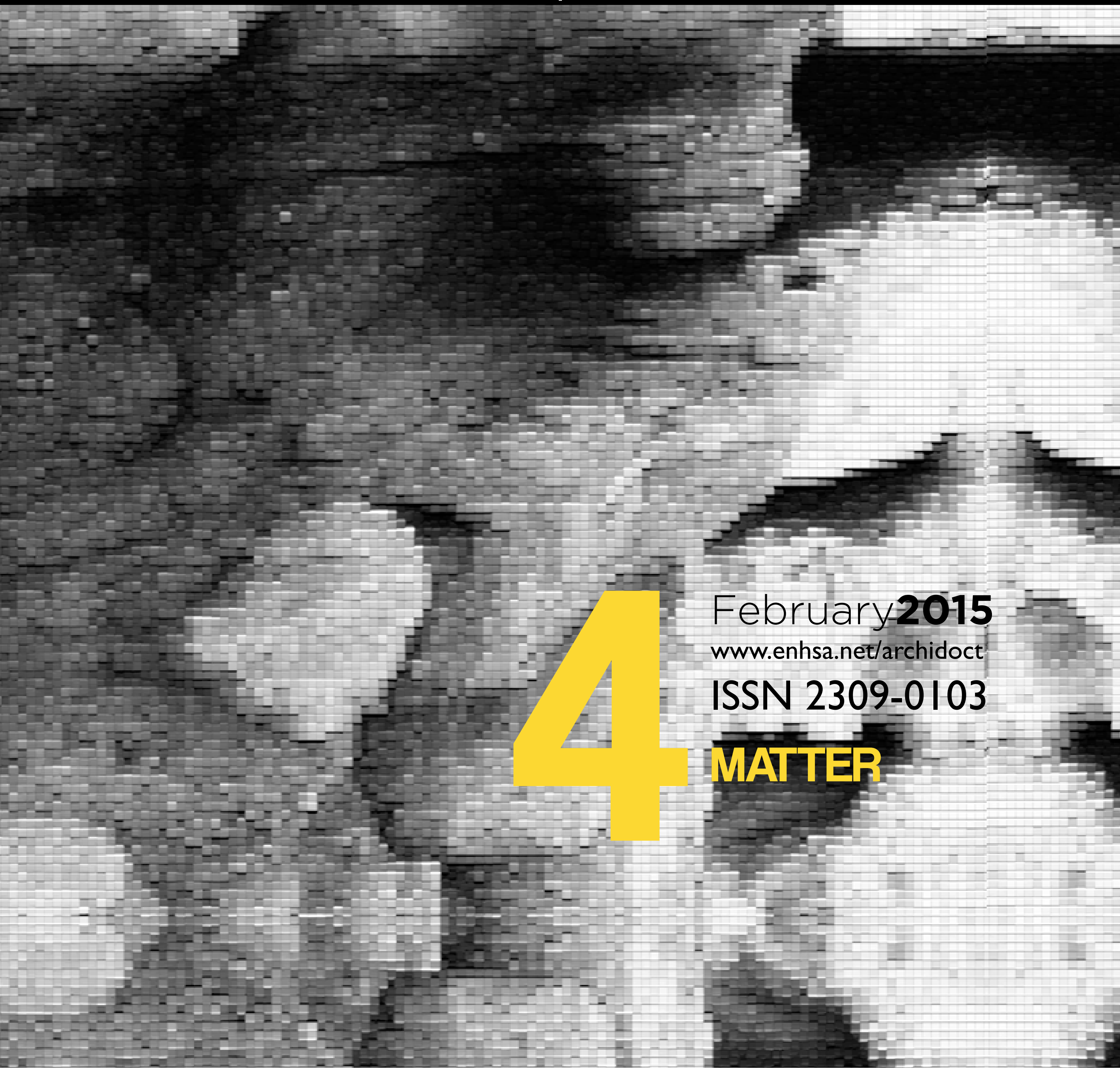
archi | DOCT

The e-journal for the dissemination of doctoral research in architecture.

Supported by the ENHSA Network | *Fueled by the* ENHSA Observatory



4

February **2015**

www.enhsa.net/archidoct

ISSN 2309-0103

MATTER

Lifelong Learning Programme

european network enhsa of heads of schools of architecture

European Observatory of Doctoral Research in Architecture

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

archi DOCT

The e-journal for the dissemination of doctoral research in architecture.

Editors of the current issue: Maria Voyatzaki, Antonios Moras

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Editorial Board // 3

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Scientific Committee //

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Scientific Committee //

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Editorial

Maria Voyatzaki and Antonios Moras

What is the position of matter in contemporary architecture? Does it have a morphogenetic power, revived and revisited, with the now ubiquitous involvement of digital technologies in contemporary design and fabrication? Is there an omnipresent shift from mute material to mutant matter? Is there increasing awareness, exchanging knowledge, thinking differently, on matter through transdisciplinary research? Is the role of matter in contemporary design processes reconsidered as a whole?

Should we not be concerned about the lost link between materiality with aesthetics, thinking, ethics and politics? Should we not register that this loss has triggered a renowned interest in materiality that spans from philosophy to architectural experimentation; from neomaterialism and eliminative materialism to material systems and the perception of the material as a morphogenetic agent in architectural design?

Why is contemporary contemplation focusing on reconnecting making alongside sensing and thinking with their material base in a post-human society? How can materiality and materialism be reconfigured in the rich and multifaceted context of contemporary computational architecture, and in the systemic context of pervasive computer simulations? How can this context nourish integration, build bridges, break barriers, alleviate fragmentation and clustering and above all nourish, foster, promote and advance relevant innovation, while paying attention to the most important social challenges we are facing regarding the deep impact of technological changes?

Contemporary architecture is appreciated as a creative process, which no longer imposes form to material as subordinate to architect's ideas but is conceived as part of a dynamical process in which non-hierarchical assemblages of natural agents interact sympathetically for form to emerge. The qualities of this emerged architectural forms are no longer judged upon their scenographic appearance as a meaningful performance but upon their performativity, at times as structural efficiency (in)formatted through a bottom up process of material formation.

Architectural creations increasingly disentangle from their consideration as tangible, finished, offered to the senses, as objects. On the contrary they tend to be conceived as part of a bigger whole, a broader assemblage of other entities, an alterity. Have we definitely moved from form-finding to form making, from archetypes to prototypes, from the identical and repetitive to the non-standard and variable, from the top down to the bottom up, from form to formation, from meaning to performativity, from symbols to material expression, from the architect author to the architect interactor? Should we not move even further, away from a possibly naïve perception of architectural creation as an emergence of a morphogenetic process and shift into a critical, (non necessarily human), alien dynamic decision-making processes and orientation selections?

The shift from sameness to similarity and from the identical to the variable, the glorification of differentiation as a core value of our times, has been reflected in building architecture in the capacities of mass customisation which enhances individualism and the individual in the

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

way it has been perceived by contemporary philosophers not as a rational being to decide, but as an affective individual in a broader system that in a process of deciding is led to other decisions; a stance that negates Albertian distinctions among designers and makers and ultimately folds them into one being, doing both in real time. The trajectory of the Materiality of Architecture can be followed on the schema: from the craftsman of the one off, to the mass produced, to the mass customized, to mass sourcing, accessible to all. The process of instantiation, that is the conversion of the digital script into a physical object, may then be severed in space and time from the making and the makers of the original file. The author of all has not died, but has become the author of the archetype, alongside other authors that take over in the journeys of time. As a consequence, the author of the original script may not be the only author of the end product, and may not determine all the final features to it, as there is no one end product in the first place. Hence the architect is no longer a sole decision maker, but part of an assemblage in an ongoing and endless process of imperceptible decisions that lead to new ones. To customise is not only a physical necessity, but also an ideological one; to be different and to assert for difference. Of course there are polemics as to the cost of customization especially in times of crises, but how can we work on the ethos of being diverse, variable and differentiated without being taxed?

This issue of e-archidoct comprises the views of five researchers, in a perpetual reinstating of the position of matter and materiality in contemporary architecture, who suggest that we have to be continuous and sympathetic interactors where beauty is the precondition of the building and not the other way around.

Ioannis Paterakis traces the common ground and mutual infiltrations between Information Technology and Architectural Design. He attempts a consideration of systems analysis and design as a fundamental Architecture discipline by suggesting another perception of consistency founded on the notion of Texture.

David Abondano addresses the conceptions of 'materiality' and 'nature' in digital architecture, through a dialectical discourse with modern architecture aiming to trace misconceptions and discern dilemmas that result from the shift in architecture caused by the effervescent technological progress.

