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Transition towards a digital architecture: new conceptions on materiality and nature

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Abstract

Industrialized societies are undergoing a transition towards an informational era, in which modes of production and culture, once transformed by industrialization, are being modified by the ICTs. The advent of *digital architecture* results from this transition, which involves a *new materiality and a new conception of nature,* just as industrial materials, techniques, and technologies not only paved the way to modern architecture, but also fostered the rejection of nature as an architectural model. If mass production of iron, glass, and reinforced concrete configured an *industrial materiality* from which architectural innovation emerged in the early 20th century, the innovative techniques of employing information through digital technologies are raising a digital materiality that is essential to novel design and manufacturing processes. Moreover, nature is once again a model for architecture through computational design, but not the visual or iconic one it used to be, due to its turn into an *instrumental model* in which natural processes, properties, and inner structures can be decoded and objectified as design parameters of form-making processes. This work addresses the conceptions of 'materiality' and 'nature' in digital architecture, through a dialectical discourse with modern architecture that will provide a historical background that aims to sidestep the misconceptions, and discern the dilemmas, which may result from observing too closely an architectural shift driven by the effervescence of technological progress.

Keywords

Computational design; Digital materiality; Digital culture; Imitation of nature; Historical background

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1. Transitional period

'Architecture is on the cusp of a systemic change, driven by the dynamics of climate and economy, of new technologies and new means of production.'

Michael Weinstock (2008: p.26)

Contemporary architecture is in a *transitional* period, just as it was in the second half of the 19th century when industrial materials — steel, glass and concrete —, and industrial production – standardization, mass production and mechanization – paved the way to modern architecture. Nowadays, a *digital architecture* is emerging as digital technologies are being introduced into design and construction processes; a fact which is redefining architectural practice along with architectural thinking. Hence, the introduction of computer aided design and manufacturing (CAD/CAM) is bringing about new concepts as these tools are changing the way in which architecture is being conceived and produced; in other words, the *digital update* of Historical Materialism's theory that contends, '[…] the mode of production of material life conditions the general process of […] intellectual life' (Marx, 1977: p.3). Under this perspective, the influence of the technological revolutions — industrial and informational — into architectural theory and practice, can be evaluated by comparing their influence on the realms of: a new productive system, a new materiality, and a new way of thinking as a result of the material and productive changes.

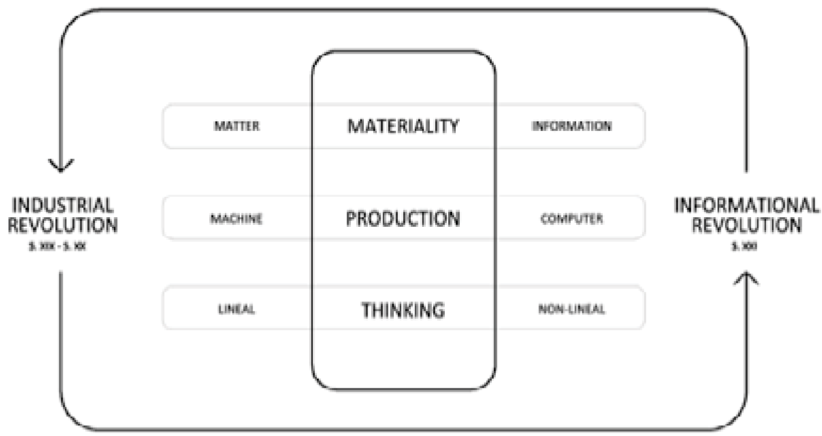

Figure 1.
Major changes brought by Technological Revolutions

In architecture, two of the most significant changes linked to the material and productive development fostered by the technological revolutions, are the new conceptions of 'materiality' and 'nature'. In the first case, the conception of a *new materiality* has emerged as a result of innovative techniques of employing information through digital technologies in architectural production, just as industrial mechanization and mass production fostered new construction materials and techniques for the development of modern architecture. In the second case, the *new conception of nature* arises from the emergence of a *new materiality*: as nature is the main source of materials for production, the conceptions of 'materiality' and 'nature' maintain a dialectic relationship via production and technology; the arising of a new

