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Popper's Mosquito Swarm: Architecture, Cybernetics and the Operationalization of Complexity

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For the architecture theorist Charles Jencks, Frank Gehry's Guggenheim Museum in Bilbao, Peter Eisenman's Aronoff Center in Cincinnati, and Daniel Libeskind's Jewish Museum in Berlin are architectural replies to the question of the cultural outgrowths of 'complexity science'. In the light of new technologies being used in architecture, it seems necessary to explore Jencks's position from new perspectives and to ask: in the context of architectural production, is it possible to discuss complexity not only as an artistic-aesthetic category, but also as a fundamental technical-constructive idea? Contemporary information technologies confront architectural-theoretical discourses with developments that call for an expanded theoretical instrumentarium. It remains unclear which architectural language might be used best to approach the concept of complexity associated with information technologies.

'The complexity of architecture begins with the impossibility of questioning the nature of space and at the same time making or experiencing a real space. [...] We cannot both experience and think that we experience,' explains Bernard Tschumi in an interview for the *Journal of Philosophy and the Visual Arts*.[1] To the question: 'What would be the foundations of a complex architecture?' he replies: 'Architecture finds itself in a unique situation: it is the only discipline that, by definition, combines concept and experience, image and use, image and structure. Philosophers can write, mathematicians can develop virtual spaces, but architects are the only ones who are the prisoners of that hybrid art, where the image hardly ever exists without combined activity.'[2] Upon closer examination of the concept of complexity, it soon becomes evident that it has always existed in more than one definition, more than one interpretation, and certainly more than one architectural variant. One can either agree with Tschumi's discussions of complexity or approach them critically. What seems essential to us in this context is his concluding thoughts: 'Architecture is not about conditions of design, but about the design of conditions [. . .].'[3] Here, it becomes evident that reflections on the concept of complexity and architecture must eventually go beyond simple terminological definitions. Perhaps even more than other cultural disciplines, architecture is confronted by the most diverse levels of contemporary complexity. Against this background, it is apparently often a question of modelling further levels of complexity, and therefore always of contriving a subsequent world picture, rather than of precisely categorizing or analyzing the existent. What is required are ways of reading complexity that – despite or even precisely because of their differences – lead unavoidably to questions of the respective systems of reference: which context generates which concept of complexity, and what concept of complexity produces what context?

'With clouds replacing clocks,' conjectured American architect and architectural theoretician Charles Jencks in his *Architecture of the Jumping Universe*, 'a revolution in thinking was under way, that can best be understood by opposing it into the dominant world view, by contrasting the Postmodern sciences of complexity with the Modern sciences of simplicity.'[4] 'In the new sciences and architectures the fundamental idea relates to feedback, self-organizing change, which the computer is well-adapted to portray.'[5] Jencks presented complexity research as a 'new science' and a 'new paradigm.'[6]

For Jencks, Frank Gehry's Guggenheim Museum in Bilbao, Peter Eisenman's Aronoff Center in Cincinnati, and Daniel Libeskind's Jewish Museum in Berlin are architectural replies to the question of the cultural outgrowths of this new science. More than a decade later, and in light of the new technologies being used in architecture, it seems necessary to explore from new perspectives not so much Jencks's answers, but rather his questions. In the context of architectural production, is it possible to discuss complexity not only as an artistic-aesthetic category, but also as a fundamental technical-constructive idea? In other words: can the epochal publication of Robert Venturi's *Complexity and Contradiction*[7] be regarded as a development of the concept of complexity in architecture?

