models became the signs and the schematisations of a science of signs. General system theory then provides a framework for such inquiry into the nature of systems and contributes to designing a 'systemic approach'; indeed, as the economist Kenneth Boulding, one of the contributors to this approach, argues, it might be the 'skeleton of science'.[14] Furthermore, information theory has come to the fore as one of the foundations of general systems theory and cybernetics, contributing the two complementary ideas of entropy and information to the vocabulary of general systems research. Moreover, this information machine triggered and associated new developments through the rise of computer technologies and algorithmic processes.

In short, from antiquity until the eighteenth century architects remained quite distant from the first generation of machines. In antiquity, the status of architecture was alternatively seen either as liberal art or mechanical art, however as a profession suited to free men of high social rank, it could not concern itself with servile manufacturing tasks. Only complicated machines requiring ingenuity (towers, mills, war machines) commanded its art, its knowledge of representation and its supervision of the manufacturing process.[15] The second-generation machines of the Industrial Revolution had a completely different relationship with architecture. Certainly, the moderns, as everyone knows, magnified these machines and viewed them as models of rationality and efficiency, but some voices, such as those of John Ruskin, William Morris and others, were already raised against such a comparison, and instead emphasised the close link between the forms of architecture and the forms of nature. More often than not, neither the vitalism of the latter, nor the machinism of the former, went beyond vaguely inspiring metaphorical speculation. Was it because these machines were no longer for transport, but agents of transformation that architecture struggled to represent them? The engine of the simple machine moves from one point to another in space, and the force, given or captured, is measured

by the displacement that occurs. Geometry and mechanics represent this displacement, that is to say the very same sciences that guarantee architecture its representation. Is this to say that the thermodynamics of engines does away with representation? Not at all, it also represents: not the point-by-point locations of forces, but their states; a power or its circumstance.[16] A reference space where intuition is certainly not as comfortable, but where representation does not disappear. It is less geometric than algebraic, that's all. The abstract space that it explores manipulates equations where operations and relationships between constants and variables replace ruler-and-compass buildable figures. Should one conclude then that abstraction is what has always been lacking in architecture and its theory?

The same story, with few variations, begins again in the era of third-generation machines. One might well have assumed that the criticisms directed at the moderns would have resulted in a different attitude towards these new machines scrutinising traces and signs, and activating reading and writing independently of meaning, all the while preserving it with attention and tact. For here the understanding of meaning is the goal, and the transmission of patterns or by patterns is the means. Mutatis mutandis, the situation is quite comparable to the earlier period. Far from freeing itself from metaphorical romanticism, whether in favour of the latter or against it, and from literal or sublimated applications, it simply gave rise to what can be termed conceptual nomadism.[17] The new proposed method allowed for few principles, concepts or operators capable of renewing the foundations of architecture. While the information machine, as we have seen, is less a machine than a method, less servomechanisms or computers than models, the architecture that embraced it retained only the primary artifice: material artificiality instead of abstract artificiality.[18] It elected new 'models for architecture' whereas what was needed was to initiate an 'architecture of the model'. It was no longer a question of knowing whether architecture and the city should be adaptive, evolutionary, criss-crossed by flows, networked, vertical, looped, immaterial, responsive, variational, curvilinear or anything else, but to develop a model that accounts for architectural forms and the city, their meanings, their transformations, their continuities or their discontinuities. Through this approach, we quickly notice that the constructive reality of architectural forms is more than construction, that forms are a complex of heterogeneous parameters that need to be explained and related. They cannot be reduced to a binary logic.

One should not confuse the old machines with purposes and information-driven machines having no purposes or encompassing all purposes. Standard machines such as the sheave or a catapult move weights, an engine produces movement, whereas the computer or 'logical computing machine' as Turing called it, can do everything. Collecting data from all types of phenomena and obeying a range of varied algorithms, it is potentially useful for every purpose and can potentially yield any result. A logic of heterogeneity becomes possible. Today's computational approach in architecture fell into this trap even as it made the digital machine its preferred tool. There is a contradiction in terms when theorists and architects of this movement claim that digital architecture is necessarily a matter of variation or smooth forms.[19] Because the computer – and the software inside it – as an information machine surely allows the designer to do everything: variation and invariance, standard and non-standard, curves and straight lines. Moreover, to implement one or the other actualisation, one needs the corresponding model, or better still, the general model that authorises them all. Hence, a human, political, ideological and academic choice is hidden or not admitted. Variation is one possibility of the digital machine among others, only the algorithmic model or the software determines the choice of this form or that other. Hence, the importance of the architecture of the model and its transparency. Hence, the task that lies ahead for architecture and architects.

The information machine as a model

If we agree that architecture is a complex empirical system, it becomes necessary to develop its formal systemic modelling in order to grasp it and to enable us to act. Nevertheless, the word 'model' contains a paradox: it is that which must be imitated, but it is also that which imitates; it is both a model *for* and a model *of*. While, for a long time, the first meaning prevailed in the fine arts and architecture, science has favoured the second. Scientific activity was imagined from its first steps as a rationality that decodes the world and defines the laws by which phenomena occur, and by what process. The model here is this knowledge or *mathesis universalis*. It imitates divine reason, if not that of the natural order. For literature and artistic practices, nature, whether divine project or autonomous reality, is, first of all, the model to imitate and to reproduce. Works of art are then the embodiment of the order or deviations that nature submits to the senses and/or reason. Truth is the model of beauty then. Now, while science, by perfecting itself and expanding its scope, has managed to harness the paradoxical status of the notion of the model for its contemporary theories and experiments, while the fine arts have, in part, emancipated themselves from the idea of imitating a model, architecture has, for the most part, remained subject to the ancients' conception of mimesis. Indeed, the modelling activity of modern science consists essentially in constructing abstract objects imitating real phenomena. However, the generality of these abstract objects also makes it possible to study a host of other phenomenal realities through analogical deduction. The imitating model is in turn imitated. Reproduction and representation involve the production and generation of knowledge, experience, simulations and equivalence relationships. The model is the condition that gives reason of a set of phenomena whose structure is equivalent; conversely, a phenomenon may fall under different models. Therefore, the model is a thinking machine. It is a construction tool to understand forms or things. The architectural situation is quite different, whether we consider its theory or its practice. The model, here, is most often a process or an object that we imitate. Architecture is then a question of representing an idea, a concept or a style, nothing more.[20] It's a 'machine to do', from models to algorithms to metaphors.[21]

