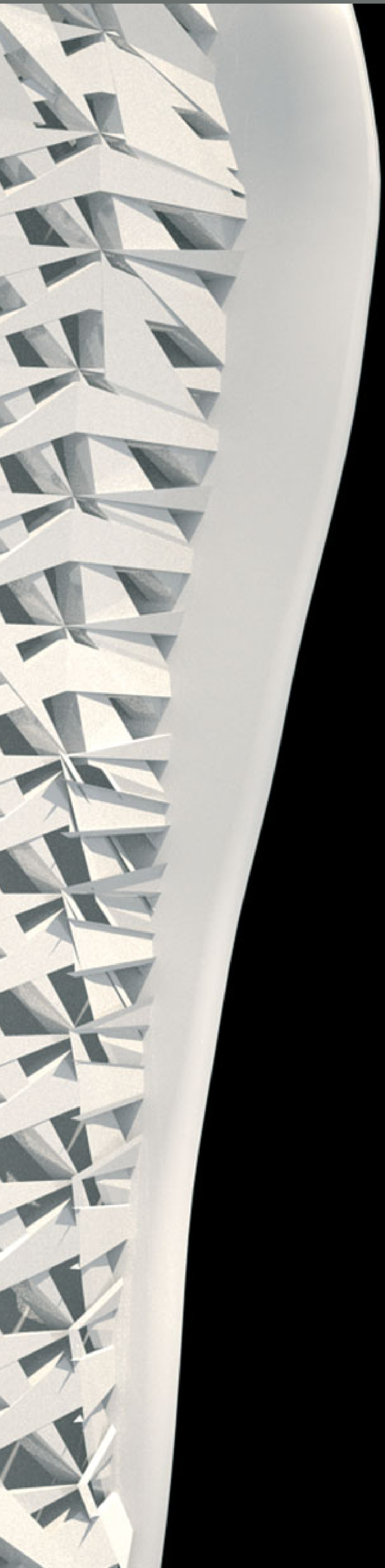
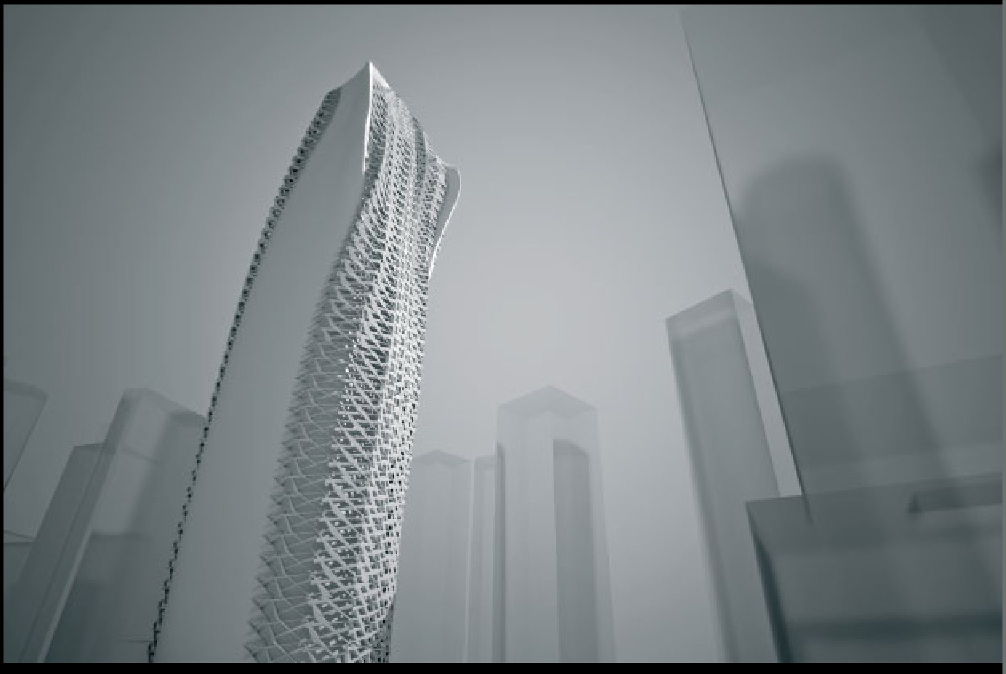


# Digital Morphogenesis

Taking its inspiration from biology, digital morphogenesis operates through a logic of optimisation. Departing from the notion of architecture primarily as form-finding that privileges appearance, **Neil Leach** describes how morphogenesis places emphasis on 'material performance' and 'processes over representation'.