The metaphor of the cloud – which achieved prominence not long ago through the pavilion constructed by American architects Elisabeth Diller and Ricardo Scofidio at the Swiss regional exhibition Expo 02 – has surfaced repeatedly in architectural history (Figure 1). Yet Jencks does not invoke this metaphor in the form in which it is found in architecture, that is to say, as a poetic counter-concept to the materiality of built architecture, or as a dream image of a space that has been liberated from physical limitations. Jencks's level of reference is

Figure 1. Diller + Scofidio Architects: Blur building, Yverdon-les-Bains, realized for the Swiss National Exhibition Expo. 02

instead linked to overarching questions such as those concerning the interrelationships between architecture, science, and metaphor, and between architecture, science, and the world picture. Does a new science generate not only new metaphors and a new world picture, but also new architectural design strategies as well? The interrelationships between metaphor, philosophy, and the history of science, for example in the context of epochal upheavals and the emergence of technical-scientific metaphors, has been the object of numerous philosophico-historical discourses.[8] Yet if 'every creative history [has] its world picture, and indeed in such a way as to concern itself from time to time about that world picture,'[9] than the question is: what world picture can be represented by a cloud (in contradistinction to the mechanism of the clock)?

In searching for the source of Jencks's metaphorical simile, the trail leads directly to the mid-20th-century discursive space of theories of science: 'My clouds are intended to represent physical systems which, like gases, are highly irregular, disorderly, and more or less unpredictable,'[10] explained philosopher of science Karl Popper matter-of-factly in April 1965 in his *Arthur Holly Compton Memorial Lecture* at Washington University, continuing, '[…] There are lots of things, natural processes and natural phenomena, which we may place between these two extremes – the clouds on the left, and the clocks on the right.'[11] While Popper's lecture dealt mainly with socio-philosophical questions, he was concerned

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in this context with the familiar philosophical question of the degree to which physical determinism or non-determinism supplied adequate descriptions of reality. The title of this lecture, ‘On Clocks and Clouds,’ supplied the relevant metaphorical dualism.

On the basis of a simple example drawn from nature, Popper further elaborated his thoughts on the cloud metaphor. Only at second glance does it become evident that by choosing this example, he anticipated something that could eventually be modelled with the technical assistance of computers only 20 years later:

> As a typical and interesting example of a cloud I shall make some use here of a cloud or cluster of small flies and gnats. [...] In this case of the gnats, their keeping together can be easily explained if we assume that, although they fly quite irregularly in all directions, those that find that they are getting away from the crowd turn back towards that part which is densest. This assumption explains how the cluster keeps together even though it has no leader, and no structure – only a random statistical distribution resulting from the fact that each gnat does exactly what he likes, in a lawless or random manner, together with the fact that he does not like to stray too far from his comrades [...] Like many physical, biological, and social systems, the cluster of gnats may be described as a ‘whole.’ Yet the cluster of gnats is an example of a whole that is indeed nothing but the sum of its parts; [...] for not only is it completely described by describing the movements of all individual gnats, but the movement of the whole is, in this case, precisely the (vectoral) sum of the movements of its constituent members, divided by the number of members.[12]

In light of the following discussion of the concept of complexity and its development, Popper’s lecture offers two concrete points of departure: first, he speaks of the possible description of the swarm as a ‘whole,’ an entity that is more than the ‘sum of its parts.’ At the same time, through his attempt to explain the enigmatic coherence of the swarm ‘without a leader,’ he also supplies us with a structural reference for the technical modelling of the behaviour of dynamic systems. An initial reading suggests the immediate adoption of a manner of expression drawn from the field of Gestalt psychology. The investigations of this theory of perception, which emerged in Germany in the early twentieth century, were driven by the central question of the perception of complex phenomena or stimuli.[13]

A second reading, on the other hand, reveals the outlines of something that would presumably be characterized (from the perspective of contemporary technology) by American computer scientist Mitchel Resnick as ‘decentralized systems and self-organized behaviors’:[14] a self-organizing, complex system consisting of multiplicity of interacting elements (Figure 2).[15]

Popper’s mention of principles drawn from theories of perception is no accident; as early as 1928, his philosophically oriented dissertation *Zur Methodenfrage der Denkpsychologie* (On Questions of Method in the Psychology of Thinking) was supervised by Karl Bühler.[16] Bühler, a German psychologist of