The science of elaborating models, according to Alain Badiou, has always recognised two approaches: a bottom-up approach from the empirical to the formal that is based upon an artificial sequencing process (the positivists) implying semantic interpretations of a reality as a model to imitate; and also, a top-down approach from the formal to the empirical (the structuralists) where the artefact – Lévi-Strauss would say *le bricolé* – is the model vis-à-vis reality and that which makes it readable. Structure is the model for this system.[22] However, contrary to Badiou's claim, formalism cannot exist without being contaminated by empiricism and vice versa. There is no need for one model to choose between the two, it is even very natural, or more exactly, more efficient and more productive to use both approaches.[23] We would therefore insist on their mixing and their alteration. More often than not, one is the extension or the embodiment of the other. While demonstrative logic uses semantics in order to guarantee the validity of the model, experimental practice or confrontation with case studies reveals its syntactic structures. Therefore, a model must 'give a reason for' – describe and explain – all the phenomena considered, or at least of a large class of objects. However, to ensure its rational validity, and perhaps even its quality as a dynamic system, it must be demonstrable locally, but also refutable and falsifiable globally. This theoretical transparency of the model is what offers the possibility of forecasting and at least of explaining, which is already significant, if not to say essential.

Thus, the model realises in an effective and specific way the general rules that have been set. It is not the ideal archetype towards which the realised works tend without ever reaching. Inverting the Platonic paradigm, it is more *eidôlon* than idea, a

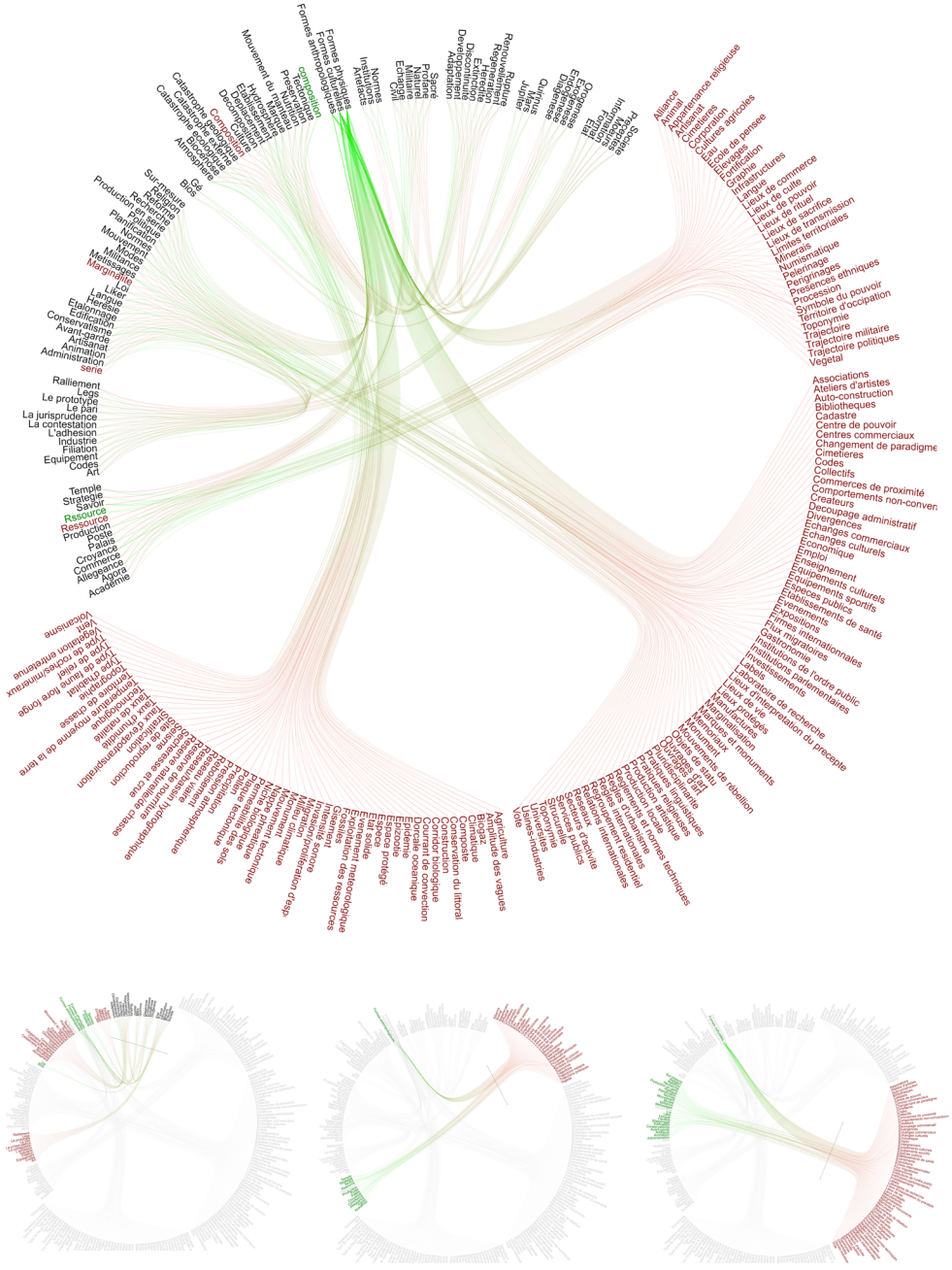

Fig. 1

Fig. 1: SofT project. Diagram (ontology) of systemic modellisation of the territory forms. Work and image: author.