**Monika Bilska and Marta Naganska, Environmental Ornamentation proposal, Hong Kong, 2007**
The design of this tower was inspired by a biomimetic study of the Cactaceae family. The plant's self-shading logic was then combined with a camera diaphragm mechanism. This drove the form-finding logic for a double skin, which was populated on the facade through scripting according to an analysis of sun exposure during different times of the day and seasons of the year.

Within contemporary architectural design, a significant shift in emphasis can be detected – a move away from an architecture based on purely visual concerns towards an architecture justified by its performance. Structural, constructional, economic, environmental and other parameters that were once secondary concerns have become primary – are now being embraced as positive inputs within the design process from the outset. Architecture, it would seem, is no longer so preoccupied with style and appearance. It is as though a new paradigm has emerged.

This new paradigm can be understood as an attempt to overcome the scenography of Postmodernism. It aims to locate architectural discourse within a more objective framework where efficient use of resources supersedes the aesthetic indulgences of works that previously came under the broad heading of Postmodernism, which might include not only the somewhat conservative movement noted for its decorative use of applied decorative motifs – as Postmodernism is understood most commonly within architectural culture – but also more progressive movements such as Deconstructivism, all of which privilege appearance over performance.

This development is by no means universal. Many areas of architectural production remain deeply rooted in Postmodern concerns for appearance, and no doubt architectural culture would be poorer if all architects were to subscribe to the same approach. However, it does represent a significant shift not only in the various 'hot spots' of architectural production – cities such as London, New York, Rotterdam and Los Angeles – but also in other cities where the designs of various progressive architects from around the world are now being built. The structural logic that informs the Bird's Nest, Water Cube and CCTV headquarters building in Beijing, no less than the environmental logic that is beginning to inform various developments in Dubai, suggests that this is a global phenomenon.

We might describe this privileging of performance within the design process as an interest in 'morphogenesis'.[1] Used initially in the realm of biological sciences, the term refers to the logic of form generation and pattern-making in an organism through processes of growth and differentiation. More recently it has been appropriated within architectural circles to designate an approach to design that seeks to challenge the hegemony of top-down processes of form-making, and replace it with a bottom-up logic of form-finding.[2] The emphasis is therefore on material performance over appearance, and on processes over representation.

We need to recognise, then, that though there may be an apparent formal similarity between the 'nonstandard' forms of architects like Frank Gehry and other, more contemporary architects such as FOA with their increasing interest in the morphogenetic questions of performativity and form-finding, there is an enormous difference in terms of design methodology. For example, Gehry represents a more traditional, 'Postmodern' approach towards design, where the architect is perceived as the genius creator who imposes form on the world in a top-down process, and the primary role of the structural engineer is to make possible the fabrication of the designs of the master architect, as close as possible to his or her initial poetic expression. Meanwhile, the more contemporary architects operating within the new morphogenetic paradigm can be seen more as the controllers of processes, who facilitate the emergence of bottom-up form-finding processes that generate structural formations.

**Kristina Shea, Neil Leach, Spela Videcnik and Jeroen van Mechelen, eifFormStructure, Academie van Bouwkunst, Amsterdam, 2002**
The design of this temporary structure was generated using the eifForm program, a stochastic, non-monotonic form of simulated annealing. This was the first 1:1 prototype of a design produced using eifForm and, almost certainly, the first architectural structure built where both the form and related structure were generated by a computer via design parameters and conditions rather than by explicitly described geometry.