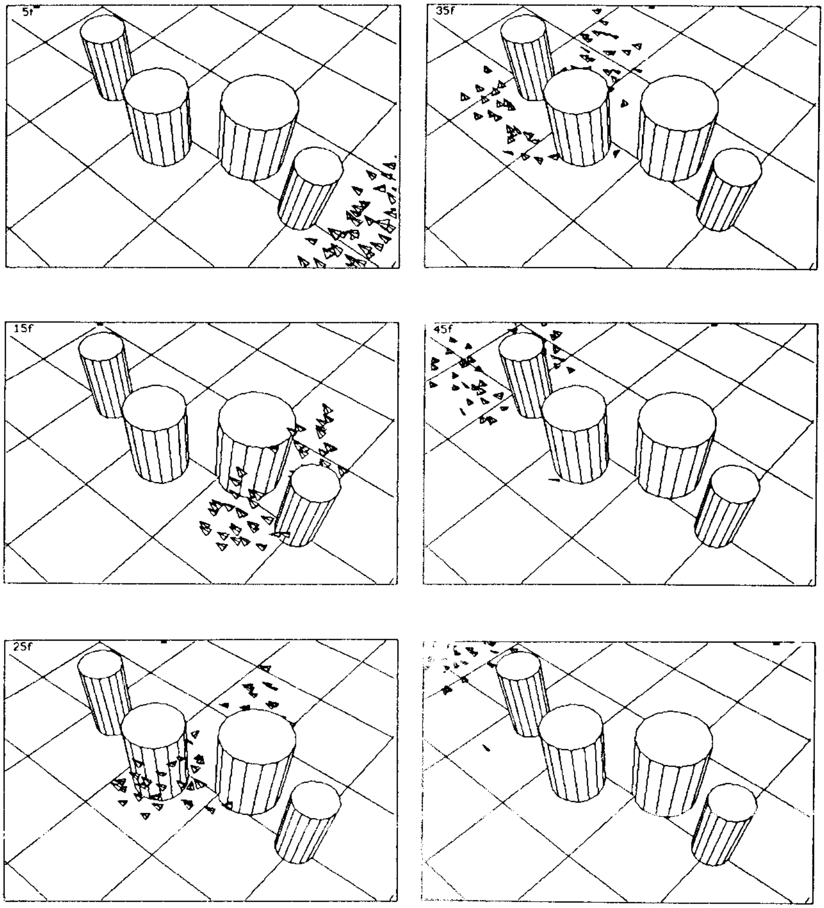

Figure 2. "Boids" model by Craig Reynolds in collaboration with the Symbolics Graphics Division and Whitney/Demos Production, 1986/87. © Craig Reynolds

thinking and perception, was a decisive influence for many of Popper's socio-philosophical views. Popper's remark that despite the nonlinear movements of each individual mosquito, the swarm as a whole functions like a coordinated collective is an allusion to the reciprocal effects in complex systems between local behaviours and global outcomes: technically, the global behaviour of a system can be modelled on the basis of local knowledge provided there exists a sufficiently large number of interacting elements. In *Die Logik der Sozialwissenschaft* (The Logic of the Social Sciences),[17] Popper presented a series of theses designed to 'articulate the opposition between our knowledge and our non-knowledge.'[18] Here, we encounter the term 'situational logic,' coined by Popper, and so reminiscent of the general term 'situated agent,' which would become paradigmatic in so-called 'new artificial intelligence.' Both concepts

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emphasize the coupling between the agent and the context in which the agent acts: whether as here in the framework of a situational analysis, or as a cognitive modelling rule for the technical implementation of a multi-agent system.[19] The agent is inseparable from the context in which it is situatively embedded. Situatedness, then, is a fundamental condition permitting the modelling of global complexity through a simple system of local rules.