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materiality implies a new conception and exploitation of nature conditioned by the integration of new technologies in the productive system. Thus, for architecture, nature ceases to be a model of beauty as it is replaced by the machine as a model of efficiency during the industrial revolution; on the contrary, nature is once again a model for architecture in the informational revolution, but not the visual or iconic one it used to be.
The notion of a *transitional period* in contemporary architecture implies the emergence of new conceptions of 'materiality' and 'nature', driven by the new materials and techniques that are being explored and assimilated during this shift. As Walter Benjamin (2002) noted in relation to industrialization and Modernism, on the one hand, the transition involves mistakes and failures in trying to take on the new techniques and materials, and on the other, a collective dream shared by both architecture and technique. In this dream, cultural values become equally assimilated and exchangeable with technological principles. According to José Ortega y Gasset (2014), 'technique' is the production of superfluous needs beyond natural needs: *natural needs* are contented by the activities necessary to sustain organic life, like heating or feeding; *superfluous needs* are fulfilled by the adaptation of the environment to the human desire of well-being. In both cases, the satisfaction of these necessities, through technique, implies maximum result with a minimum effort — efficiency; therefore, for Ortega (2014), 'technique is […] the effort to save effort' (p. 79). In this context, the idea of *human well-being through efficiency* — making a virtue out of economy — becomes fundamental to understanding the concepts that are driving the shift towards a new architecture determined by the employment of digital design and manufacturing techniques.

2. New materiality

2.1 Information as a 'raw material'

Industrial development was considered to rely on the production of physical-material goods, on the transformation of raw materials into products (Marx, 1887); therefore, the conception of a new materiality at the beginning of modern architecture was based on the use of *tangible* materials that were introduced into construction. Nowadays, through digital technologies, the conception of a *new materiality* emerges from the use of information as a *raw material* in the production process (Castells, 1996). Therefore, since the 19th century the arising of a new materiality in architecture has been correlated to the development of the new productive processes fostered by technological progress — and with it, architectural innovations related to new materials: *modern materiality*, as a result of the mass production of *construction materials* enhanced by the industry, and *digital materiality*, as a result of encoding *tangible and intangible* properties of the physical world, into algorithms which are employed as protocols in architectural production through computational techniques.
Technical production is divided into management and executing tasks; in architecture, this productive organization led to the separation of design and construction processes, and was mirrored by the schism between architects and engineers during the 19th century. A rupture of architectural production that is reflected in architectural thinking by the definitions of 'design' given by Adrian Forty or Manfredo Tafuri: in the first case, 'the word «design» refers to the preparation of instructions for the production of manufactured goods' (Forty, 1986: p. 7); in the second, 'Industrial design [is] a method of organizing production even before it is a method of configuring objects' (Tafuri, 1976: p. 98). In this context, *modern materiality* conditioned design decisions but it was not really

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employed in the design process due to the fact that iron, glass, and concrete were materials for construction. On the contrary, *information* has become a useful element in the whole productive cycle, as it can be *objectified* and *exploited* in design and construction processes. In design processes information is exploited as a means to represent, generate, and analyse a designed object, through computational operations in which information becomes a mediator between the human mind and the computer's processing power (Terzidis, 2006). In construction processes, information is objectified as it becomes a mediator between the digital and analogue realms, through data flows between machines which are used to control executing machinery in order to: first, manufacture differentiated series of objects without losing the efficiency of standardised production — massive customization; second, to synthesise new materials, or improve existing ones, by structuring the intrinsic composition of matter in order to enrich material properties or performance. Definitively, the difference between *modern materiality* and *digital materiality* relies on the fact that the first is based on the mass production of synthetic materials, which replaced natural ones in architectural production; and the second comes from the employment of information as a 'raw material' in digital design and manufacturing processes.