The difference, then, lies in the emphasis on form-finding over form-making, on bottom-up over top-down processes, and on formation rather than form. Indeed the term 'form' should be relegated to a subsidiary position to the term 'formation'. Meanwhile, 'formation' must be recognised as being linked to the terms 'information' and 'performance'. When architecture is 'informed' by performative considerations it becomes less a consideration of form in and of itself, and more a discourse of material formations. In other words, 'form' must be 'informed' by considerations of 'performative' principles to subscribe to a logic of material 'formation'.

However, the logic of morphogenesis in architecture is not limited to questions of design methodology; it also extends into the ethical arena.

If we can find forms that operate more efficiently from a structural point of view, then we can use fewer materials. Equally, if we can devise forms that perform more efficiently in terms of energy consumption, we will consume less energy in heating or cooling our buildings. In either case morphogenetic design will help to preserve the world's resources. As such it can be taken not only as a critique of the scenography of Postmodernism, but also as an ethical argument in terms of the environment.

**Material Computation**

Biology provides one of the major sources of inspiration for research into morphogenesis in architecture. Nature operates largely through a logic of optimisation, and can therefore offer important lessons for architects. Biomimetics – the study of what we can learn by replicating the mechanisms of nature – has therefore emerged as an important field of research. It is not simply that nature can inspire products such as Velcro or recent fabrics used in the manufacture of swimwear that are based on the hydrodynamic properties of shark's skin; rather, nature itself can teach us important lessons about the efficiency of certain structural organisations. Following on from the early experimentation of Gaudí, Frei Otto has become a champion of observing the behaviour of certain structures in nature, and reapplying their principles through analogue modelling. Thus spiders' webs and soap bubbles can provide deep insights into the behaviour of form-finding lightweight structures.

These observations come under the heading of 'material computation'. They offer us analogue forms of computation, which – despite the apparent crudeness of the modelling process – are actually highly sophisticated means of understanding structural performance. To describe them as a form of computation is not to undermine the role of digital computation; rather it is to recognise that computation is everywhere in nature. 'Computation' – a term derived from the Latin '*computare*' (to 'think together') – refers to any system where individual components are working together. But it is equally important to recognise that digital computation has its limitations. It necessarily involves the reduction of the world to a limited set of data that can be simulated digitally, but it can never replicate the complexity of a system such as a soap bubble whose internal structural computation involves an intricate balance between highly complex surface material organisations and differential atmospheric pressures.

A number of contemporary architects have re-examined the works of Gaudí and Otto, and found in them sources of inspiration for the new morphogenetic generation of form-finding research, often coupling the lessons of their analogue experimentation with more contemporary digital techniques. Mark Goulthorpe of dECOi Architects describes his work as a form of 'post-Gaudían praxis', while Mark Burry, as architectural consultant for the completion of Gaudí's Sagrada Família church in Barcelona, has been exploring digital techniques for understanding the logic of Gaudí's own highly sophisticated understanding of natural forces. Meanwhile, Lars Spuybroek of NOX has performed a number of analogue experimentations inspired by the work of Frei Otto as a point of departure for some innovative design work, which also depends on more recent software developments within the digital realm.[3]

This work points towards a new 'performative turn' in architecture, a renewed interest in the principles of structural performance, and in collaborating more empathetically with certain progressive structural engineers. However, this concern for performance may extend beyond structural engineering to embrace other constructional discourses, such as environmental, economic, landscaping or indeed programmatic concerns. In short, what it amounts to is a 'folding' of architecture into the other disciplines that define the building industry.[4]