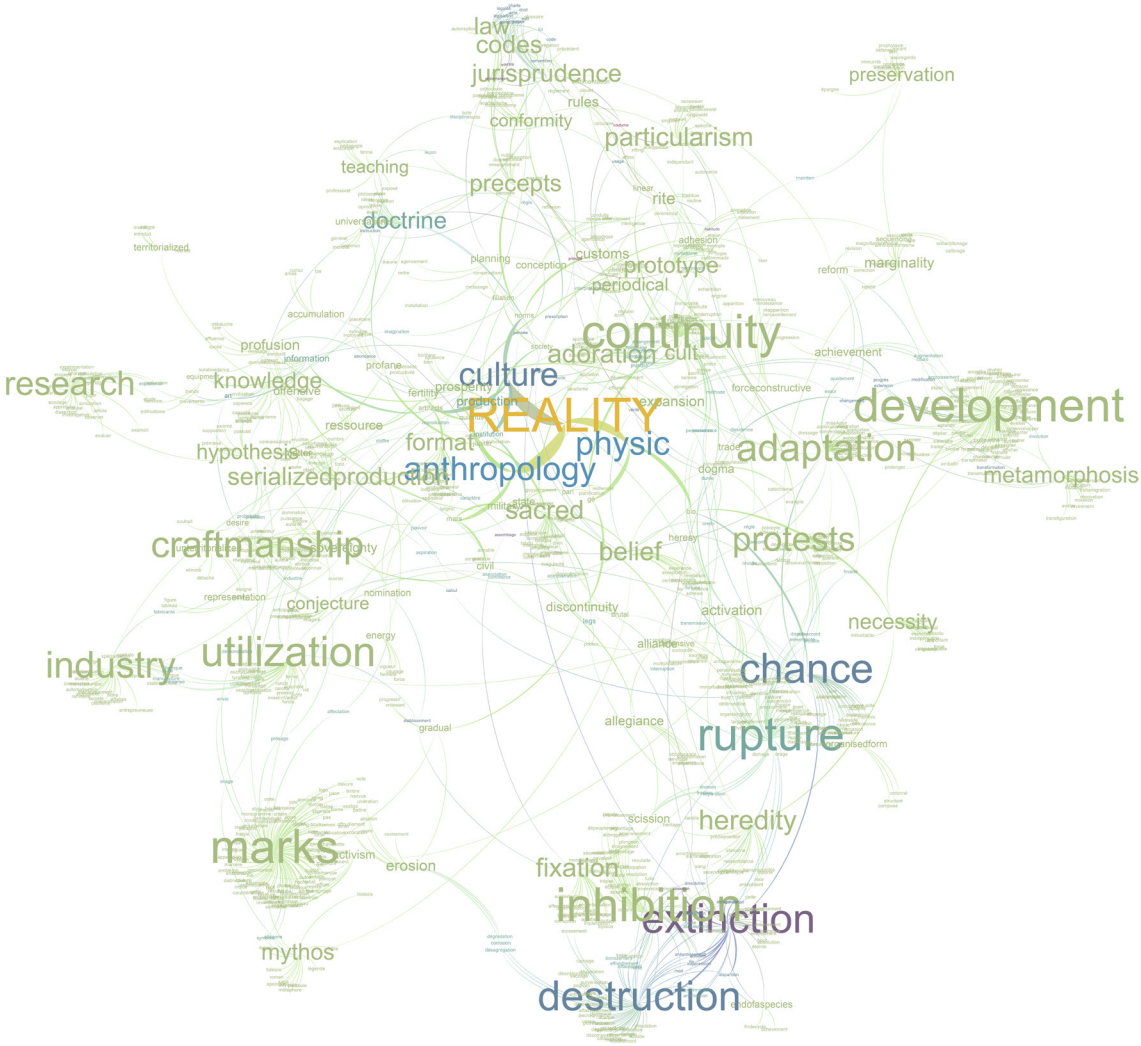

Fig. 2

Fig. 2: SoFT project. Diagram (ontology in RDF) for the semantic interoperability of territory's mapping data. Work and image: author.

simulacrum that deciphers the modalities by which forms are made or invented. Its consistency is its fundamental property and can only be determined through a comparison with 'facts'. In other words, a model is an artificial object, a formalisation, reproducing or imitating a reality through laws or rules, however without preventing contradictions. Thus, modelling is nothing more than a true description of reality. Its primary qualities seem to be its convenience and simplicity. The model is a machine for producing knowledge and actions that is itself experienced, tested and transformed in terms of its rigour and generality. It has a verification/rectification function. Hence the process of producing knowledge where the model does not only designate an outside empirical reality to be formalised, but also an inside knowledge to be experienced. Nevertheless, although destined to undo itself, the model seems to be the condition for its surpassing. Whoever renounces the model renounces knowledge and invention. This not to say that all (scientific) knowledge is knowledge by model. However, any invention of a model is a scientific activity in itself. Developing a model is always a work of art, whether it is a model of an automobile, a telephone or anything else manufactured, or any theoretical and abstract model. This is the case whether it is the work of an architect, an engineer, a designer, an economist, a sociologist, a philosopher or a physicist. As the French mathematician and epistemologist René Thom wrote: 'but the moment will come where the construction of models itself will become, if not a science, at least an art.'[24]