Dimitris Gourdoukis examines whether digital fabrication protocols, in a protocol-mediated fashion, can oppose Alberti's concept of the architect and offer a possibility to place importance on concepts like craftsmanship that root in pre-modern practices.

Anders Kruse Aagaard, similarly, uses digital fabrication tools to discuss the emerging exchange between digital architectural drawing and the process of materialization. The essay suggests an approach where an overlapping of virtuality and the tangible material output from digital fabrication machines could connect the reality of materials to an exploring process.

Finally, Stig Anton Nielsen examines how the idea of the algorithm could provide an alternative to making predictions in unstructured environments. The essay focuses on possible applications for this new tool, debates the paradox of prediction and proposes improvements to the computational system.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Table of Contents

A Good Practice Example

Essays

Contributors

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Hacking architectural materiality towards a more agile architecture

Maria Voyatzaki // Faculty of Architecture // Aristotle University of Thessaloniki

Abstract

It is a condition of architecture to constitute a statement, -a strong, meaningful cultural statement. As statement requesting the 'other', the better, more appropriate and expected, architecture cannot help rejecting the existing or established. This very profound revolutionary nature of architecture is accountable for its agility. Agility in architecture is always historically relevant as well as relative. From Vitruvian times, right through to modernism and later postmodernism, architecture, with a relative time lapse, has been steadily and latently agile in its own right. Agile in its obligation to move rapidly towards the new and different as prescribed by society's demand and commitment to change and progress.

It is only in the recent past that the agility of architecture began acquiring (a different shade and pace, becoming bolder, omnipresent, ubiquitous and faster. Agility can be perceived not only as an effect, an obligation or a commitment of architecture to its human, social, political and ethical dimensions, but also in terms of its increasingly more vivid, more evident, more affective and faster attributes. This new demand for agility stems from not only the speed of changes occurring in all spheres of our daily social, political and economic life. It is also dictated by a new conception of architectural materiality as it is now emerging through computational and advanced digital technologies. The creation of architectural form is now conceived as the result of the 'genetic process' dictated by the implementation of computation upon the formation of matter. It is the new role of the material aspect of architecture in morphogenetic processes that accelerates and reinforces the agility of architecture as a whole. The present essay argues that in IT- driven architecture, agility is a modus operandi; it is an affect, a preoccupation, an objective throughout the genesis of form through the exploration of materiality. Agility has become a mission of architecture itself. It has become a value, a meaningful objective to be achieved, an expected goal to be attained and, as such, a driving force in the way we think, design and fabricate architecture itself to be more agile.

Keywords

Design Agility; Pregnant Matter; Digital Fabrication; Hacking; Hacked Materiality

Note

This paper was previously published in: "Agile Design, Advanced architectural cultures", Tellios, A. (ed.), Cannot Not Design Publications, Thessaloniki, 2014, ISBN 978-960-886-109-1, pp. 15-22.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Agility

Whilst at first glance the word agility echoes its English French (agilité) or even its Latin origin (agilitas=activity, quickness), in a more thorough investigation its Proto-Indo_European ag root derives from the Greek agra, agein, axios and Latin agere / ambactus. The Greek word agein (άγω) on the other hand comes to mean the verb to guide, to lead, to move. It is interesting to note however that from its contemporary French connection and the verb agir (=act) that come from the Latin equivalent (agere=drive, urge, conduct)) agility could come to mean the action of moving fast towards a given stimulus. Another connection that will prove useful in the development of this essay is that of the verbs act and react, that are associated with physics and chemistry, both of which are necessary to grasp certain aspects of the material existence of contemporary artifacts.

Agility and architecture

Architecture in its perpetual effort to reflect the zeitgeist or spirit of the time by means of transcribing values and ideas into built form is obliged to be agile, to move quickly towards the new and changing, thus differing from what it was. Through agile architecture, one appreciates the sensitive, reflective, adaptive, flexible and alert act of transition in its formation.

Despite its inherent mobile capacity, architecture, as an entity, has also always been stable both physically and metaphorically (just like a tree, with its root and shoot system -crown and trunk). The root system is deeply founded and hidden in the earth whereas the shoot system is what grows above ground level[1] with(deep, heavy, strong, rigid, old hidden roots forming the root system and with fresh, airy, light, vulnerable, young branches, leaves and buds forming the shoot system. It is interesting to observe the connotations of each of the two systems in architecture. On the one hand, the roots –its history, tradition, values and derivations- are there to hold the tree intact in place and time, nurture it, filter the bad, benefit from the good and maintain its support and growth. On the other hand, the crown –its growth and relation to the new world, reaching outward and forward looking-benefiting from the sun and fresh air, while simultaneously, vulnerably exposed to the elements. Historically speaking, architecture with a seemingly paradoxical, binary opposed nature of motion and stability can alternate between both, but in a sequence (Similarly, it can be immaterially founded on ideas, values and material through its physical presence, rendering architecture conceptual and materialisable). Any isolation of the materiality of architecture from its conceptual references is utterly dismissive. What has rendered architecture stable and agile, material and immaterial, conceptual and materialist at the same time?

1. http://www.phschool.com/science/biology_place/biocoach/plants/basic.html

Agility, Architecture and Materiality

'..matter should not be used merely to suit the purpose of the artist, it must not be subjected to a preconceived idea and a preconceived form. Matter itself must suggest subject and form; both must come from within matter and not be forced upon it from without.'

C. Brancuzi[2]

2. As quoted in Bach, F., T., (1995)

The characteristic of the so-called conceptual architectural paradigms of the pre-computational times is that the designer imposes materiality; in other words, the appropriate

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

putational times is that the designer imposes materiality; in other words, the appropriate material is chosen on the premise that it can best serve to materialise the envisaged form. The designer has firstly conceived a form and comes to test its materialization through appropriate materials. Architecture observes the change and adapts to its context.

The shift that has altered this perception radically, more than ever before, is that in computational times the genesis of form is understood as yet another natural and biological process. Any artifact and, consequently, any architectural creation is now conceived as another material entity, as part of nature. Architecture is now attempting to be part of the Cosmos. And it is its materiality that comes to offer its ultimate morphogenetic power. Nature is now defined as the materiality of the universe.

According to this new vision, matter is conceived as a dynamic system with capacities and properties. These capacities and properties are considered as the fundamental agents of architectural creation, the dynamic interaction, which with other agents can have a decisive contribution to the generation of form. Matter as a non-linear, dynamic system in its interaction with other agents and small changes can cause great effects. According to Manuel Delanda (Delanda, 2009) a material as yet another complex, dynamic system actively organises itself into new structures and forms. Material performance comes from the complex dynamic behaviour of the components of a material that attribute to it emergent properties. Delanda points out that the expressivity of material is a "capacity of matter to express itself in many ways, from the simple emission of information to the deliberate use of melody and rhythm" (Delanda, 2009) . It is a conception of an agile materiality.

Appreciating how this materiality generates form becomes a challenge for contemporary architectural experimentation. Understanding through the appreciation of form generating mechanisms of reproduction, evolution and development not through physics but through the chemistry of proteins in generating, preserving and evolving life. Life is agile. The generating mechanisms of reproduction, development and evolution are extremely agile. This is why agility becomes a value to be assured, an objective to be achieved.

Agility, Architecture, Materiality and Computation

'We are beginning to recover from a certain philosophical respect for the inherent morphogenetic potential of all materials. And we may now be in a position to think about the origin of form and structure, not as something imposed from the outside on an inert matter, not as a hierarchical command from above as in an assembly line, but as something that may come from within materials, a form that we tease out of those materials as we allow them to have their say in the structures we create. '

(Delanda, 2004)

In the notional framework of computational times, agility is strongly related to the virtual. Virtual is a key word in understanding the ethos underlying this new condition. According to neo-materialist philosophers, the virtual is a potential state, a state of agility, which could become actual. In contrasting the virtual with the actual, but not real, it appears as something, which though not real, displays the full qualities of it, and for this