Popper's *Holly Compton Memorial Lecture* was published in 1966. Also published that year was Venturi's *Complexity and Contradiction*. For decades, Venturi's concept of complexity would remain central to the discourse concerning the opposition between narratives of complexity in postmodernist architecture and productive clarity in modernist architecture. Only relatively late would ideas concerning complex systems be brought into relationship with postmodernist ideas of complexity, for instance by Jencks, Wolfgang Welsch or Klaus Mainzer.[20] To be sure, Postmodernism had honed an aesthetic gaze for nonlinear processes. An awareness of the dynamics of complex systems in nature, however, could be generated only through the technical clarity of computer simulation. Contributing to this development were personalities such as Claude Shannon, John von Neumann, and Herbert Simon. The question of whether to credit the emergence of theories of chaos and complexity in the history of science with a qualitative transformation of the world picture will surely receive further discussion. Also meriting continuing philosophical-scientific debate is the question of the degree to which humankind has – in opposition to the sciences in modernity – come closer to nature. Is it the case that 'all that we can infer about the nature of the world from the fact that we have to use mathematical language if we want to describe it, is that this world has a certain degree of complexity or, that there are certain relationships in this world that cannot be described with too primitive means?'[21]

Against the background of the concept of complexity, cybernetics has conjured up a structural-scientific foundation of which the technological potential and cultural magnitude for architectural production can be discussed only from the perspective of contemporary information technology. 'The thought of every age is reflected in its technique,' observed American mathematician Norbert Wiener in his *Cybernetics*.[22] Wiener's book has fostered the 'technification' of concepts in the humanities, natural sciences, and arts. This has had consequences for architecture as well. Through processes of 'metaphoricization', such cybernetically minted concepts as 'communication' and 'feedback' advanced to the status of productive and effective guiding ideas in the architecture of succeeding decades. Abstract control processes now stood in the foreground, having supplanted individual features, and much influenced by a future universal science that would, it was said, integrate the various disciplines. Relegated to a secondary status was the question of whether we are talking about biological organisms, technical processes of automation, human perceptions, concepts of architectural engineering, or architectural planning and design processes.

In short, it was a question of the 'ontological restlessness' referred to by German media theoretician Claus Pias in his essay on the utopian potential of cybernetics.[23] 'This restlessness,' writes Pias, 'resides in the indistinctness or interchangeability of that which was previously distinguished from artifacts under the concept of the human.'[24]

In discussions of architecture and complexity, the cybernetic period is accorded an important role. The appearance of *Complexity and Contradiction* coincided with Time Magazine's heralding of the 'Cybernated Generation' in April 1965.[25] Coinciding with Venturi's manifesto was a concept of complexity that could be discussed in the context of a 'general, formal science of the structure, relations, and behavior of dynamic systems.'[26] Complexity, then, could be understood from the perspectives of broadcast technology and information theory.[27]

Just one year after Venturi's publication, György Kepes, a Hungarian-American artist and theoretician of art, announced the emergence of an integrated structural order encompassing the arts, architecture, science, and technology, which would interconnect the disciplines. Occurring in the present, according to Kepes, was a movement from the 'classical sciences of simplicity toward a modern science of ordered complexity.'[28] Against this background, he juxtaposes Pier Luigi Nervi's supporting frame constructions, Buckminster Fuller's spatial frameworks, and Max Bill's concrete painting with electron-microscope images and X-ray images of crystals, cells, and fluids. Just as he had done a year earlier in his New Landscape in Art and Science,[29] Kepes presents his arguments through a rhetoric of visual analogies, announcing in this connection that 'the most powerful imaginative vision is structure oriented.'[30] Despite the fact that concepts such as nonlinearity and self-organization are accorded no explicit significance in Kepes' structural aesthetics, they are a fundamental condition in terms of Gestalt psychology for attempts to unify scientific conceptions of form with those found in art and architecture at the level of structural science (Figure 3).[31] From today's perspective, Kepes should be accorded a pivotal function: he marks the transition from a Gestalt-theoretical conception of complexity to an aesthetic based on technical-scientific structural principles. At least three developmental tendencies are derivable from Kepes's structural conception of complexity.