The information machine as a system (thinking relationally)

The model assumes a systemic reality. It is always about interacting elements and relationships whose activity is identifiable by its form.[25] Consequently, the forms form a system. Ultimately, the model invites us to think relationally. Buffon, the French naturalist, considered the encyclopedia to be against the system. He was ironic, as he liked to be, about the scientists who cannot distinguish a tree from a burnet and must therefore count the stamens.[26] The argument had already been used by Descartes concerning the universal language project, which Leibniz later took on by attempting to define its 'characteristic'.[27] In either undertaking, the encyclopedia and the system, carried out separately and independently, the reasoning remains stable, the points of view irreconcilable and the intelligibility of the forms confused. Like a diplomat constantly seeking a peace deal, Leibniz, who already feared the barbarity that multitude and multiplicity could produce, in particular following the invention of the printing press, insisted: 'there is no multitude without real units'.[28] This is the condition for the plurality of possible worlds and their harmony.

One can neither expect this encyclopedic knowledge to be complete, nor this systemic alphabet of architectural forms to be perfect. As philosopher Michel Serres writes: 'had the Greeks waited for the complete demonstration of their axioms and for their reduction to identicals, geometry would still have to be elaborated.'[29] The only hope to see more clearly in the shapeless cloud of forms that surround us, to grasp the universal in the proliferation of singularities, to find its way in this labyrinthine exuberance is to lead the two together, to link one to the other and vice versa. The becoming of one is the adjunct of the becoming of the other. The completion of the exhaustive description and the perfection of the systemic order cannot be preconditions but horizons. Thus, the more a system is developed and structured from a plurality of samples of identified knowledge, the more the intelligibility of forms progresses; the more precise it becomes, the better the definitions we have in the atlas knowledge, the more concise and operational the tables, the more organised the synopses. And again, the more the encyclopedia improves, the more it will reinforce the systemic foundation with better adapted samples, more formal relationships and unexplored dimensions or regions. Hence, better chances of combining reasoning and computing, of entangling

description and explanation: might this be the real morphology?[30] Serres made the argument that all our discourse about computers was Leibniz's dream. But Leibniz's idea is that calculus is only the way to realise the systemic universal language and the encyclopedic knowledge – the two principal sources of information about the world – that will code and encode everything.

The problems of systematicity arise for architecture as for the other disciplines. If architecture is a totality, we must define it and define its constituent components. Neither multidisciplinarity nor interdisciplinarity can cope with this requisite; only transdisciplinarity embodied in a formal model that intertwines and 'translates' them into one another can be the key to describing architectural forms as a whole. Hence a system that must articulate encyclopedias and regions of knowledge, hence an axiomatic or a formalisation that subsumes the multiplicity of dimensions of phenomena and objects. Hence the continuum of the morphological description and subsequently that of the morphogenetic process. This problem is subtler than previously believed: one cannot be satisfied with cursory and broad allegations of the kind: 'Intentions in Architecture', 'Notes on the Synthesis of Form', 'Parametricism', 'Biomimetic', and so on, or even more common expressions such as architectural space. This problem needs to be modelled.

Not only is the architectural object a system caught in overlapping connections that extend beyond it and therefore link it to other systems, not only is the territory or the city a system of systems, the set of architectural forms and settlements is also a system.[31] [Fig.1,2] That being the case, then, as the Stoics put it: all things work together and conspire, the world is born from a cosmic sympathy. Stoicism is this philosophy where the world is organised into a coherent and organic whole, it is a system in which each element is united with the others and constitutes a unified totality. Either all the dimensions that contribute or conspire to architecture are found in its built, drawn or imagined form, or the latter is nothing.

The information machine as a morphology and morphogenesis

If the model, as we have explained, is at once a model *of* and model *for*, then all modelling activity is first a morphology before leading to morphogenesis. The model can only be constituted and formed by a morphological and systemic description of empirical forms, from which paths for new forms and morphogenetic processes emerge, condense and open up. The morphological description is an apparatus. There is no point in involving 'thinking' in advance, real 'measuring' instruments are sufficient. The observer is a reality just as much as the observed reality and the measurement is nothing other than the use of effective procedures taking into account the conditions of observation.

Furthermore, there is no point in getting lost in philosophical arguments around the subjectivity or objectivity of the description. The reality changes with theories and means of observation, with the tools and devices for measurement or qualification, science and epistemology provide examples and demonstrations.[32] Description in this sense is not a subject-to-object relationship, nor even of a relativist or post-positivist subject and an object now active and itself changing; it is a relationship of subjectivation.[33] Description is an activity revealing of all the structures that organise a form; it removes the subjectivity of the subject by founding autonomous and regulated methods independent of the reasoning system of the one who thinks; it suspends the objectivity of the object while avoiding having to claim it knows the essence of things beyond what the form shows us, regardless of what it tells us. Furthermore, description is neither subjective nor objective, it is a subjectivating action since it is a joint operation between two forms: a form that manifests itself and 'would like' to be seen and read and another that 'wants' to see and read. But to want to read and see a form is not to impose a point of view on it, it is to go towards it and sneak in. With his very particular style, the French poet and essayist Charles Péguy once explained that reading is not a

passive operation, that being a reader is in no way being a pure spectator, that reading is entering into

> a work, into the reading of a work, into life, into the contemplation of a life, with friendship, with fidelity ... that one should not receive the work passively; that reading is the common act, the common operation of the reader and what is read, of the work and of the reader.[34]