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

the real, the virtual is embedded into it in the form of seamless boundaries. As the artefact (artificial) is now conceived as virtually alive (natural) -not following the image of the alive or according to its functionality or its expressive ability- and in this new condition of virtuality, the alive is no longer a reference, but a body embedded into the artificial and inseparable part of this new hybrid condition (Oosterhuis, 2002: p. 161), which is creating a new species resulting from the availability of the advanced digital means and this new vision of reality.
Expressivity as a capacity not only of form, as suggested in the pre-computational design approach, but also of matter, appears as a legitimising mechanism that shifts the focus of interest to the materiality of form as a morphogenetic agent. Thus, computation can allow the designer to have low access to the properties of the material by changing parameters through simulations in order to appreciate the affordances of a system.
It is interesting to note that dealing with materiality in computational design is adherent to the development of digital fabrication. An essential trait of digital fabrication is that it has changed the perception of building production, which has been traditionally autonomous with implications in labor division and specialist role attributions. Digital fabrication attempts a dynamic and agile involvement in the process of generating form at two different and parallel levels. The first is that it can provide speedy, rectifying feedback in the manufacturing process, which reactivates a new loop in the design process. This can occur as: (a) the immediate correcting of mistake(s), b) an obligation to reassess in a short time some parameters that have been over or underestimated or even omitted in the form generation process, and c) new emergent ideas that came out of the manufacturing process. At a second level, digital fabrication attempts to delve into the design process undertaking, to a greater or lesser extent, a small or a large part of it. In this case, digital fabrication is not an a-posteriori indication of a transformation, but the active participation in the morphogenetic process.
In contrast to the past where, as previously mentioned, the designer imposed materiality to a preconceived form, and was, therefore, not in partnership with natural morphogenesis, computation assures an exploration of materiality both as genesis and fabrication of architectural form, as well as exploration of matter as such. Change happens in real time, simultaneously and rapidly, in an agile manner. Based on the fact that any material has expressive and morphogenetic powers, makers do not let it form in its predictable natural formations but work with it and tease out of the material its full repertoire of capacities, forcing it to do what they want[3]: Designer/makers and harnessed material meet half way and work in a partnership; On the one hand, designers can compute[4] in an analogue way trying to optimize problems, just the way Antonio Gaudi and Frei Otto did. On the other hand, the material does its minimization process while, on the other hand, designers do their constraining process[5].

Agility, Architecture, Materiality,Computation and Hacking

Materiality is at the core of experimentation in Architecture nowadays. The use of computation to deal with the complexity of form generation, the implementation of algorithms to simulate and reproduce patterns of evolution and the consideration of new parameters related to the broader environment of morphogenetic process render materiality the core investigation on the agility of architectural creations. The agility of architecture assured by the computation on its materiality can be ultimately augmented and further accelerated by hacking this computation.

3. It is interesting to observe that respect for and harnessing of material was an innate part of the work of craftsmen of the 19th century. Class arrogance toward craftsmen, however, dates back to ancient Greece where society would undermine their preoccupation to harness material by manipulating it with fire, as opposed to engaging in the art of developing theories to harness material by manipulating it with fire, as opposed to engaging in the art of developing theories and philosophy in the Agora (the market place). Meanwhile, Deleuze and Guattari make the distinction between royal and minor sciences by associating the former with the exercise of power, and by praising the latter for becoming the source of philosophical intuition. The work of minor scientists revealed the open-ended repertoire of capacities of the material world around us. Nature, through its materiality, can be inventive, creative and divergent. In: Delanda, M. (2004), Material Complexity, In: Digital Tectonics, Leach, N., Trunbull, D. and Williams, C. (eds), Willey Academy, London, pp. 14-21
4. To compute does not necessarily mean to use the computer to calculate. Origin early 17th cent.: from French computer or Latin computare, from com- 'together' + putare 'to settle (an account).'
5.Any material as a dynamic system can offer elegant and optimized formation if left to form itself. On the other hand, designers try to adjust to the form envisaged a formation that meets half-way between a desired form and that which the material would wish to form. Take for example a soap bubble which would form in a sphere. Frei Otto used soap liquid to simulate a topological surface of a saddle shape by forcing the soap to 'inhabit' the boundary condition of the saddle shape.
6. It's not necessarily high tech. It has to do

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

In his book "The Hacker Ethic: and the Spirit of the Information Age" Pekka Himmanen offers insights into the life, values, operations and traits of a hacker, clarifying from the start that hackerism is a life style and does not necessarily concern those that work on information technology exclusively. In fact, he argues that the same attitude (of hacking) can be found in a number of other walks of life -among artisans and the 'information professionals'. From managers and engineers to media workers and designers. ….'You can be a hacker carpenter'[6] he claims.
On this premise the communalities that can be identified between the world of hackers and that of designer-makers that work with the logics of form generation in nature are that: 1. They are both passionate and enthusiastic about what they do. 2. They both live in and deal with the intertwined worlds of material and immaterial, programme and information, virtual and actual. 3. Despite the fact that through hacking they try to bifurcate towards innovation they refuse to serve the ruling class through patenting and copyrighting their fresh ideas. They are an open source of information sharing but not patent protected. 4. On the contrary they live as part of, and contribute with their work, to the evolution of a broader open source network. They are enthusiastic programmers who are after abstraction and not after money making. 5. They see innovation as a political act with social responsibility and they support innovation that comes from individuals and not from the ruling class that controls forms of production. 6. They share a similar view of nature. The computational architect is a population thinker and not a typologist[7]. Above all they code and decode life not necessarily in this sequence, which is what architects need to do.

A Building Agility and Agile Building

There can be observed five types of materiality which, through their hacking, the agility of architecture can be enhanced. Materiality can be hacked by:
1.Plugged-in materiality in computational architecture:
The use of anisotropic, Agile Matter: stretching limits, capacities and properties of existing materials
2.The exploitation of Agile dynamic, real-time Fabrication
3.Creating machines to fabricate materiality:
The exploitation of Agile dynamic, real-time Fabrication
4.The literary use of agility through the design of adaptive buildings through phase or shape changing materials and/or form, positioning of construction components (sun protection systems, control of the degree of porosity and pixellisation of building envelopes…) that is of a more technical preoccupation and therefore irrelevant to the content of this essay [8].

1. Plugged-in materiality in computational architecture:
The use of anisotropic, Agile Matter: stretching limits, capacities and properties of existing materials.
This approach can integrate material by intervening and 'customising' some of its properties. Still at experimental stage, some of the material properties can act as another parameter in a software. Plug-ins are form-finding, structural-design biased and can introduce the variable density of a material depending on its location and role in the structure. D'Arcy Thomson's (Thomson, 1961) work analyzes the variable composition of bone structures depending on their role of undergoing certain loads and distortions.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

work of Achim Menges[9] focuses to a great extent, on the correlation between structural performance and materials.

The material is not used with its given physical or biological properties. Material is born out of the interrelation of the properties of its units (voxels) and the environment. The material units involve qualitative parameters, data which determine their behaviour, their morphologies and their assembling. It is a controlled auto-genesis, a dynamic which integrates Geometry, material and energy. Fabrication becomes energetic and works morphogenetically real time, being defined as an aggregation of any materials, physical or biological. By appreciating the logics of cellular automata, voronoi diagrams and other mechanisms, materiality can be designed and based on the computation of an agent-based materiality. Structure and matter are bound in colonies that progress from generation to generation. Through evolution, it is possible to change the quantitative, qualitative and traditional parameters of an architectural program, but maintain the same rules of generation. Hacking has a role to play. For example, hacking in the variation of the structural capacity of a component has implications on the degree of freedom for formal variations based on the fact that form and structure coincide.

Neri Oxman's work[10] developed the theory and practice of material-based design computation. In this approach, the shaping of material structure is conceived as a novel form of computation. Some of the work involves creating entities synthetically by the incorporation of physical parameters into digital form-generation protocols. Projects combine structural, environmental, and corporeal performance by adapting thickness, pattern density, stiffness, flexibility and translucency to load, curvature, and skin-pressured areas.

2. The exploitation of Agile dynamic, real-time Fabrication

This approach works on the emergent properties of certain materials that derive from experimenting with fabrication machines that manipulate them. Mette Ramsgaard Thomsen's (Thomsen, 2011) work is about transcending the formal properties of materials through the use of fabrication techniques and by customising the machines to offer materials with new capacities. The transformations of materials that have been elaborated through digital fabrication offer new perspectives in their use as revised, emergent and afresh.

Hacking the natural properties of materials by harnessing and 'stretching' their known properties with new processes of pleating, weaving and folding, happening at once or simultaneously, offer new possibilities that not only systematically control variation, but fundamentally change the performative understanding of materials. Here work focuses on algorithms that will describe and calculate materials with regard to their employment. For example, the variations of the pervasive surface condition are the ornaments that depend on the levels of pixellisation through perforation that determine the grain of the surface material (Thomsen, 2011: 138-158).

3. Creating machines to fabricate materiality:

The exploitation of Agile dynamic, real-time Fabrication

Research focuses on developing tools, improving machine time and speed of tooling towards greater tool efficiency. Nevertheless, that would still not necessarily involve matter in the evolutionary process of generating form. However, Robert Aish[11], given his bias as software developer, suggests that the creativity and experimentation of the designer should go as far as to interact and develop the machine in order to define the relationship between the computational abstraction and the design intent. He argues that tools have to be creative, intelligent and customizable. Tools have to embody conceptual knowledge and

with craftsmanship and caring about what you are doing.