2.2 Conceptions on digital materiality

In the 1990s the notion of 'digitalization' was closely related to the idea of transferring material entities from the physical world to virtual reality; or in the terms of Nicholas Negroponte (1995), the movement from atoms to bits. Likewise, during this period most architects were conditioned by the misleading opposition between the real and the virtual, where the term 'virtual' was often used to express the pure and simple absence of existence, assuming reality as a material realisation, as a tangible presence (Lévy, 1998). Nowadays, digital architecture has overcome this notion by extending the instrumental capacities of the computer from the processing of data in design processes — mainly for representative purposes like CAD drawings and photorealistic renders —, to the manufacturing of architectural components in which data flows are essential to its fabrication. In this sense, if 'digitalization' represented the movement from atoms to bits, the notion of 'digital materiality' coined by Stan Allen (2000), renders the movement from bits to atoms; that is, using computers to produce objects from digital files, instead of merely generating images or *virtual realities*.

Bernard Cache's aligns with Allen's notion of 'digital materiality', as he argues that 'the digital world is made analogue flesh' when sources of the real world are coded into a digital series which is recomposed by a physical platform; the source coding is backed up by a channel coding (Cache, 2011: p.25) — *bits incarnated* through physical objects, objectified data. Consequently, Allen's notion of 'digital materiality' coincides with Cache's (2011) demand:

'[To] move from [the] virtual possibilities to actual realities, […] to move from scanning techniques and replace the electronic remote control that activates the pixels in our video screen with a digital command router that manufactures any material.' (p. 28)

In this sense, Cache refers to the use of information as a 'raw material' only in the construction process, as he centers on the manufacturing process, but his concept of "Non-Standard Architecture" encompasses and prioritizes the new roll of information in design processes, as Cache (2011) states:

'Prior to taking shape as constructed buildings, non-standard architecture proceeds from an abstract architecture that orders flows of data necessary for digital production.' (p. 70)

By referring to an 'abstract architecture that orders flows of data for digital production',

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Cache is pointing to the fundamental procedure of digital design: the use of *algorithms* in representational, generative, evaluative and manufacturing processes. An algorithm is a codified problem or procedure, through a fixed symbolic language, in a series of finite, consistent, and rational steps (Berlinski, 2000; Terzidis, 2006). Thus, the essence of digital design is the codification of design problems and procedures in algorithms, which are processed by computers — computed — in order to explore potential design solutions through nonlinear equations whose complexity cannot be solved analytically, and require the use of digital computation. Precisely this is how data and information turn into 'raw materials': by being used as the *processing matter* of computers, by becoming the mediator between the architect and his digital design tool. Hence, before modelling matter or applying a geometric language, a digital design process implies the organization of data and information through programming languages and algorithms; or in Robert Woodbury's (2010) terms, 'the designer [needs] to take one step back from the direct activity of design and focus on the *logic* that binds the design together' (p. 25). Under this perspective the designer prioritizes the relationships by which elements connect, instead of their shape; therefore, relationships become fundamental as they establish organization-paths for the *data flows* that will deeply affect the possible design solutions (Woodbury, 2010) — formal, spatial, functional, or ornamental.

The employment of algorithms in digital design has introduced an important shift in design thinking *by turning the focus from the object to the process*; that is, approaching design through procedures codified into algorithms. Thus, *digital design is driven by form-generating parameters rather than components*, and as the form-generating information can be codified into algorithms, the cognitive process and the ideas implicit to the designer are externalized. In other words, what happens in the designer's mind, in a partially unconscious and inexplicable way, stops being a creative mystery or a 'black box', in Jones' (1992) terms. Furthermore, the externalization of cognitive processes and form-generating procedures into algorithms enables reusing that information as a *processing material* in other design processes; a fact that is confirmed by the common practice of digital designers of copying and editing existing algorithms, instead of starting them from scratch. The use of information as a 'raw material' to create algorithms that codify design procedures, has redirected design to the configuration of processes rather than objects. Consequently, digital technologies are fostering a process driven architecture that comes to the fore as a property of the process of organizing matter, rather than matter thus organized.