A subject is therefore the one who gives or receives, but it is the act of description that is subjectivity. The forms speak, so let's decipher their alphabet. There is action and reaction in both directions. Similarly, Italo Calvino, in order to avoid all the blatant misadventures of a preformed and prefiltered language, observed this experience, and tried to guide us there. In *Mr Palomar*, in the chapter entitled 'The world looks at the world' he writes:

> Having the outside look outside is not enough: the trajectory must start from the looked-at thing, linking it with the thing that looks. From the mute distance of things a sign must come, a summons, a wink: one thing detaches itself from the other things with the intention of signifying something... What? Itself: a thing is happy to be looked at by other things only when it is convinced that it signifies itself and nothing else, amid things that signify themselves and nothing else.[35]

If architecture is a form, full of itself and of its meanings, then we will recognise them whether we are spirits or material devices. Contrary to what idealism claims, a morphology is an opening towards meaning, a reading of reality through which to decipher information, to reveal meanings, all the meanings we can find. To ignore forms is to extinguish all the promising signs of the whole semantic enterprise. It is only because we are active constituents of forms that we have the 'sense' of the information they convey.

It is not because we suspend our meanings that forms vanish and lose theirs. The form 'sensifies' before even signifying, according to philosopher Raymond Ruyer's famous formula.[36] Nothing would then prevent us from overturning René Thom's proposal, without fear of stripping it of all its rigour. As the relationship here is strictly bijective and the equivalence exactly one-to-one, it might be possible to state that all form is, in the first place, information. The latter is, so to speak, coded in form. However, as Thom specifies, 'to reduce information to its scalar measure (evaluated in bits) is to reduce form to its topological complexity ... and to throw away almost everything about its significance'.[37]

If, as Goethe wished, the morphological description must contain what the form, formation and transformation teach, then it will have to grasp all the architectural forms, consider all the built things to hope to deduce the laws which govern them, the organisations that structure them, the filiations continuing them, and the ruptures dividing them.[38] Morphology would thus be this spatio-temporal description on horizontal planes of all the levels of reality that the building act can subsume. On the other hand, morphogenesis in the strong sense of the term is this dynamic enabling to jump from one level to another, it is this vertical, trans-spatio-temporal movement activating the links between horizontal structures. While it is indisputable that morphology is deduced from the observation of phenomena in usual space-time, it is formative activity, which makes us, in the most striking way, see forms as products of a morphogenesis that no calculation or algorithm can predict. Thematic morphogenesis 'overflights', in Ruyer's sense, and goes beyond the structural morphogenesis which itself continues and extends into a material morphogenesis; ends and means are difficult to distinguish.[39]

For a long time, artistic literature – such as vitalism with its obscure principles in philosophy for the forms of the living – treated architectural forms and those of art as the simple result of an almost divine skill, where combined structures emerged from the mind of a genius, a demiurge in other words, defining the rules by which beauty is achieved.[40]

In this conception, the matter of these forms, be it drawing or stone, obeys precise laws of beauty and a corresponding system of symbolic rules. The whole process is organised by obscure forces based in the artist's mind. The invention of architectural forms was therefore a variation around a certain number of orders, subject to the whims of contingent and inexplicable inspirations. So conceived, morphogenesis is at best a morphology describing structures that already exist. Geometrical transformations then pass from one constituted structure to another, but where the structures are previously formed in various materials: diagrams, drawings, maquettes or buildings.[41] If not, morphogenesis merges with a deterministic mechanical explanation, reducing everything, as Poincaré pointed out, to an 'immense game of billiards', merely an abstract play of forces producing forms from elementary figures or predefined algorithms.[42] Hence the formal experiments of the first generation of post-deconstruction architects, on software such as Maya, and likewise the recent developments in computing design with Grasshopper or by cellular automata producing complex forms.[43] In the architectural literature of the last twenty years, morphogenesis is therefore synonymous with processes supported by spatial motions of non-local characteristics, pattern formation with a static reference.

However, showing what a difference is, especially since it is essential, is not equivalent to removing a link or interaction. To recognise that all form is the result of morphogenesis is to admit from the outset that for there to be a form, there is a formation; that a morphological description can certainly describe formed and realised forms, compare them, classify them, group them, but that morphogenesis is the guarantee of grasping the informational dynamics underlying the constitution of forms, their parameters or their conditions of emergence. It is also the guarantee of seeing the forms generate each other; to observe the transformations. Thus, they will not only be described, but also explained using dynamic morphogenetic models.

Outputs, refinements

To consider architecture as a production of forms and architectural theory as well as architectural history as particular modes of knowledge of these forms, is not a superficial undertaking. Such an approach neither privileges the letter over the spirit, nor does it ignore the depths to be probed in the form itself, whose enigmas remain to be elucidated. Studying architectural forms means seeking within the form all the information it envelops, but also delving into its sources and its mechanisms of emergence, transformation, transmission or extinction. Is this not literally the definition of the information machine? The real cybernetic machine then is the one enabling architecture to show and use the footprints and the signs of ecological systems. Gauging architecture through its form does not imply that we end up with architecture minus everything else. On the contrary, we have architecture plus a powerful process that enables us to investigate the multiplicity of its dimensions, to grasp its increasing complexity, and to describe and, by the same token, understand the conditions that systematically articulate the great diversity of phenomenal structures and meanings. This process helps to translate the multiple dimensions of the whole system. Form is what makes it possible to define the general dynamics of architecture. The formalism advocated here is the one that recognises the entire cosmological extension of form. It is a formalism that diffracts into all the dimensions of the built or projected 'thing', including the specific automated formalisations required by the contemporary era. Such is the automation, we would argue, that corresponds nowadays to the information machine. Here, the theory of practices (simple machines and engines) joins the practice of theories (the forms of information and signs).[44] This is what is in circulation today. The machine or the automaton is not an end in itself, nor a tool for a finality, but a degree of refinement of the relationship to forms, that is to say, to things. As Samuel Butler already observed in the nineteenth century, is it not by so perfectly grasping

and with such great mastery that the body renders thoughts and gestures automatic? Or, as Leibniz put it, nature is the real and perfect machine, complete and successful. As such, automation is not about machines, it is about refinement.