First of all, there are Kevin Lynch's empirical experiments in the field of perception, which dealt with visual complexity in urban structures, converting Kepes's approaches into an interface joining architecture, urban planning, and the cognitive sciences, which were then just on the point of becoming established.[32] Second, there are the 'generative aesthetics' of early experimental computer graphics, for example those of the German computer art pioneers Georg Nees and Frieder Nake, which emerged as a new graphic trend.[33]

However, for current architectural production using information technology, a third aspect harbours perhaps the greatest potential, located on the level of

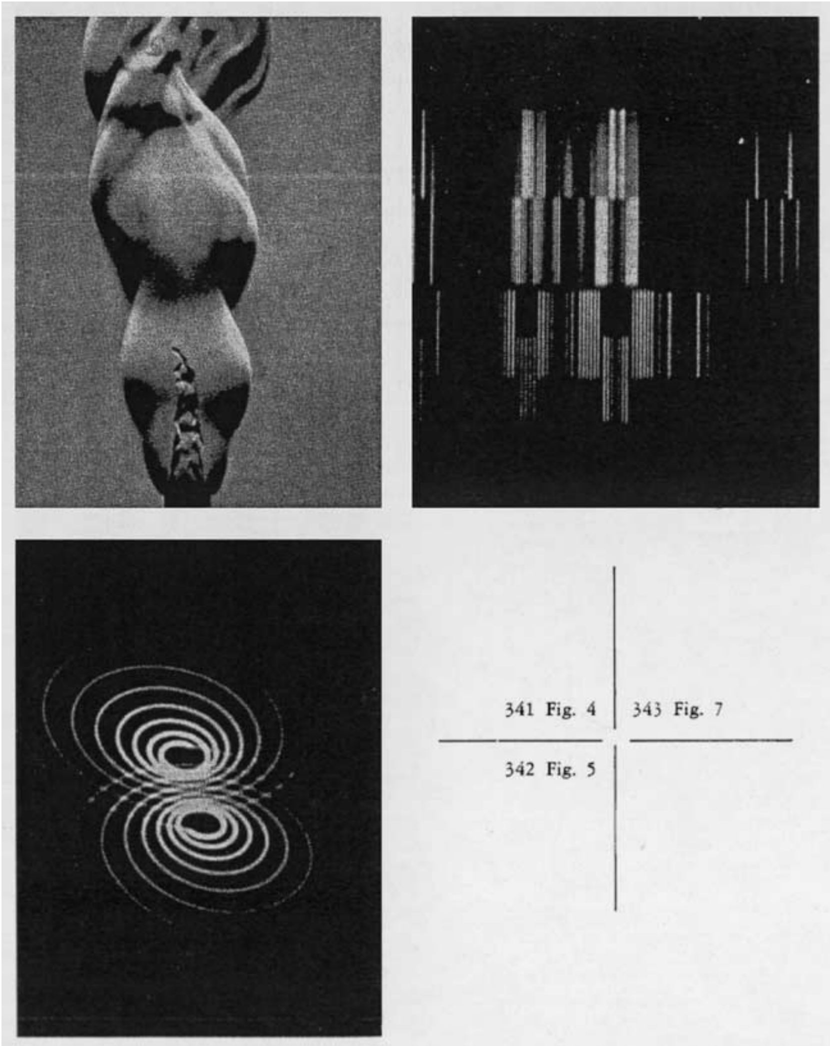

Figure 3. Visual materials accompanying Norbert Wiener's essay "Pure Patterns in a Natural World," from the exhib. cat. *The New Landscape in Art and Science*, ed. by György Kepes, Boston 1956

construction. The point of departure is what Frei Otto referred to as 'natural construction.'[34] On the basis of the investigation of complex systems, he attempted to constructively translate into architectural terms the economics governing the processes of formal invention in nature. Processes of self-organization were investigated from the perspective of their structural significance for construction.