2.3 From bits to atoms

In the design of the Beast Chaise Lounge, Neri Oxman exploits the potential of digital materiality — decoding a given source and encoding it into matter — to generate complex structures of multifunctional composites. Oxman (2012) proposes the creation of a 'synthetic anisotropy' by modelling, simulating, and fabricating material assemblies with varying properties that respond to multiple and continuously varied functional constraints. To achieve it, Oxman traduces mechanical, material, and functional requirements into a geometric organisation by applying *texture-based computational algorithms and tilling algorithms*. The algorithms were used to discrete and distribute different materials properties, and turn them into a geometric tessellation in which behavioural patches are dispersed along the surface of the chaise, according to variable performance criteria (Oxman, 2011). *Voxel-based graphics* methodologies were employed in the modelling process. Voxels are digital volume elements: digital atoms inside digital environments. Material properties were assigned to each voxel according to its position and its requirements

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within the whole surface. In additive manufacturing, a *maxel* describes a physical *voxel* (Oxman, 2011). Therefore, *maxels* and *voxels* are the material units of physical and digital matter (Oxman, 2013); that is, the means by which bits were incarnated into atoms, enabling a bottom-up design process in which form emerges from structuring matter in relation to its intrinsic material properties, rather than modelling matter by imposing an abstract form. Over the last decade the employment of information as 'raw material' in digital production gave rise to the notion of *non-standard production*, which referred to the mass production of non-identical parts (Carpo, 2009); and to the idea of *non-standard architecture*, which pointed to a dynamic structuring of data flows for digital manufacturing (Cache, 2011). Nowadays, one can refer to the concept of a *non-standard materiality*, as the isotropy (homogeneity) of industrial materials is being overcome by the production of anisotropic (heterogeneous) materials, customized in order to perform a variety of functions; in other words, digital technologies enable the production of synthetic materials that resemble anisotropic qualities of the materials produced by nature.

3. The return of nature as an instrumental model

3.1 Controlling Nature through Technique: from its Exploitation to its Conservation

As stated by Manuel Castells (1996), matter includes nature, nature modified by humans, nature produced by humans, and human nature itself. In this sense, the notion of 'matter' supersedes that of 'nature', as reflected in the social and political ideas on nature which have arisen since the second half of the 19th century under the influence of industrialisation: 'the first, that from which man takes his materials, the second being the nature produced by man as a result of his activities, and which itself becomes a commodity' (Forty, 2000: p.236). In the first case, industrialisation paved the way for understanding nature as a field of infinite recourses for a human exploitation oriented to the satisfaction of its own *well-being*. A purpose, acknowledged as an architectural principle by J.N.L Durand (1802), as he stated that throughout history the totality of human thoughts and action were generated by two principles: love of well-being and aversion to pain. In the second case, the socio-political conception of nature points to a second synthetic nature achieved by humanity and comprehended as the outcome of natural evolution and technical development rolled into one (Mertins, 2011).

Technological development gave the power to optimize natural cycles of production, for example, fields were able to produce more crops during the year. Therefore, according to Walter Rathenau (2002), throughout the *mechanization of the world* natural production did not rely on itself, but on human work and eagerness (p. 159). As nature became the source of resources for industrial production, the city was conceived as the *productive organism* of the second synthetic nature; that is, as the instrument of coordination of the production-distribution-consumption cycle (Tafuri, 1976). But this cycle is based on principles such as substitution and novelty — fashion —, which imply an unceasing expenditure of resources that was questioned during the 1960s, as the Earth started to be viewed as a finite world with limited natural resources that may be depleted. At this point, the conception of nature start-