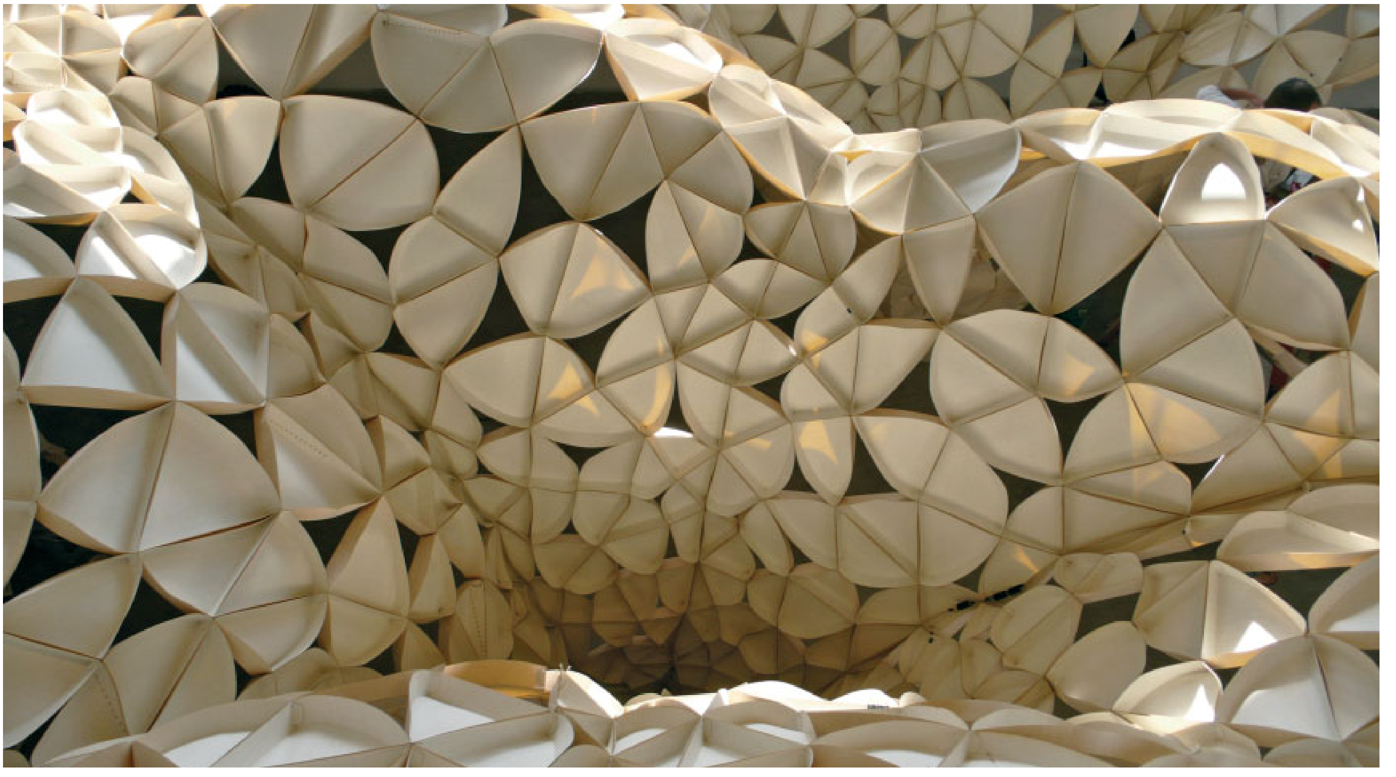
**Digital Computation**

Not surprisingly in an age dominated by the computer, this interest in material computation has been matched by an interest in digital computation. Increasingly the performative turn that we have witnessed within architectural design culture is being explored through new digital techniques. These extend from the manipulation and use of form-generating programs from L-Systems to cellular automata, genetic algorithms and multi-agent systems that have been used by progressive designers to breed a new generation of forms, to the use of the computer to understand, test out and evaluate already designed structures.

The seemingly paradoxical use of the immaterial domain of the computer to understand the material properties of architecture has spawned a new term in architecture: 'digital tectonics'. In other words, the old opposition between the highly material world of the tectonic and the immaterial world of the digital has broken down. What we have instead is a new tectonics of the digital or 'digital tectonics'.[5]

A certain genealogy can be detected in the use of the computer in architecture. What distinguishes this new digital paradigm from early uses of the computer in the architectural arena is that it reinterprets the computer not simply as a sophisticated drafting tool – an extension, in other words, of the possibilities of the previous paradigm of ink on tracing paper – but also as a device that might become part of the design process itself. With this we see a development in the very nature of the architect from the demiurgic 'form-giver' to the architect as the controller of generative processes, where the final appearance is a product not of the architect's imagination alone, but of the generative capacities of computer programs. It is not that the architect here is any less imaginative; rather, the architectural imagination has been displaced into a different arena – into the imaginative use of various processes.[6]