7. p.58 Intensive Science….Delanda, For the typologist the type (eidos) is real and the variation an illusion, while for the populationist, the type (the average) is an abstraction and only the variation is real. No two ways of looking at nature could be more different.

8. This approach deploys computational materiality which, unlike what we have discussed so far, sees the building as part of the agile system from its conception to its materiality and performance. Interactive and adaptive buildings are agile by their nature. Chuck Hoberman, Michael Fox, Robert Kronenburg. Peter Cook (http://www.youtube.com/watch?v=HoICIJVL-BWE) and Frei Otto with their known biases belonged to the group of pioneers that talked about adaptive architecture.

9. http://www.achim-menges.net/?cat=236

10. http://web.media.mit.edu/~neri/site/

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

challenge the designers as much as the designer challenges them.

In their fairly recent essay 'Factory @ Home: The Emerging Economy of Personal Fabrication', Hod Lipson and Melba Kurman supported by Andrew Dermont[12] suggest that owning a personal fabricator is the way forward towards all-inclusively cheaper customised and personalised objects This concept is based on hacking and programming small-scale machines known as fabbers. Matthias Kohler and Fabio Gramazio[13] have been pioneers in developing a unique digital craft through the systematic use of medium-sized robots. Hacking takes place by designing the construction trajectory so that brick laying acquires new non-standard formations.

Along the lines of interacting, developing and ultimately devising a tool, Marta Malé-Alemany's work is experimental, based on trial and error. Small-scale robots are designing the trajectory, introducing parameters that can affect and be affected by the fabricated structure that will emerge. Namely, the design of a robot trajectory, to drop acid on a polyurethane panel offers different degrees of porosity, transparency and tactile qualities of material. Marta Malé-Alemany[14] also experiments with phase changing materials such as wax used as a 3D printing material, which is injected through a nozzle, as another example of active fabrication. The wax solidifies in cold water. The formal proposition of these experiments is assessed and the composition of the material changes through reinforcement to offer new formal possibilities with different structural capacity. Work develops not only on changing the composition of material that gives away its emergent properties but on hacking a CNC milling machine by replacing its drill with a home-made deposition nozzle. Matthias Kohler and Fabio Gramazio similarly experiment with robots that by designing algorithmically their paths, they can 'arrange' active foam to create acoustic panels. Finally, Italian engineer, Enrico Dini's[15] works on large scale (6-meter stroke of the printing head) colossal stereolithography from CAD (-CAE-CAM) drawings to 3D objects Z-Corp 3D printing machine sandstone buildings with no human intervention in the construction, thus offering new perspectives in the construction industry.

Informing Materiality and Agile Architecture

"In "Regarding Economy' Adolf Loss argued that the "the old love of ornament" should be replaced by a love of material. In proposing materiality to replace ornamentation, he was advocating the exposure of "inherent qualities" of materials, which has remained an enduring, at times nostalgic, approach towards materiality in architecture. This correlation overlooks Loos's deeper argument of societal values and taste toward materiality, which must therefore be constantly reevaluated and questioned."

Gail Peter Borden and Michael Meredith[16]

The contemporary exploration, questioning and reevaluation of architectural materiality is directed by a new value of architectural creations, which is that of agility. Agility is no longer just a condition or a property of the materiality of the artifact but a value- an objective to be assured, a goal to be fulfilled. The exploration of possibilities to assure agility is unlike the insular research pursuits of an acclaimed transdisciplinary area of digital design where form-generating techniques, study of advanced geometry, development of robots and laboratory experiments on new materials are undertaken. Rather it is an exploration of natural processes that enable us to arrive at a design. By following processes that generate form in nature, processes of morphing in architecture can be generated.

publications/publications.html

11. Aish, R. (2011) Foreword, In: Glynn, R. and Sheil, B. (eds) Fabricate, Riverside Architectural Press, London Architectural Press, London

12.http://web.mae.cornell.edu/lipson/FactoryAtHome.pdf

13. Gramazio, F, and Kohle, M. (2008), Digital Materiality in Architecture, Lars Mueller Publishers, Zurich

14. Malé-Alemany, M. (2010) Machinic Control. Design Experiments with Customised CNC Machines, In. Voyatzaki, M. (ed.) The Design and Fabrication of Innovative Forms in a Continuum, Charis Ltd, Thessaloniki

15. http://www.d-shape.com/d_shape_presentation.pdf. D-Shape

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

16. Gail Peter Borden, Michael Meredith: Matter: Material Processes in Architecture, Introduction

17. "…..genuine creative novelty is not about emulating stylistic trends … instead it is the irruption into the normative sphere of architecture something that touches on the condition of truth :: generic fidelity to the infinite … / … now tell me: which digital architect is concerned with opening up the path for creative novelty that is in tension with generic truth instead of fetishizing the technical and the stylistic … ?" Karl Chu in his facebook page

Architecture in its effort to pursue agility is offered a great opportunity to flourish through the exploration of its materiality through hacking. Hacking the materiality of architecture can render architecture agile. This hacking of architecture speeds up its agility, gives it an active and dynamic role, unlike in the past where its vocation was to latently reflect with a time lapse.

Agile is the architectural act of moving fast towards a given stimulus. The verbs act and react, in connection to the ultimate degree of agility in architecture through hacking its materiality is exactly about the relationship of affect and effect, of influencing and being influenced. It is about the dynamic relationship between the seemingly opinionated designer-maker and the uncompromising matter that in computational design and fabrication loosen up and meet half way through in a reciprocal, giving relationship of mutual respect of one another's dynamism towards a more agile architecture.

As Karl Chu states in his facebook: 'genuine creative novelty is not about emulating stylistic trends … instead it is the irruption into the normative sphere of architecture something that touches on the condition of truth: generic fidelity to the infinite … '. As he explains to use readymade software or even to use readymade scripts will produce architecture of a debatable and parochial style and technical accomplishment. If architecture is about novelty that it can find through hacking. Computation can transcend itself through hacking. Hacking the materiality of architecture is yet another 'irruption into the normative sphere of architecture something that touches on the condition of truth"[17]. Architecture, through this hacking, is there to stimulate, generate and sprawl ideas in order to provoke, stimulate, challenge and revolutionize contemporary societies. In-forming materiality becomes progressively an essential part of the design process and the core of contemporary design thinking, guided by the will and wish for a more agile architecture.

References

Aish, R. (2011). Foreword. In: Glynn, R. & Sheil, B. eds. (2011). Fabricate: Mak- ing

Borden, G. & Meredith, M. (2012). In- troduction: Foreign Matter. In: Borden, G. & Meredith, M. eds. (2012). Matter: Material Processes in Architecture. Oxon & New York: Routledge, pp 1–4.

D-shape (2013). D-shape. [online] Retrieved from: http://www.d-shape.com/d_shape_presentation.pdf [Accessed: 8 July 2013].

Digital Architecture. Cambridge, ONT.: Riverside Architectural Press.

Bach, F., Rowell, M. & Temkin, A. (1995). Constantin Brancusi, 1876 – 1957. Philadelphia, Pa.: Philadel- phia Museum of Art.

DeLanda, M. (2004). Material Complexity. In: Leach, N., Trunbull, D. & Wil- liams, C. eds. (2004). Digital Tectonics. London: Willey Academy, pp 14–21.

Gramazio, F. & Kohle, M. (2008). Digital Materiality in Architecture. Zurich: Lars Müller Publishers.

Lipson, H., & Kurman, M. (2010). Fac- tory at home: The emerging economy of personal manufacturing. Retrieved from http://www.maglab.fr/wp-content/uploads/2011/09/FactoryAtHome. pdf

Malé-Alemany, M. (2009). Machinic Control: Design Experiments with Customised

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

CNC Machines. In: Voyatzaki, M. ed. (2010) The Design and Fabrication of Innovative Forms in a Continuum. Thessaloniki: Charis Ltd.

Menges, A. (2013). Achim Menges Design Research Architecture Product Design. [online] Retrieved from: http:// www.achimmenges.net/?cat=236 [Accessed: 8 July 2013].

Phschool.com (2013). Plant Struc- ture: Basic Plant Structure. [online] Retrieved from: http://www.phschool. com/science/biology_place/biocoach/ plants/basic.html [Accessed: 6 July 2013].

Thomsen, M. (2011). Computing the Real: Time, Scale and Material. Copen- hagen: Royal Danish Academy of Fine Arts, School of Architecture.

Thompson, D. & Bonner, J. (1961). On growth and form. Cambridge: Cambridge University Press.

Web.media.mit.edu (2013). Publica- tions. [online] Retrieved from: http:// web.media.mit.edu/~neri/site/publications/publications.html [Accessed: 8 July 2013].