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ed to change at the same time as the cohesion of society started to rely on the imagery of disaster instead of the imagery of progress (Baudrillard, 2002): if early industrial society's well-being relied on the idea progress, based on the domination and exploitation of nature to produce material goods; since the second half of the 20th century, the notion of well-being has depended on the conservation of natural recourses, in order to sustain human life without losing the welfare state introduced by the industry.
A new approach toward nature was framed by the preservation of its material and energy resources, paving the way for *sustainable development* and its introduction to architecture's imagery during the last decades of the 20th century. As Mark Jarzombek (1999) argues, 'In recent years there has been a growing interest in the project of Sustainability as a site where ethical commitment, architectural practice, capitalism and good design could come together' (p. 32). With sustainability as a common interest, as a new agenda for the market, the industry, politics, and design, some of its principles were widespread. Hence, along with the erroneous idea of nature as an infinite source of resources, other old concepts, like the reductionist and atomistic notion of nature characterised by early scientific theories — like Descartes' Mechanism, in which material systems are reduced to units in order to be explained — were overridden by organisational and integrative approaches like Holism and Cybernetics. Under these approaches, and with the development of digital technologies, a new sensitivity towards the intangible properties of matter and the complex organisational processes of nature arose in architecture. In other words, there was a new interest in the behaviour of nature, not in its appearance, as it started to be comprehended as a process and not as a product.

3.2 The Mechanical Model and the Rejection of Nature

3.2.1 Renaissance's Heritage

One of the main characteristics of modern architecture was the *machine aesthetics,* which implied a new formal logic based on the productive processes and principles of the industry. However, the foundations of the machine aesthetics need to be found in the *scientific revolution*, which paved the way to a *mechanistic model* of the world in which the role of nature was taken over by the machine (Forty, 2000). Since the Galilean distinction between primary and secondary qualities, and the following Cartesian separation between body and mind (*res cogitans, res extensa*), the understanding of nature under scientific thinking was primarily based on what appeared tangible in the world — that is, the quantitative, objective, measurable, visible, and ultimately controllable physical properties of nature. Everything that could not be expressed in mathematical terms was deemed to be irrelevant, so not only the material properties, but all the properties of living organisms that could not be observed and quantified using scientific methods were neglected. Consequently, Galileo built a world in which only quantifiable matter was relevant, so material qualities turned out to be 'immaterial', becoming a superfluous projection of the mind (Mumford, 1974).
The conceptual fragmentation between the tangible and intangible spheres of reality, introduced by Galileo and Descartes, was anticipated in architectural thinking by Leon Battista Alberti, as he proclaimed the superiority of intellectual work over manual work in the 15th century, leading to the schism of architectural production into lineaments *(lineamenta*) and structure (*structura*). For Alberti (1988), the intellectual work of the architect (*disegno*) had to do with *lineamenta*, that is, 'the precise and correct outline [of the building], conceived in the mind, made up of lines and angles, and perfect in the learned intellect and imagination' (p.7). Therefore, lineaments were independent of the material,

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material, or in Alberti's words, 'it is quite possible to project whole forms in the mind without any recourse of the material' (Alberti, p.7). Consequently, as Alberti proposed conception of architectural form inspired by theory (Madrazo, 1995), he fostered an understanding of architecture in which materials lost their capacity to act as form-making inputs; an architectural form-finding reduced to intellectual operations, to rational prescriptive rules in which material qualities are unconsidered.