In this connection, Austrian-American architectural historian Eduard Sekler refers to the distinction between structure and construction: 'The real difference between these two words is that "construction" carries a connotation of something put together consciously while "structure" refers to an ordered arrangement of constituent parts in a much wider sense.'[35] Both rhetorically and methodologically, Otto attempted to overcome the purportedly intentional difference between construction and structure delineated by Sekler. Structure and construction were to be rendered equally controllable via the experimental transfer into architecture of the economic criteria of natural processes of formal invention.

One of the most fruitful aspects for digital architectural production lies in Otto's attempt to effect a rapprochement between structure and construction. 'I examined natural, technical, and artistic objects, and in particular those processes through which objects acquire their characteristic forms, their gestalts,'[36] explains Otto. Through the application of complex systems devoted to the structural determination of this 'gestalt,' Otto succeeds in discussing complexity not only on an aesthetic level, but on an economic one as well. His point of departure was the conviction that 'if you begin the design process not from a formal canon, but instead from the modelling of processes, then [it is] recommended that [these] be formulated like the rules of the game.'[37]

Architectural production hence opened up for Otto a procedural-technical interpretation of the complexity found in nature. Evident, however, with regard to the potentialities of joining architecture and information technology is a conceptual reservation concerning his methodology: both Otto's concept of natural construction and the design ideas resulting from it rest as a rule on the structural principles of non-biological processes. Investigated, for example, are the involved geometries of birds' nests, but not the behaviour of flocks of birds. The multi-layered structures of anthills are analyzed, but not the behaviour patterns of the ants themselves. Otto's natural constructions are concerned, so to speak, with the design outcomes and finished products of nonlinear processes of formal invention.

Yet through growing research into new methods, such as of 'artificial life'[38] in engineering-oriented, marginal areas of digital architectural production, it has now also become possible to exploit the dynamic behaviour of biological systems. Emerging here as well is the decoupling of elements that remained unified in Otto's concept of 'gestalt': the structural process on the one hand, and the forms it generates on the other. In other words: the separation of structure and form. In the process, something has penetrated into technical thinking in architecture that derives unmistakably from the logic of information technology. The technologization of nonlinear processes serves as the foundation for an independent method of construction.[39] Constructing with complex systems can be regarded, then, as 'an additional phase of the technical world'[40] (see Figure 4).

In summary, it can be said that there are three lines of development of the concept of complexity in architecture: a gestalt-psychological line, a cybernetic line, and an algorithmic line. Of course, these lines are not mutually exclusive,