Woods, L. (2013). Manuel De-Landa: Material Expressivity. [online] Retrieved from: http://lebbeuswoods.wordpress.com/2009/01/05/manuel-delanda-matters-4/ [Accessed: 6 July 2013].

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Structures vs Textures: challenging the hegemony of geometrical consistency

Manolis Paterakis // Faculty of Architecture // National Technical University of Athens

Abstract

In a context where standard methodologies of Information Technology – such as algorithmic analysis, data management and visualization – have infiltrated into common practices of Architectural Design, there is a substantial claim that these two faculties of knowledge share a field for a common theoretical approach. Along this direction, this paper attempts a consideration of systems analysis and design as a fundamental Architecture discipline through established computational concepts, such as the object-vs-process duality. Thus, in view of the transformations induced on architectonic thinking by the integration of algorithmic and computational methodologies, it is suggested that our view of Architectural systems as arrangements of entities and objects must evolve, encompassing temporal qualities such as duration and transformation. Primarily, this research starts off from the very notion of Structure as a conception of consistency, its close association to the legacy of diagrammatic reasoning and its formalization as Object-oriented modeling in the computational domain. Structural perception of systems, as the backbone principle of architectonic analysis, is an inherent aspect of geometric inference and spatial intuition. However, as Henri Bergson has suggested, it fails to grasp Time as an affective quality instead of a differential quantity, and restricts perception of dynamic, evolving systems, such genetic and biomimetic formations, to static apprehensions frozen at arbitrary states. Thus, another perception of consistency is suggested, opposite to that of Structure, founded on the notions of Time and Duration as primitive intuitions; the concept of Texture.

Keywords

Entity; Object-oriented; Structure; Geometry; Texture; Duration; Computation

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Ever since Architecture was detached from its artisanal grassroots and adopted a more authorial creative role[1], the notion of *Structure* has become one of the most fundamental topics of architectural thinking. And although structural design may be considered a synonym for engineering and load distribution analysis, the modern concept of Structure as the *architectural perception of consistency in a system of discrete units* has been introduced into many faculties of knowledge as a transdisciplinary principle. The most prominent example of all, the domain of Information Technology, has adopted the term *architecture* to describe the process of analysis and design of a system; object-oriented modeling principles regard systems and networks as diagrammatic aggregations of discrete objects and components; *spatial arrangements between logical entities*. This evident focus on spatiality draws attention to the dominance of Geometry, both in the Eulerian and in the Euclidean sense, as the fundamental discipline of inference under which a system is being analyzed and designed. For the domain of a strict formal science, such as Computer Science and Mathematics of Computation, this is a relatively newfound practice; formal sciences have generally preferred *a view of inference as the manipulation of symbols according to formal rules*[2] and have traditionally rejected geometrical inference as 'subjective' and 'unscientific'. However, for the domain of Architecture, the concept of Structure that describes geometrical consistency through diagrammatic reasoning has been the backbone principle of architectural design as an intellectual practice since the Age of Euclides. This is further indicated by the extensive use of sketches, diagrams and blueprints, that regardless of their medium of transmission – either analog or digital – establish this tight association of architectural design with geometrical inference. Apparently, for many domains of knowledge that deal with the design of systems, Architecture has become the archetypal *science of Structure*.

However, the Age of Computation has introduced new instruments of creation. *Algorithm*ic and computational technologies of design and production claim an important place in the architect's toolset. Their inherent vocabularies of uninterpreted symbols, filled with programming code and mathematical formulas, leave little place for geometrical intuition. Furthermore, visual manifestations of computationally designed systems often seem inadequate to convey their constantly evolving nature; they restrict representation to still snapshots of their state. In short, the ubiquitous presence of the Algorithm, evident in almost all contemporary creative practices that deal with design and synthesis, makes it clear that the Age of Computation requires all faculties of knowledge to reformulate even their most fundamental principles into computable processes. Concerning the field of Architecture, we are left with a question; does the infusion of algorithmic logic in design mean that the dominance of diagrammatic reasoning is being undermined in favor of a more symbolic mode of inference? Furthermore, is the architectural concept of Structure as the notion of geometrical consistency between entities, being threatened by more syntactical, formalistic and less diagrammatic notions of consistency?

1. Mario Carpo focuses the humanists' invention of intellectual authorship on the Albertian Paradigm (Carpo 2011: p. 24-26, 71-79).

2. As James Franklin suggests, for the most part of 20th century the Logical Positivism intelligentsia ruled out the image as an unscientific instrument intended for the intellectual marginals: diagrammatic reasoning for the engineers and mental images for the Freudians (Franklin 2000: p.84).

Entity vs Process: an architectonic history of information systems

The reign of Cartesian rationalism established a view of the universe as a system of primitive entities, as a complex apparatus made of machines down to a level of final and discrete elements. As a direct intellectual product of newtonian mechanistic thought, the concept of the Entity[3] has been the dominant paradigm of analysis ever since; a self-contained, discrete, individual unit of information described from a finite set of properties and qualities. Thus, multiple faculties of knowledge consider systems as aggregations of entities, as articulated compositions of discrete *Objects*. In the field of Architecture, the consideration of buildings and structures as modular compositions of either primary or industrially prefabricated components has established architectural design as the archetypal example of the entity-oriented design paradigm. Under these terms, when the concept of the entity was introduced into the domain of Computer Science, during the late sixties with the emergence of object-oriented programming principles[4], it immediately shifted the interest of software development towards diagrammatic reasoning practices (such as blueprinting, prototyping, and pattern-based design) and rendered the term 'Architecture' as the primordial concept that characterized that new perspective on considering information systems. Object structures and genealogies have been the core topics of interest ever since, in several fields of Information Technology such as software design patterns, structured data-storage systems and agent-based simulation applications. Moreover, recent approaches have attempted to introduce the concepts of object-oriented modeling in domains of sociology and psychology, with the Actor-Network Theory[5] being the most prominent example of this adaptation. In short, developing formations of both Matter and Data along this entity-oriented tradition has always been a pursuit for a coherent and consistent Structure; a logical and efficient arrangement of the relations between entities and their components, translated into the spatial vocabulary of diagrams and graphs. In this context, architectural problems are abstracted into issues about entity *nature, classification* and *composition*.

3. For the purposes of this analysis and in favor of briefness, terms like 'Entity', 'Object' and 'Thing' will be considered essentially as synonyms, although there has been a lot of philosophical debate regarding their semantic differences and qualities.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

On the other hand, the recent fusion between computational technologies and design practices has introduced systems and formations that remain on a constant evolutionary progress; for example, biomimetic algorithms and particle swarms require the progression of time in order to *grow*, to evolve into a state of equilibrium. Hence, there is a shift of focus in design analysis from the forms and formations being developed towards the actual transformations they are undergoing in order to evolve. The static, mechanistic nature of entity-oriented structuring however, appears to leave out not only the prospect of a qualitative change of the system, but altogether the concept of Time considered as an affective quality, rather than a differential quantity[6]. In essence, diagrammatic inference constructs a static image of the system, where the only possible representation of evolution or transformation is through the Newtonian mechanics of motion. Thus, computational design has drawn attention to the concept of the *Process*, a term that has been extensively investigated from a computational as well as a philosophical perspective.

A 'Process' describes the execution of an algorithm, a procedure that takes arbitrary data as input and subjects them under multiple transformations to produce new information. Not all algorithms signify processes though; their purpose is usually associated with some ongoing, repeating execution of instructions that receives and produces a continuous flow of information. In that sense, evolution in a system of processes can be seen as a series of convoluted parallel flows, a continuous surface of interweaving *threads of execution* that fold and unfold progressively; in essence, a system of processes can be regarded as *deleuzian machine of a continuous flux*[7] in which the primary perspective of analysis is Time as concrete Duration. To further grasp this temporal aspect of the Process, it is necessary to consider it in a sequential manner; in fact, the essence of computation as an abstraction of evolution and transformation, lies in the concept of *Ordinality*, the principle of order and succession in which the elements of a flow, or a *generation* are laid out.

It was Georg Cantor who first, in the context of formulating his set theory, divided the nature of the natural numbers into two aspects; *cardinals and ordinals*.[8] These concepts where later applied to other faculties of knowledge, such as linguistics and computation.

4. For a brief summary of object-oriented principles see (Weisfield 2009: p.5-12).

5. For an introduction see the related wikipedia article: http://en.wikipedia.org/wiki/Actor-network_theory (last accessed: Jan 17, 2015). For a more detailed view see (Latour 2005).