3.2.2 The Machine Aesthetics and the Oblivion of Material Knowledge

The irrelevance of matter as a generative design parameter became a general reality throughout architectural industrialization and the subsequent rise of Modernism. As the uniformity and the homogeneity of mechanisation were transposed to the products, the industrialised production led to a conceptual shift of *materiality*. In Le Corbusier's (1982) words, 'Natural materials, which are infinitely variable in composition, must be replaced by fixed ones' (p.214). Materials were homogenised by industrial production, so their heterogeneous properties were forgotten and downgraded to a secondary role; the regularity of the machine required regular materials (De Landa, 2001). Before industrialisation, material qualities were integrated into the form-making process as craftsmen did not impose a form from the outside. As Manuel De Landa (2001) contended:

'Instead of imposing a cerebral form on an inert matter, materials were allowed to have their say in the final form produced. Craftsmen did not impose a shape but rather teased out a form from the material, acting more as triggers for spontaneous behaviour and as facilitators of spontaneous processes than as commanders imposing their desires from above' (p. 135).

The quest for utmost efficiency disparaged craftsmanship, so the bonds that held craftsmen knowledge (*techné*) and the materials were broken by the industry. If matter was previously a generator of form in the *natural* production system, in the *industrial* system it is regarded as a feature of form, but not its first cause (Oxman, 2012). Matter ceased to inform the form-making process, leading to the 'crisis of form': applying matter opportunistically to a given form, so that shape predominates over matter in the process of form generation (Oxman, 2010).

Along with the downgrade of matter as a design input, nature also ceased to inform the design process as a consequence of the Modernist idea of bringing architecture into line with the modern industry. The assumption of a *mechanical model* implied the maturing of a new aesthetics in order to emancipate architecture from historical styles and the traditional modes of production, which Modernism sought to move away from. The *machine aesthetics* became the counterpoint to a *natural model* linked to 19th century historicism and craftsmanship, which would copy nature's appearance as a source of beauty; or as postulated by Theo van Doesburg, a style freed from nature, the aesthetic of a new epoch determined by the new possibilities introduced by the machine (Banham, 1980). But, more importantly, modern architecture was conditioned by the limitations of the machine to mass produce the irregular and organic forms of nature with the same efficiency achieved by producing regular and simple forms — sublimated by Modernism, i.e. Le Corbusier's apology for *purist* forms (Le Corbusier, 1982; 1993). In this sense, the regularity, simplicity, and linearity that characterized modern's formal language, rather than a self-determined choice was a productive imposition of an industrial ideology-reality, in which buildings were to be economical, as stated by Durand (1802), through simple and symmetrical geometrical forms that should be built with the least amount of money. Under this perspective, principles such as efficiency and optimisation, essential to the form-making processes of nature, started to be understood as industrial demands related to the cost of production and to the productivity of the machine. In other words, the idea of efficiency was detached from

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the geometrical and structural *performance* of form, and was rooted in the straight and clean forms that the machine can produce better and faster than the hand.
For Durand, economy and efficiency were sources of inspiration, and they became the only acceptable values of architecture (Pérez-Gómez, 1983). In this way, Durand introduced a system of values that is essential to any architecture that operates under a mechanical model, in which design is driven by a *rationalistic logic* determined by economic decision models that expel all kinds of mystical ideas (Schumpeter, 2003). In this context, the regularity and linearity of standardised architecture reveals that Modernism operated under a mechanical model in which nature's beauty as a mystical value was replaced by mechanic efficiency as a rational-productive principle. Hence, the approach toward nature under the mechanical model relies on reproducing the efficiency of its generative processes and performance, rather than representing its appearance and beauty. Certainly, the significance of the *machines aesthetics* under the *mechanical model i*s not constrained by its formalist terms; instead, it operates from the Marxist viewpoint as a compound of technical devises, social alliances, and general intellect (Raunig, 2008), driven by the laws of economy.