To say that the architect's knowledge relates above all to forms is neither to disregard its architectural materiality, nor to dismiss its social implications and determinations, nor to diminish its possibilities of symbolic expressions. Even less, is it to ignore the political or ecological dimension of architecture. Moreover, to observe these forms is to attentively perceive and discern as many structures as possible that organise their various dimensions as a whole. It is to explicitly state that which remained a confused object in the traditional approach of separate disciplines. In an operational way, it means building an interface of forms that enables us to pass from the geometry of a form or its topology, to its materiality and its environmental or symbolic consequences, to the organisation of individual and collective practices that it implies, to the professional organisation it fosters and even to the affects it provokes. Observing and describing forms from this point of view not only takes architectural theory out of the rut of criticism or doctrine and makes it cumulative, it also returns to the essential aspect of the architect's creative act as expressed through its forms: 'showing a world'. To successfully describe architecture from its forms, from all its forms, is to attempt and hope to see a new way of doing architecture. A perilous and colossal enterprise for sure, but is that a reason not to start it?

Notes

1. Gregory Bateson, *Steps Towards the Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution and Epistemology* (Chicago: University of Chicago Press, 1972), 484.
2. Blaise Pascal, *Œuvres Complètes* (Paris: La Pléiade, Gallimard, 1954), 37. Unless otherwise indicated, translations from French sources are my own.
3. Charles Jenks, *The Language of Post-Modern Architecture* (London, Academy Editions, 1977).
4. Mario Carpo got it right when he pointed out 'In retrospect this current of digital design does appear like a continuation of Deconstructivism with digital means', *The Digital Turn in Architecture 1992–2012* (Chichester: John Wiley & Sons, 2013), 10.
5. 'What I used to call the "parametric blanket" (largely because these works resemble a featureless blanket thrown over a highly articulated traditional workshop model) has nonetheless a materiality that could sustain discussion', 'A conversation between Sanford Kwinter and Jason Payne', in Michael Meredith, *From Control to Design: Parametric/Algorithmic Architecture* (Barcelona/New York, Actar, 2008), 235.
6. Mario Carpo deplores the absence of theory around what he calls architecture in the digital age and describes the 'autopoietic, morphogenetic, or biomimetic' experiments as a vast metaphor. Cf. 'La fin du numérique, la fin du commencement, et la fin du projet', *Le Visiteur* no. 11 (November 2011): 77–81.
7. For a large panorama of the Industrial Revolution period, see for example Sigfried Giedion, *Mechanization Takes Command: A Contribution to an Anonymous History* (New York: Norton, 1948); Reyner Banham, *Theory and Design in the First Machine* Age (London/New York: The Architectural Press/Paeger, 1960); Peter Collins, *Changing Ideals in Modern Architecture, 1750–1950* (Montréal: McGill-Queen's University Press, 1965). For post-industrial vision, see the work of theorists or historians such as Mario Carpo, Antoine Picon, Sanford Kwinter, Manuel DeLanda and so on, as well as architects like Greg Lynn, Karl Chu, Lars Spuybroek, Alejandro Zaera-Polo, Farshid Moussavi and so on.
8. Vitruvius, *Les dix livres d'architecture* (Paris: Bibliothèque de l'image, 1995). For a more detailed presentation on the status of the machine in antiquity and in philosophy, cf. Pierre-Maxime Schuhl, *Machinisme et philosophie* (Paris: PUF, 1947).
9. Pierre de Latil, *La pensée artificielle* (Paris: Gallimard, 1953). On the history of machines, I refer to Franz Reuleaux's classic *Principes fondamentaux d'une théorie générale des machines* (Paris: Librairie F. Savy, 1877).