But even within the logic of digital tectonics there is a certain genealogy of development. Computational methodology had first been



**IwamotoScott Architecture, Voussoir Cloud installation, SCI-Arc, Los Angeles, August 2008**
Voussoir Cloud explores the structural paradigm of pure compression coupled with an ultra-light material system. The overall design draws from the work of engineer/architects such as Frei Otto and Gaudí who used hanging chain models to find efficient form. The hanging chain model was here coupled with vaulted surface form-finding to create a light, porous surface made of compressive elements.

used as a means of testing and thereby verifying and supporting the initial designs of the architect. The objective here was simply to use the computer to make the designs of the architect realisable. The only significant contribution to the design process occurred when findings of this process influenced the original design and forced minor amendments to it. Examples here would include the use of software to test out the acoustic performance of the Greater London Authority building by Foster + Partners.[7] Occasionally, also, a more precise structural definition of a loosely formulated architectural concept could be made by the computer, for example the use of algorithms to define the form of the glass canopy to the British Library on the part of Chris Williams, and the 'dynamic relaxation technique' to define the precise vectorial layout of the mullion system.[8]

A second generation of computational methodology, however, can be detected in the work of Kristina Shea, whose eifForm program serves to generate structural forms in a stochastic, non-monotonic method using a process of structural shape annealing.[9] The 'designer' merely establishes certain defining coordinates, and then unleashes the program, which eventually 'crystallises' and resolves itself into a certain configuration. Each configuration is a structural form that will support itself against gravity and other prescribed loadings, and yet each is different. Such is the logic of a bottom-up, stochastic method.

It is programs such as this that reveal the true potential of the digital realm in influencing the process of design itself, by opening up fields of possibilities. The computer, then, emerges not only as a prosthetic device that extends the range of the architectural imagination, but also – much like a calculator – as a tool of optimisation that offers a more rigorous means of searching out possible options than what could be described as the pseudo-computational logic that often dominates contemporary practice.

### New Theoretical Paradigms

This interest in digital production has also prompted a broad shift in theoretical concerns. If the 1980s and 1990s were characterised by an interest in literary theory and continental philosophy – from the Structuralist logic that informed the early Postmodernist quest for semiological concerns in writers from Charles Jencks to Robert Venturi, to the post-Structuralist enquiries into meaning in the work of Jacques Derrida that informed the work of Peter Eisenman and others – the first decade of the 21st century can be characterised by an increasing interest in scientific discourses. It is as though the dominant logic of today has become one of technology and material behaviour.

This is not to endorse the position of architectural theorist Michael Speaks who claims that we have witnessed the 'death of theory'.[10] For

such a theory, it could be argued, is merely an anti-theory theory in that there is surely no position that stands outside theory. Any form of practice must be informed by a theoretical impulse, even if it is a positivistic one that purportedly disdains theory. Rather, what we are witnessing is the ascendancy of a new branch of theory, one that engages with science, technology and material behaviour.

As such, one can detect a waning of interest in literary theories and literary-based philosophies, and an increase in interest in scientific thinking and in philosophies informed by scientific thinking and an understanding of material processes. So it is that just as the work of Jacques Derrida is fading in popularity, that of Gilles Deleuze is becoming increasingly popular. Indeed it has been through the work of secondary commentators on Deleuze, such as Manuel DeLanda, that the relevance of Deleuze's material philosophies has been championed within architectural circles.[11]

DeLanda has coined a new term for this emerging theoretical paradigm: 'New Materialism'. This should be distinguished from Marx's 'Dialectical Materialism' in that the model is extended beyond mere economic considerations to embrace the whole of culture, and yet the principle behind Marx's thinking – what we see on the surface is the product of deeper underlying forces – remains the same. Here we might understand cultural production not in symbolic terms, but in terms of material expressions. It is not a question of what a cultural object might 'symbolise' – the dominant concern in the Postmodernist quest for interpretation and meaning – but rather what it 'expresses'. The concern, then, is to understand culture in terms of material processes – in terms of the actual 'architecture' of culture itself. Within this new configuration the economist, the scientist and the engineer are among the reassessed heroes of our intellectual horizon, and figures such as Cecil Balmond have become the new 'material philosophers' – to use another term adopted by DeLanda – of New Materialism.