6. According to Henri Bergson, "the systems science works with are, in fact, in an instantaneous present that is always being renewed; such systems are never in that real, concrete duration in which the past remains bound up with the present. When the mathematician calculates the future state of a system at the end of a time t, there is nothing to prevent him from supposing that the universe vanish-

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

es from this moment till that, and suddenly reappears. It is the t-th moment only that counts—and that will be a mere instant. What will flow on in the interval—that is to say, real time—does not count, and cannot enter into the calculation." (Bergson 1911, p.22).

7. See (Deleuze and Guattari 2004).

8. For a simplified version on Cantor's distinction see (Davis 2001: p.120-121).

The notion of Cardinality applies to numbers that describe sizes and populations; the multitude of a set as the number of its elements. In this sense, cardinality is a pure entity-oriented concept as it induces issues about nature, classification and composition; in order to specify cardinality for a set of elements, the elements themselves must be discrete, individual units; to be included or excluded from the set, each element's nature must be resolved according to the set precondition. On the other hand, the notion of Ordinality applies to numbers that describe succession; the position of each element in a series. Symmetrically, ordinality implies a focus on evolution; in the pursuit of deciding on the order of things in a sequence, we must reflect on the law that incites which elements precede and which elements follow, we must deduce the Rule of the sequence. And in reverse, having the initial order of things or knowing the Rules that conduct an evolutionary system, the principle of ordinality enables us to compute, to construct, to produce the rest of the sequence up to a virtual infinity.

One of the most signifying differences between entity-oriented and process-oriented modeling, is the legitimization of self-referentiality; *enabling definitions of a thing in terms of itself*. Self-references have always been a constant problematic issue in several domains of epistemology, such as mathematics, computer science, or even philosophy and architecture theory. From an entity-oriented perspective, a self-referential definition of an object undermines its discreteness and induces paradoxes and inconsistencies in an object-oriented system. In traditional predicate logic, as well as in Axiomatic systems (such as Euclidean Geometry) self-reference is a synonym to paradox, inconsistency and falsity. The most characteristic self-reference paradox example, the Russel paradox first observed on Cantor's set theory[9], emerges when trying to classify sets that contain themselves as elements. Simply put, a discrete object that contains itself cannot be modeled or visualized by modes of reasoning based on spatial intuition, such as Geometry.

9. For this reason, sometimes the first formulation of Cantor's Set Theory is called "Simple" or "Naive". For a complete review of Russel's paradox, see the relevant wikipedia article: http://en.wikipedia.org/wiki/Russells_paradox (last accessed: Oct. 12th 2014).

10. Douglas Hofstadter includes a detailed review on recursive structures and processes. See (Holfstadter 1999: p.127-152).

On the other hand, self-referentiality in the process-oriented model is entirely inherent as it provides powerful mechanisms of Recursion[10]. The extensive application of recursive functions, that is functions that contain themselves inside the function body, is evident in all faculties of knowledge that deal with pattern recognition or its reverse counterpart; *form generation*. Most examples of form generational algorithms, currently widespread in computer graphics, visual design and architecture, are either recursive or employ some kind of self-referential iteration. Since the lambda-calculus system, formulated by Alonzo Church, and Noam Chomsky's work on syntactic structures and generative grammars, recursion has always been linked to generative systems that produce new structures from a finite set of elements. This close association of recursion with generation can be decoded if we consider a recursive process as a transformational mechanism; *the current state of the system is expressed as a modification of its previous one*. In this sense, a system evolved through multiple iterations of a recursive process contains (or in the deleuzian sense, *enfolds*) all its predecessor generations, thus *immanently accumulating duration; in essense, a recursive system transforms qualitatively rather than quantitatively*.

Structure vs Texture: a computational approach on architectural systems

Thus, a process is a thread of continuous progression. Images of branching vegetative growths, or interweaving patterns of textile threading used more frequently to visualize systems of processes are not mere metaphors employed incidentally; it is well established

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

that a significant impact on the evolution of modern computing was generated by the weaving machines of the industrial revolution. During the early 19th century, Joseph Marie Jacquard, a weaver and a merchant, invented a mechanical weaving machine that simplified the process of producing textiles, using a set of punched cards to specify the textile patterns. It was Jacquard's programmable machine that later influenced mathematician and philosopher Charles Bubbage, the grandfather of computing machines, to design the Analytical Engine, the first programmable mechanical calculator. At a later time, Ada Lovelace, Lord Byron's daughter and Bubbage's most beloved student, proposed that the Analytical Engine would *weave algebraic patterns, just as the Jacquard loom weaves flowers and leaves*[11]. However, both Bubbage and Lovelace died long before they could see their designs implemented.

11. From translator's notes in Menabrea, L.F., Sketch of the Analytical Engine Invented by Charles Babbage, Translated by Ada Augusta, Countess of Lovelace, in Scientific Memoirs, Vol 3 (1842). Available from http://www.fourmilab.ch/babbage/sketch.html (last accessed: Jan 17, 2015).

The conceptual archetype of modern computing, Alan Turing's *Tape Machine*, originally conceived to address Hilbert's *Entscheidungsproblem* (problem of decision), can be regarded in a similar manner in view of Ada Lovelace's analogy; it manipulates a thread of information symbols. Instead of folding and twisting transformations on a flow of fibrous matter, it performs replacement and expansion transformations on a stream of arbitrary atomic symbols: digits, letters and images; *a loom of data*. Under these terms, contrary to the object-oriented perception of digital culture as an aggregation of networks, process-oriented thinking shifts this perception towards an assemblage of interwoven informational threads, *a continuous Deleuzian body textile*. Instead of the Cartesian analytic paradigm of a continuous dissection into primitive entities, nodes or particles, another paradigm is suggested: that of *ordinality, serialization and Duration*. Transitioning from one paradigm of analysis to the other, induces fundamental conversions; objects and entities become procedures and processes, questions about status and being, turn into questions about *transformation and becoming; the recursive system is no longer in pursuit for a consistent Structure; it seeks to create an emergent Texture.*

Biologists use the word "hypha" from the greek word υφή ("texture"), to describe the branching structure of fungi and bacteria; a visual description of vegetative growth. It is extensively used in several creative fields where digital computational methods are applied to produce forms influenced by nature and biology. In greek, the word υφή is used both in the occasions of vegetative growth, equivalently to the word "hypha", as well as in expressing the feeling of a surface, the taste of a food or drink, or the ambient sensation produced while listening to a musical piece, occurrences where the word "texture" is applied in English. The word υφή is typically examined in contrast to the word δομή ("structure"), since the two concepts occasionally have overlapping interpretations in the Greek language. While the latter is usually applied to a logical or spatial perception of relations between entities, tightly associated with the sense of vision and consistent with the ocularcentric tradition[12] of western culture, the former, originating from the verb υφαίνω which actually means to weave, is usually linked to experiences generated by other senses, such as touch, taste and smell, and denotes the result of blending different elements into a single emergent result. The English equivalent word Texture, originating from the same semantic root of textile manufacturing and weaving, is used in similar multi-sensory contexts to describe *a complex, yet indivisible experience* accumulated progressively through the primitive temporal intuition of continuity and sequentiality.

12. For an in-depth view of Ocularcentrism and the hegemony of vision in western tradition, see (Pallasmaa 2005: p.15-19).

In order for an experience to emerge as a Texture, a concrete temporal duration is required. In contrast to the instantaneous, concurrent and uniform visual stimuli of a Structure, the tactile stimuli of touch or the chemical stimuli of taste and smell are transmitted sequentially; the hand must perform a calm, uninterrupted sliding motion on a

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

surface in order to transmit as much sequential information to the brain for the feeling of the surface texture to emerge. The receptor neurons on the tongue and mouth send continuous, consecutive stimuli to produce a variadic and evolving sensation of taste that transforms perpetually from the first foretaste into a lingering (and sometimes totally different) feeling of aftertaste[12]. *A texture-experience is therefore a process, not an event;* in contrast to structures being perceived as spatial arrangements of discrete elements, textures rely primarily on the temporal intuition of duration and are perceived as indivisible emergent experiences generated by interweaving threads of matter, sounds, chemical stimuli or digital data subjected to continuous transformations. The role of the main processing unit (e.g. the human brain) is to weave these flows into a single experience; it becomes a *loom of sensory threads*.

Along these lines, object formations in the domain of Textural perception are volatile and mutable; the static structures needed to support the computationally evolving form diminish into small ephemeral elements, symbolic atoms. In Architecture, large building structures reduce their actual structural designs into atomic modules, junctures, elementary cells subjected to the total control of the computational form; a series of *semantically arbitrary monads* upholding the continuity of the emergent Texture. Along the same process-oriented perspective, Big-Data structures in Information Technology are implemented essentially as vast, flat data pools of *unstructured information atoms*, ready to be fused into domain-specific transformational processing and ad-hoc object-ontologies. Under these circumstances, process-oriented modeling undermines the dominance of spatial intuition or sense of vision as the primary guides of analysis, and focuses on the temporal aspect of the systems designed, their rules of evolution and their mode of becoming. Visual representations of such systems, such as diagrams and images, capture only still snapshots; transient depictions of their state in arbitrary points of their evolution history.