10. Vitruvius gives a definition of the simple machine as a wooden structure, having the virtue of moving great weights. 'Vitruvius appears to include the *simple mechanical powers*, which, however, when used in combination, as in the crane and other machines, become *machinae*'. Sir William Smith, *A Dictionary of Greek and Roman Antiquities* (London: John Murray, 1875). Also, cf. Vitruvius, *Les dix livres,* book X, chapter I. Let's mention here that Aristoteles states (*Mechanical Problems*) that the law of levers is the fundamental principle of mechanics. For the motorised machines, cf. Michel Serres, *La Distribution* (Paris, Minuit, 1977), 43–58; Latil, *La Pensée artificielle,* 32–50. For the information machines, cf. Norbert Wiener, *Cybernetics or Control and Communication in the Animal and the Machine* (Cambridge, MA: The Technology Press of MIT, 1949), 49–55.
11. The word adopted for the French translation of 'pattern' was 'modèle'. I prefer to retain this word and the corresponding English term (model) because of its active and general connotation.
12. Norbert Wiener, *Cybernétique et Société*, (Paris: Deux Rives, 1952), 15–17, emphasis in original. In his very detailed work on the presuppositions and results of cybernetics, Latil notes the emergence of this method by model: 'There is here', he writes, 'a new scientific method for approaching knowledge: the models method'. Latil, *La Pensée artificielle*, 207.
13. John von Neumann, *Theory of Self-Reproducing Automata*, ed. Arthur W. Burks (Urbana: University of Illinois Press, 1966), 33–35 and the Introduction by Burks, 2–4.
14. Ludwig von Bertalanffy, *General System Theory* (New York: George Brazier, Inc., 1968); Kenneth E. Boulding, 'General Systems Theory: The Skeleton of Science', *Management Science* 2, no. 3 (April 1956): 197–208.
15. Gilles Bertrand, *Les ingénieurs de la Renaissance* (Paris: Hermann, 1964) and *Les mécaniciens grecs, la naissance de la technologie* (Paris: Seuil, 1980). Latil points out that Bertrand had identified an ancestor of retro-action machine in the Renaissance, the 'baille-blé' or shoe (a mechanism of the millstone that regulates the feed of grain to the millstones by making it dependent on the speed of the runner stone). Cf. Latil, *La Pensée artificielle*, 110.
16. Sadi Carnot, *Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance* (Paris: Blanchard, 1953 [1824]), 66–67. Carnot gives access to this algebraic writing in the notes that accompany his text.
17. Christian Girard, *Architecture et concepts nomades : traité d'indiscipline* (Bruxelles, Mardaga, 1986).
18. While these experiments had made us believe in a painful historic decision and an avant-garde breakthrough, they remained short-lived, and without shareable methodology, impossible to increase or to transform. Some of the works that fall into this category are: Peter Cook's *Plug-In City*, Cedric Price's *Fun Palace*, Gordon Pask's 'The Architectural Relevance of Cybernetics', Dennis Crompton's *The Piped Environment* and *Computer City,* Constant's *New Babylon*, Koichi Tonuma's *Network City*, John Frazer's *An Evolutionary Architecture*, Arata Isozaki's *Computer Aided City*, Nicolas Schöffer's *La ville cybernétique* and Yona Friedman's *L'Architecture mobile*. The works of Christopher Alexander, Nicolas Negroponte and William J. Mitchell belong to another register that we cannot include for discussion here due to lack of space.
19. Manuel DeLanda and Lars Spuybroek's texts (DeLanda, 'Material Evolvability and Variability', 10–17; Spuybroek, 'The Radical Picturesque', 34–39) in *The Architecture of Variation,* ed. Lars Spuybroek (London: Thames & Hudson, 2009). Both of these authors curiously insist on this notion of variation. Furthermore, I do not subscribe to the opinion of the historian Mario Carpo in studying these approaches when he writes: 'All that is digital is variable … In architecture, this means the end of notational limitations, of industrial standarzation, and, more generally, of the Albertian and authorial way of building by design.' Mario Carpo, *The Alphabet and the Algorithm* (Cambridge, MA: The MIT Press, 2011), preface.
20. The 'idea' can come from various registers (aesthetic, social, moral, economic, political, and so on). For a

detailed presentation on this subject and its various deployments in artistic history see Erwin Panofsky, *Idea*: A *Concept in Art Theory* (Columbia, SC: University of South Carolina Press, 1968 [1924]). 'Model behavior' was the theme of *Log* 50, but when we read through all the articles, as Cynthia Davidson noticed it 'it was obvious that how [they] might elicit or project behaviors was not always a primary concern. Rather, the making of models, whether they have digital or physical properties, and the unmasking of the largely invisible transactional models that underpin the systems of architectural education and practice (models that could be said to standardize behaviors) came to the fore'. *Log* 50 (Autumn 2020): 15. What appears then is that new modelling activity is needed.

21. On the entanglement and ambiguity between theory and practice I refer to the works of Manfredo Tafuri. It is curious that the computational approaches in architecture have retained scientific models while only borrowing their capacity to simulate and not their very basic modelling dimension. In other words, these approaches neglected the role of modelling, which implies the process of imitating and being imitated to produce knowledge and ordering classes of equivalence of problems.
22. Alain Badiou, *Le concept de modèle* (Paris: François Maspero, 1970), 9–68; Claude Lévi-Strauss, *La pensée sauvage* (Paris: Plon, 1962), 26–47.
23. Thus, if geometry from the start seems to be the example of the formal approach, starting from an axiomatic system, in particular from the Euclidean model, which will offer the model of reality, the arithmetic resulting from the enumeration of objects and the rules of their manipulation or their property tends to be empirical. For the Pythagoreans, it is not only the model of reality; the latter is also only considered to be a pale copy. However, both experienced contradictory movements: arithmetic explored total axiomatisation and failed, but in the meantime, it yielded significant results; geometry, notably thanks to topology, fractals and Thomian morphology has formalised a host of empirical phenomena. The controversies that opposed Riemann and Poincaré to Frege and Hilbert on the foundations of mathematics primarily served to open up new branches including computer science and cognitive sciences (with Gödel on one side and Turing on the other).
24. René Thom, *Modèles mathématiques de la morphogénèse* (Paris: Christian Bourgeois, 1980), 18.
25. 'In summary, the individuality of the body is ... that of a *form* rather than that of a fragment of matter.' Norbert Wiener, *Cybernétique et Société*, 142. Emphasis added.
26. Allusion to Linnaeus's *Systema Naturæ* (1748) while addressing his criticisms to botanist Joseph Pitton de Tournefort. Cf. Buffon, *Œuvres complètes* (Paris: Abel Ledoux libraire, 1846), 48. Although Linnaeus's system was called a masterful reading of the organisation of living forms, the fact remains that it was a static system. See Fréderic Houssay, *La Forme et la vie: essai de la méthode mécanique en Zoologie* (Paris: Schleicher frères, 1900), 71.
27. René Descartes, Letter to Mersenne, 20 November 1629, Adam and Tannery, *Œuvres de Descartes*, I, 76. Although the idea of a universal language discussed with Father Mersenne seemed to interest him, he considered it impracticable: 'Philosophy not having completed this enterprise is not possible'.
28. G.W.F. Leibniz, Letter to Arnauld, 30 April1687, Paul Janet, ed., *Œuvres philosophiques de Leibniz, Correspondance de Leibniz et d'Arnauld* (Paris: Felix Alcan, 1900).
29. Michel Serres, *Le Système de Leibniz et ses modèles mathématiques,* (Paris: PUF, 1968), 550.
30. René Thom, *Prédire n'est pas expliquer: entretiens avec Emile Noël* (Paris: Flammarion, 1993). Furthermore, René Thom points out: 'The errors come more from the theory (or the absence of theory) that presides over the construction of the model, than from the approximations resulting from the digital processing of the system', Thom, *Modèles mathématiques,* 114.
31. Regarding the forms of settlements, the structural geography study overseen Gilles Ritchot and Gaëtan Desmarais stands out for how clearly it grasps the