To some extent this can be read as a highly positive development within architectural circles in that the domains of science and technology, for so long neglected at the expense of history and theory and treated as largely positivistic domains, have now been reappropriated and recognised as offering a highly relevant and rich domain of intellectual enquiry.

But it is not just materialist philosophies that have seized the imagination of architectural theorists. So, too, has scientific thinking itself begun to find its place in the architectural curriculum, from the early observations of D'Arcy Thompson on growth and form to more recent theories – such as 'emergence', popularised by Steven Johnson, and Stephen Wolfram's discourse of 'A New Kind of Science', both of which deal with complexity emerging from a simple set of initial rules.[12]

If we add to these the developing interest in computational methodology – the possibility of scripting, parametric modelling and performance-based generative techniques such as multi-agent systems or genetic algorithms – we can begin to define a broad shift that has already appeared in certain progressive schools of architecture and that is beginning to spread into mainstream architectural culture. AD

**Notes**

1. Morphogenesis is derived from the Greek terms '*morphe*' (shape/form) and '*genesis*' (creation).
2. See Michael Hensel, Achim Menges and Michael Weinstock's issues of *AD: Emergence: Morphogenetic Design Strategies* (July/August 2004) and *Techniques and Technologies in Morphogenetic Design* (March/April 2006).
3. See Mark Burry, 'Virtually Gaudí'; Mark Goulthorpe, 'Gaudí's hanging presence'; Lars Spuybroek, 'Softoffice', all in Neil Leach, David Turnbull and Chris Williams (eds), *Digital Tectonics*, John Wiley & Sons (London), 2004.
4. As Alejandro Zaera-Polo and Farshid Moussavi comment, their interest is to recognise the other disciplines in the building industry not simply as offering a service that should be treated as an afterthought in the design process, but rather as an important range of design considerations that should be embraced and incorporated into the early stages of the design process itself. Farshid Moussavi and Alejandro Zaera Polo (Foreign Office Architects), 'Rollercoaster construction', in Neil Leach (ed), *Designing for a Digital World*, John Wiley & Sons (London), 2002, pp 80–7.
5. See 'Introduction', in *Digital Tectonics*, op cit, pp 4–12.
6. See Manuel DeLanda, 'Deleuze and the use of the genetic algorithm in architecture', in *Designing for a Digital World*, op cit, pp 117–20.
7. See Michael Weinstock and Nikolaos Stathopoulos, 'Advanced simulation in design' in *AD Techniques and Technologies in Morphogenetic Design*, op cit, p 56.
8. See Chris Williams, 'Design by algorithm', in *Digital Tectonics*, op cit, pp 78–85.
9. See Kristina Shea, 'Creating Synthesis Partners', in *AD Contemporary Techniques in Architecture*, No 72, March 2002, pp 42–5.
10. Michael Speaks, 'No Hope, No Fear', *ARQ*, 6/3, pp 209–12.
11. See Manuel DeLanda, *War in the Age of Intelligent Machines*, Zone Books (New York), 1992; *A Thousand Years of Nonlinear History*, Zone Books/Swerve Editions (New York), 1997; and *Intensive Science and Virtual Philosophy*, Continuum (New York and London), 2002.
12. D'Arcy Wentworth Thompson, *On Growth and Form*, Dover Publications (New York), 1992; Steven Johnson, *Emergence: The Connected Lives of Ants, Brains, Cities and Software*, Penguin (London), 2001; Stephen Wolfram, *A New Kind of Science*, Wolfram Media (London), 2002. On emergence, see also Eric Bonabeau, Marco Dorigo and Guy Theraulaz, *Swarm Intelligence: From Natural to Artificial Systems*, Oxford University Press (New York and Oxford), 1999; and John Holland, *Emergence: From Chaos to Order*, Oxford University Press (Oxford), 1998. AD