12. The temporal aspects of the human gustatory system are a domain of constant research. For a brief summary with extended references, see (Katz 2005).

Epilogue: challenging the hegemony of geometrical consistency

This ubiquitous presence of the process-oriented modeling paradigm highlights another characteristic of the Computation Age; the inherent dynamics of the Process cannot be drafted, illustrated or sketched. Despite Bergson's critique on early 20th century mathematics about their inadequacy to grasp time and duration as concrete qualities instead of differential quantities, it is suggested that up to a certain extent, modern computational mathematics, theory of recursion and functional programming offer the potential of formalizing the notion of time as quality, both conceptually and notationally. The importance and power of this notational formalism however, as far as architects and designers are concerned, lies exactly where diagrammatic reasoning falls short; in expressing infinity, iteration and self-referentiality without compromising the consistency of the representation. Those who have worked with software packages such as Grasshopper, which involve some kind of visual programming, a replacement for writing actual code, realize that the inability of the diagrammatic representation of a process to express iteration or recursion is not because of some limitation or inadequacy of the software implementation, but, as described earlier, due to the nature of object-oriented, diagrammatic reasoning to reject self-refentiality as a foreign concept.

Naturally, this fact poses a notable competitor opposite the dominance of diagrammatic reasoning and geometric inference as the prime architectural instruments. Not in the sense that their representational function is being undermined or that they are being replaced by programming code; the tight bonds between architectural thinking and spatial

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

intuition are far too primitive to be threatened. What in this case is being challenged is the *hegemony of Geometry in the justification of the architectural form*. The main semantic operation of the diagram is identificatory, it associates a visual geometric object with an (abstract) discrete entity or concept; a distinct shape installed precisely because of its logical identicality to the idea it represents. Hence, the consistency of the diagrammatic installation is evaluated through the geometric associations of identicality between the entities that compose it. On the contrary, the existence of spatial relations in a computationally produced formation is just a secondary derivative layer of interpretation; there is no point trying to distinguish a strict underlying Structure there. The formation is not justified geometrically but syllogistically; *we can conceive the logic and consistency of a recursive system because we can distinguish the Rule that produced it.* We can conceptualize the generative process that produces a variadic geometry through the rules that conduct its evolution, without the need to justify it diagrammaticaly through its ephemeral manifestations. In the end, we can perceive it as an *indivisible emergent Texture*.

"No doubt, for greater strictness, all considerations of motion may be eliminated from mathematical processes; but the introduction of motion into the genesis of figures is nevertheless the origin of modern mathematics. We believe that if biology could ever get as close to its object as mathematics does to its own, it would become, to the physics and chemistry of organized bodies, what the mathematics of the moderns has proved to be in relation to ancient geometry. The wholly superficial displacements of masses and molecules studied in physics and chemistry would become, by relation to that inner vital movement (which is transformation and not translation) what the position of a moving object is to the movement of that object in space. [...] Such a science would be a mechanics of transformation, of which our mechanics of translation would become a particular case, a simplification, a projection on the plane of pure quantity. […] But such an integration can be no more than dreamed of; we do not pretend that the dream will ever be realized. We are only trying, by carrying a certain comparison as far as possible, to show up to what point our theory goes along with pure mechanism, and where they part company."

(Bergson, 1911: p.32-33)

Acknowledgment

This text is a revised edition of an original paper titled "Entity-oriented vs process-oriented modeling in Architectural thinking: the rise of the functional algorithm" presented in the "What's the matter: Materiality and Materialism at the Age of Computation" International Conference in Barcelona, Spain organized by the ENHSA on September 2014. Both texts are part of a work-in-progress doctoral dissertation under the supervision of Prof. Dimitris Papalexopoulos at the School of Architecture of N.T.U. of Athens.

References

Bergson H. (1911) Creative Evolution, Translated by A. Mitchell, New York: Henry Hold & Co. Full text available online from Project Gutenberg, http://www.gutenberg.org (last accessed Jan 17, 2015).

Bitsakis E. (2003) [Being and Becoming]. Athens: Daedalos 6th ed. (In Greek)

Carpo M. (2011) The alphabet and the algorithm. MIT Press, Cambridge MA.

Davis M. (2001) Engines of Logic: Mathematicians and the Origin of the Computer.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

New York: W.W. Norton & Co.

Deleuze G., Guattari F. (2004) Capitalism and Schizophrenia Vol.1: Anti-Oedipus. Trans. Robert Hurley, Mark Seem and Helen R. Lane. New York: Continuum.
Eden, A. H. (2002) A theory of object-oriented design. Information Systems Frontier 4:4, p. 379-391.

Franlin J. (2000) Diagrammatic reasoning and modelling in the imagination: the secret weapons of the Scientific Revolution. In: Freeland G., Corones A. (eds.) 1543 and All That: Image and Word, Change and Continuity in the Proto-Scientific Revolution, Dordrecht: Kluwer, p.53–115.

Hofstadter D. R. (1999) Godel, Escher, Bach: An Eternal Golden Braid. New York: Basic Books Inc.

Katz D. B. (2005) The Many Flavors of Temporal Coding in Gustatory Cortex, Chemical Sciences vol.30, No. suppl. 1, Oxford University Press. Available online from: http://chemse.oxfordjournals.org/content/30/suppl_1.toc (last accessed: Jan 18, 2015).

Latour B. (2007) Reassembling the Social: An Introduction to Actor-Network-Theory. OUP Oxford.

Leibniz G. W. (2006) [The Monadology]. Ed. Anapolitanos D., Trans. Lazarides S., Athens: Ekkremes. (In Greek)

Pallasmaa J. (2005) The Eyes of the Skin: Architecture and the Senses. Pref. S. Holl, New York: John Wiley & Sons Ltd.

Weisfield M. (2009) The object-oriented thought process. Boston: Addison-Wesley, 3rd ed.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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

David Abondano // School of Architecture La Salle

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

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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.

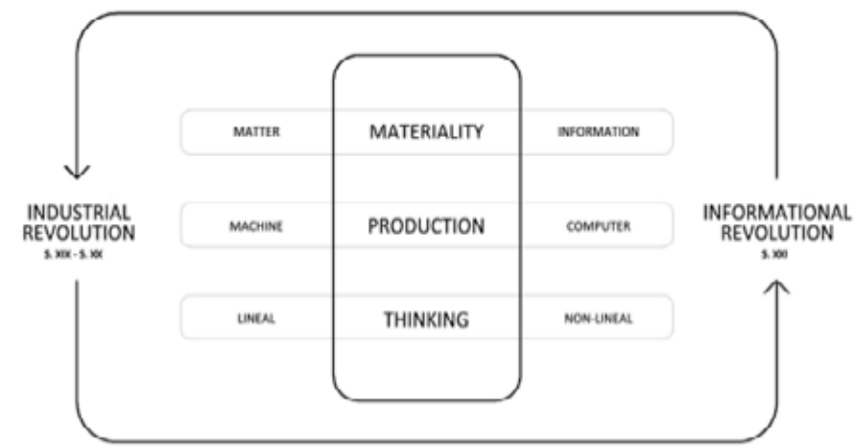


Figure 1.
Major changes brought by Technological Revolutions

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

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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', 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

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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 started 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.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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,

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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* is 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

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

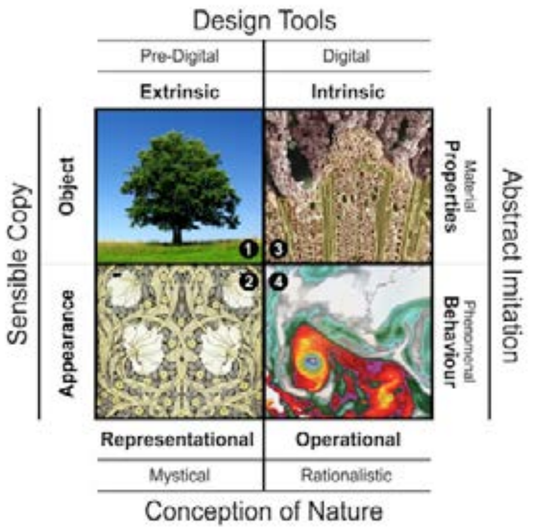


Figure 2.
Nature as Architectural Model

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.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

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.