structures and judiciously models the dynamics of human settlements. See in particular Gilles Ritchot, *La morphogenèse de Rome, de la discontinuité première au débordement actuel* (Paris: L'Harmattan, 2011); Gaëtan Desmarais, *La morphogenèse de Paris des origines à la révolution*, (Paris: L'Harmattan-CELAT 2000); Gaëtan Desmarais and Gilles Ritchot, *La géographie structurale* (Paris: L'Harmattan, 2001).

32. Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007).
33. Gilles Deleuze and Félix Guattari have provided the richest interpretations of this concept. Cf. especially *Mille-Plateaux: capitalisme et schizophrénie* (Paris: Minuit, 1980).
34. Charles Péguy, *Clio: dialogue de l'histoire et de l'âme païenne* (Paris: Gallimard, 1932), 19–21.
35. Italo Calvino, *Mr Palomar*, trans. William Weaver (London: Vintage, 1999 [1983]), 102.
36. 'Sensifiying' is a process of elaborating a sense or a piece of information, 'signfiying' needs signs and language. Cf. Raymond Ruyer, *L'Embroyogenèse du monde et le Dieu silencieux* (Paris: Klincksieck, 2013, posth.), 244; *La gnose de Princeton* (Paris: Fayard, 1974), 131–37.
37. René Thom, *Stabilité structurelle et morphogenèse*, *Essai d'une théorie générale des modèles* (Massachussetts: W.A. Benjamin, 1972), 164.
38. J.W. von Goethe, *La métamorphoses des plantes*, trans. Henriette Bideau, (Boissière en Thelle: Triade, 1975), 216. In the last century, Georges Kubler, in seeking to better understand the dynamics of artistic forms, seems to have glimpsed this need when he invited art historians to undertake not only a history of works, but also a history of 'things'. Georges Kubler, *The Shape of Time*: *Remarks on the History of Things* (New Haven and London: Yale University Press, 1962).
39. Raymond Ruyer, *Genèse des formes vivantes* (Paris: Flammarion, 1958).
40. The legend of the genesis of the Corinthian architectural order provides us with an illustration: Vitruvius believed that only an exceptional mind could have revealed the figure of the Corinthian capital, an achievement he attributes to the sculptor Callimachus. According to Pausanias, the latter was the first to carve out voids in the marble objects he sculpted. Pierre Gros, *Vitruve et la tradition des traités d'architecture* (Rome: l'École française de Rome, 2006).
41. We can easily understand the enthusiasm, which we are witnessing today, for robotics and its capacity to model shapes at scale 1.
42. Henri Poincaré, *La science et l'Hypothèse* (Paris: Flammarion, 1932), 193.
43. It is also instructive that this line of thought found in D'Arcy Thompson's work a literal justification for this purely mechanical approach. Cf. Sanford Kwinter, 'La Città Nuova: Modernity and Continuity', in *Zone 1/2*, *The [Contemporary] City*, ed. Michel Feher, Sanford Kwinter and Jonathan Crary (New York: Zone Books, 1986), 80–127; Greg Lynn, *Animate Form* (New York: Princeton Architectural Press, 1999). It is not to diminish their interest to say that the formal research and approaches discussed in the publications of *Architectural Design* (London, J. Wiley) often stem from this conception. They surely participated in exploring different types of morphogenetic operations but neglected to define the system of forms.
44. The ongoing automation using robotic processes to produce and assemble architectural or structural components or using AI to generate or choose from a range the most efficient or the most suitable patterns is certainly interesting. It improves the process of fabrication and design in architecture. But the prime automation that remains a challenge today is that which arises from the refinement of the descriptive model dealing with complexity beyond a territorial system of forms – their signs and meanings – allowing its intelligibility and its sharing as a whole. Automation is not simply a matter of enhanced productivity and economic performance, it is above all a means of pro-duction (pro - forward; duct - connection), of comprehending relationally.

Biography

Tewfik Hammoudi is an architect and associate professor of architecture at l'École Nationale Supérieure d'Architecture de Nantes (ENSAN) where he teaches Architectural Theory and Design Studio. He holds a PhD in architecture from the University of Paris 8 in France. To deepen his knowledge, he has a Diploma of Advanced Studies in Philosophy, and followed as free listener Michel Serres's History of Sciences courses at the Sorbonne, Paris I. In 2007 at ENSAN, Hammoudi initiated a research programme on 'Territorial Thinking Machines', based on a morphological approach and data resources. His theoretical work focuses on the development of a new general theory of singularities for architectural, urban and territorial forms.