3.3 The Return of Nature through Computational Design
3.3.1 Imitation of Nature
In the informational era architecture's interest in nature is returning, but with a different approach: nature ceases to be understood as a *visual* model and becomes an *abstract* model. This approach, implicit to the idea of *imitation* given by Quatremère de Quincy in the 19th century, now takes a whole new meaning to the extent that digital architecture explores the abstract qualities of nature aided by computers. Thus, while Modernism replaced nature with the machine as its architectural model, in digital architecture nature turns out to be a model through computation machines: *nature through the mechanical model.*
For Quatremère, *imitation* conveys the repetition of the idea of an object into another object, which in turn becomes an image. Instead, a *copy* is the repetition of a particular object without grasping the idea. The idea of *imitation* transcends the comprehension of nature based on its *appearance,* as it tries to reproduce its *abstract principles*. Thus, Quatremère raised two types of apprehension of nature: a sensible one that observes its extrinsic qualities, and an intellectual one, which deduces through reason the abstract shape or pattern from which the visible form emerges (Madrazo, 1995). The visual apprehension of nature was the predominant approach in architecture until the 19th century, so the intellectual abstraction implicit in the idea of *imitation* was considered extremely conceptual and rational at that time. Quatremère's *imitation* of nature was questioned for trying to emulate the intangible qualities of nature instead of literally copying its physical properties (Forty, 2000), but nowadays his theory is being revaluated, since digital technologies have enabled designers to perceive, analyse, and reproduce several features of nature that cannot be apprehended, comprehended or quantified through the human senses and intellect.
In digital architecture nature has shifted from the *copy* of its appearance to the *imitation* of its structures and processes — a shift that implies a *transition from a visual-sensible approach toward an abstract-rational approach of nature*. Nature's relevance has shifted from extrinsic to intrinsic, and become an *instrumental* model as architects have started to *imitate* the organisational processes from which its formal genesis occurs — its *morphogenesis*. An approach influenced by the discovery of the DNA structure, which

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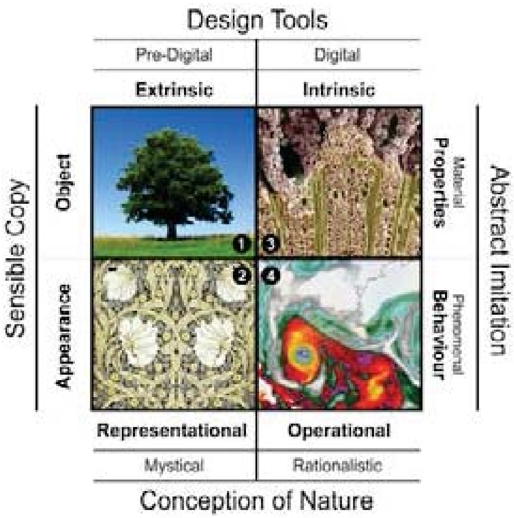

Figure 2.
Nature as Architectural Model

Pre-digital Model
1. Extrinsic image of a tree
2. Decorative motif for wallpaper

Digital Model
3. Intrinsic configuration of wood
4. Simulation of natural phenomena

Figure 2.

became the new emblem of nature (Urprung, 2007), and also because the advancement of genetic engineering has provided architects with a better understanding of the importance of the physical processes of self-material organization and structuring in *morphogenetics* (Menges, 2012). Furthermore, the understanding of nature in digital architecture was conditioned by the development and introduction of cybernetics into the architectural thinking since the late 1960s, when Gordon Pask highlighted the idea that architecture and cybernetics share the philosophy of *operational research* (Pask, 1969). Then, architects would be the first and foremost system designers, so architectural interest relied on the organisational properties building as a system that belongs to an ecosystem, in which they interact with its inhabitants while determining their behaviour (Pask, 1969). The conception of buildings as interactive objects and the built environment as an interactive space were encouraged.