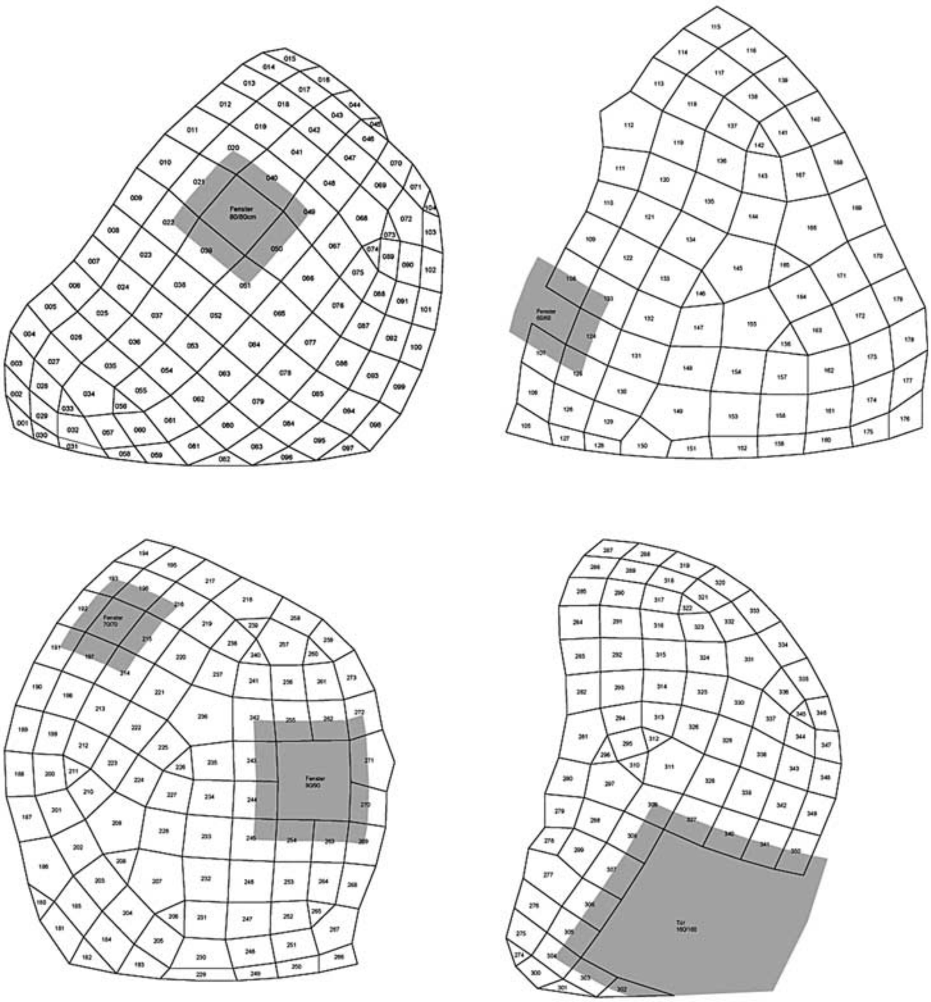

Figure 4. Realized project „Swissbau 2005“, Basel, Switzland: Based on evolutionary optimization strategies in design and construction. The grid adjusts itself during the growth process to various constructive requirements. The result is a complex grown spherical structure. © Ludger Hovestadt, Chair for Computer-Aided Architectural Design, ETH Zurich / Fabian Scheurer, designtoproduction

but an advancing technologization of the concept of complexity cannot be overlooked. With regard to the structural-scientific model of cybernetic thinking and in connection with our initial question concerning the extension of the complex of complexity, this development could be designated therefore as a rapprochement with an ‘operationalization of the complex.’

To discuss this development from an architectural-theoretical perspective requires more than simply designating individual buildings as trademarks of

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the new science or of a new world picture. Equally unsatisfactory in exploring the influence of complexity research on architecture is a restriction to aesthetic criteria. Nonetheless, the buildings by Eisenman, Gehry, and Libeskind enumerated by Jencks can be seen with justice as artistic and architectural symbols of complexity. Still, the development of the concept of complexity discussed here demonstrates that Jencks never goes beyond the level of the visual. In other words: for Jencks, complexity remains indebted to architectural form. The present discussion by no means extends as far as conceptualizing the concept of 'algorithmic complexity,' for example. Information technologies function independent of form; they operate rather at the structural level.

Discussions of architecture and complexity, hence, become a play with the unrepresentable. Contemporary information technologies confront architectural-theoretical discourses with developments that call for an expanded theoretical instrumentarium. It remains unclear which architectural language might best be used to approach the concept of complexity associated with information technologies. This question might serve as a point of departure for critical discussions of the syntactic models of information technologies from the perspective of the semantic requirements of architecture. How can we render the concept of complexity that is operative in the information technologies comprehensible in architecture? How can architectural meaning be generated and even shaped by a technology whose operations are non-semantic in nature?

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