3.3.2 Design by Computing Natural Laws

Natural phenomena have been considered in architecture throughout history, but the capacity to apprehend, analyse, and simulate its behaviour through digital tools allows its objectification and employment in the design process with a high range of precision and predictability that was impossible to accomplish before the advent of these tools. The capacity to codify and reproduce natural laws through digital simulation, recalls the notion that Farshid Moussavi (2009) coined as 'Supramateriality': '[an] approach toward materiality, away from our understanding of material as exclusively physical and tangible, to include both the physical and the non-physical' (Moussavi, 2009: p.8). Two projects by Achim Menges illustrate the *imitation* of natural laws in computational design: the ICD/ITKE Research Pavilion 2010, designed through generative processes in which form emerges from intrinsic physical properties and behavioural constraints of plywood lamellas; and the Responsive Surface Structure II (2008), based on the responsive capacity of wood to take moisture from the atmosphere when dry and yield to the atmosphere when wet — hygroscopic behaviour. In both cases, the projects illustrate the possibilities of a new material synthesis based on hybrid assemblies of matter and phenomena.

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The main input in the form-making process of the ICD/ITKE Research Pavilion 2010, was the information obtained from physical form-finding experiments on the structural and material properties of wood: more precisely, the *elastic bending* characteristics of plywood lamellas, which were coded and introduced into an informational model (a parametric model and a multi-subroutine script) in order to generate a design model in which performative and morphological requirements were defined through algorithms. The result was a *bending-active* structural envelope determined by the equilibrium state between the embedded forces (Fleischmman, Lienhard, & Menges, 2011); an equilibrium grounded on the physical qualities of matter and the structural-geometrical constraints of form. According to its authors:
'The result is a novel bending-active structure, an intricate network of joint points and related force vectors spatially mediated by the elasticity of thin plywood lamellas.' (Fleischmman, Lienhard, & Menges, 2011: p. 760)
In the Responsive Surface Structure II, Menges studies the interaction of conifer cones with the environment through hygroscopic behaviour enabled by its anisotropic material qualities. He observes that in the process of absorption and desorption of moisture the material changes physically, as water molecules are bonded or released by material molecules, stimulating an expanding or contracting reaction of the cone scales — a dimensional movement enabled by the bilayered structure of scale's material (Menges, 2012). Menges *imitates* this material behaviour-structure to produce a veneer-composite element with a responsive capacity by designing a bilayered element that combines a wooden material with a synthetic composite. In wood, there is a proportional relation between its dimensional change and moisture content, but Menges changes this linear dependency by combining wood with a synthetic material in order to control and diversify the shape changes. In his own words, these 'elements [were] physically programmed as material system to perform with different response figures in various humidity changes' (Menges, 2012).
The imitation of natural laws in these projects, not only renders the shift from a mechanical to a biological model — responsiveness is achieved by applying natural principles instead of mechanical devices — especially, it illustrates how quantification and understanding of material behaviour and natural phenomena, through digital technologies, is helping to overcome the conceptual fragmentation of nature that prevailed in architectural thinking since the scientific revolution until the end of the 20th century.

4. Conclusions

What contemporary architects describe as a systemic change in architecture, driven by the new technologies and the dynamics of climate and economy (Weinstock, 2008), is nothing more than the *transition from an industrial towards a digital architecture*, in which digital technologies have become the fundamental tools of an architectural production, and conception, driven by the efficient exploitation of nature. Therefore, the romantic view of nature has been overridden by a *materialist* approach in which material processes embedded in digital form-finding, sidesteps any transcendental apparatus to validate architectural design — a fact which updates Tafuri's (1976) idea of the dissolution of architectural ideology under capitalist development.
The introduction of digital technologies into architectural production implies a new conception of 'materiality' that arises from the use of information as a 'raw material' in design and construction processes. But above all, the *new materiality* implies a different

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relation with nature which comes from abstracting intrinsic material properties and natural phenomena as design inputs. In other words, an extended materiality based on the potential of digital technologies to encode nature's behaviour into algorithms that are employed as *processing* material in computational design processes. Consequently, the conception of nature — through computers — ignores its mystical character, as it turns it into an *operative* model that shifts the interest from its *beauty* towards the efficiency of its morphogenetic and adaptive processes. Nature's transcendental aura is gone; the matter is to *instrumentalise* it, in order to sustain human life without losing a welfare state that industrialized societies are not willing to reduce.

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