Acknowledgements

I would like to thank my PhD thesis advisor, Dr. Leandro Madrazo, and SUR de ECO (Government of Catalonia) for supporting this research, which is part of my PhD studies (2014FI_B2 00138).

References

Alberti, L. B. (1988). On the Art of Building in Ten Books. Cambridge: MIT Press.

Allen, S. (2000). Terminal velocities: The computer in the design studio. In S. Allen, & D. Agrest, Practice: Architecture, technique and representation Critical voices in art, theory & culture. London: Routledge.

Banham, R. (1980). Theory and Design in the First Machine Age. Cambridge: MIT Press.

Baudrillard, J. (2002). Screened Out. London; New York: Verso.

Benjamin, W. (2002). The Arcades Project. New York: Belknap Press.

Berlinski, D. (2000). The advent of the Algorithm: The Idea that rules de World. Orlando: Houghton Mifflin Harcourt.

Cache, B. (2011). Projecticles. Lóndres: Architectural Association.

Carpo, M. (2009). La desaparición de los identicos: La estandatización arquitectónica en la era de la reproductibilidad digital. In, L. Ortega La digitalización toma el mando (pp. 59-65). Barcelona: Gustavo Gili.

Castells, M. (1996). The Information Age. Vol. I: The Rise of the Network Society. Oxford; Malden, Mass.: Blackwell.

De Landa, M. (2001). Philosophies of Design: The Case of Modeling Software. In ACTAR, VERB: Processing (pp. 130-143). Barcelona: Actar.

Durand. (1802). Précis des Leçons d'Architecture.

Fleischmman, M., Lienhard, J., & Menges, A. (2011). Computational Design Synthesis. Embedding Material Behaviour in Generative Computational Processes. In T. Zupancic, M. Juvancic, S. Verovsek, & A. Jutraz, Respecting Fragile Places (pp. 759-767). Ljubljana: eCAADe & UNI Ljubljana, Faculty of Architecture.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Forty, A. (1986). Objects of Desire. Design and Society since 1750. London: Thames & Hudson.

Forty, A. (2000). Words and Buildings. A vocabulary of Modern Architecture. New York: Thames & Hudson.

Jarzombek, M. (1999). Molecules, Money and Design. The Question of Sustainability's Role in Architectural Academe. Thresholds (18), 32-38.

Jones, J. C. (1992). Design Methods. London: John Wiley & Sons.

Le Corbusier. (1982). Towards a New Architecture. London: Architectural Press.

Le Corbusier. (1993). Modern decorative art is not decorated. In J. Jenger, Le Corbusier: Architect, Painter, Poet (pp. 134-137). New York: Abrams.
Lévy, P. (1998). Becoming Virtual: Reality in the Digital Age. Cambridige, MA: Da Capo Press.

Madrazo, L. (1995). The Concept of Type in Architecture. An Inquiry into the Nature of Architectural Form. Zurich: Swiss Federal Institute of Technology.

Marx, K. (1887). Capital: A Critique to Political Economy. Vol.I. Moscow: Progress Publishers.

Marx, K. (1977). Preface to A contribution to the Critique of Political Economy (1859). Moscow: Progress Publisher.

Menges, A. (Mach /April de 2012). Material Capacity: Embedded Responsiveness. Architectural Design, 52-59.

Menges, A. (March/April de 2012). Material Computation. Higer Integration in Morphogenetic Design. Architectural Design , 14-21.

Mertins, D. (2011). Modernity Unbound: Other Histories of Architectural Modernity. London: Architectural Associetion.

Moussavi, F. (2009). The Function of Form. Barcelona: Actar & Harvard University School of Design.

Mumford, L. (1974). Pentagon of Power: The Myth of the Machine, Vol.II. Harcourt, Brace Jovanovich.

Negroponte, N. (1995). Being Digital. New York: Alfred A. Knopf

Ortega y Gasset, J. (2014). Ensimismamiento y alteración. Meditación de la técnica y otros ensayos. Madrid: Alianza.

Oxman, N. (2013). Material Ecology. In R. Oxman, & R. Oxman, Theories of the Digital in Architecture (pp. 319-326). London: Routledge; Taylor and Francis.

Oxman, N. (2012). Structuring materiality. Design fabrication of heterogeneous materials. Architectural Design , 80 (4), 78-85.

Oxman, N. (2011). Variable Property Rapid Prototyping. In Virtual and Physical Prototyping (pp. 3-31). Taylor & Francis.

Oxman, N. (2010). Material-based Design Computation, PhD Thesis, MIT Press,

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Cambridge, MA.

Pask, G. (1969). The architectural relevance of cybernetics. Architectural Design , 7 (6), 494-496.

Pérez-Gómez, A. (1983). Architecture and the Crisis of Modern Science . Cambridge, London: MIT Press.

Rathenau, W. (2002). La Mecanización del Mundo. In T. Maldonado, Tecnica y Cultura (pp. 153-181). Buenos Aires: Infinito.

Raunig, G. (2008). Breve filosofía de las máquinas como movimiento social. Madrid: Tafricantes de Sueños.

Schumpeter, J. A. (2003). Capitalism, Socialism and Democracy. London; New York: Routlegde.

Tafuri, M. (1976). Architecture and Utopia. Design and Capitalist Development. Cambridge, Massachusetts, and London: MIT Press.

Terzidis, K. (2006). Algorithmic Architecture. Oxford: Elsevier.

Urprung, P. (2007). Nature and Architecture. In F. Sauter, Natural Metaphor: An Anthology of Essays on Architecture and Nature (pp. 10-21). Barcelona: Actar; Swiss Federal Institute of Technology Zurich.

Weinstock, M. (2008). Metabolism and Morphology. Architectural Design , 78 (2), 26-36.

Woodbury, R. (2010). Elements of Parametric Design. London; New York: Routledge.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Digital craftsmanship: from the arts and crafts to digital fabrication

Dimitris Gourdoukis // School of Architecture // Aristotle University of Thessaloniki

Abstract
Alberti's writings introduced a new conception of the architect that started with the Renaissance and continues to dominate until today. During modernity however there have been movements that challenged that idea, like the arts and crafts, by placing importance on concepts like craftsmanship; concepts that had their roots in pre-modern practices. Digital fabrication protocols are offering a possibility to reconnect to some of those properties, albeit in a new, protocol-mediated fashion.

Keywords
Digital Fabrication; Protocols; Arts and Crafts; Modernity; Antimodernity; Altermodernity; Cratsmaship

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

1. Authorship in Modernity

When, in the middle of the 15th century, Leon Batista Alberti was writing his ten books on architecture under the title De Re Aedificatoria, he was forming a new concept of the architect. Alberti, following the values that humanism was dictating, established in this publication, among other things, the idea of authorship in relation to the profession of the architect. As Mario Carpo points out (2011, p. 138), when Alberti was writing his books the term '*author*' (auctor) had two different meanings: when used in relation to written works it referred occasionally to the writer once she or he defined a new literary tradition, but it primarily referred to the patrons who supported or commissioned the work, that is the agents who 'authorized' the work. However, it was also used, in a broader context to signify the originator, the inventor, the creator or the maker. Alberti in De Re Aedificatoria "*conflates the two meanings of the term: the architect is the originator, inventor, and creator of the building, but at the same time, the architect's design becomes as authoritative as any 'authorized' literary text*" (Carpo 2011, p. 138). That new, double meaning of the author becomes fundamental in modernity. The 'auteur', the author in modernity, is someone who generates a concept, a vision or an idea while the act of creation is the process of materializing that concept. Everything else comes after that first concept and has to submit to it. The process is the means that will make the initial idea work. There is, therefore, a clearly defined temporal relation in place: The concept comes first and its materialization follows and has to remain as faithful to the initial idea as possible.
The way that modernity appreciates the concept of the architect is a variation on the way it understands the concept of the author at large. An architect too, in the context of modernity, is after all an author, a creator. Therefore in architecture too, if we try to idealize the design process, we will find that it is the concept, the idea, which comes first. The architect is the 'mastermind' that conceives that idea and has to pursue it to the end. Alberti makes clear that this temporal relation is very important in architecture: The architect has to generate his design, make as many revisions as required, but after it is finalized nothing should change; "'*the author's original intentions' should always be upheld*" (9.11.5 Alberti 1997, p. 319/ Carpo 2011, p. 22). This conception of the author during modernity, in architecture finds its highpoint in what we usually describe as modern architecture. For example, Le Corbusier's Plan Voisin is very characteristic of this notion: His idea of the orthogonal street grid and the sixty-story cruciform towers was the focal point of the project; everything that followed was serving that idea. Even if that meant that the whole center of Paris had to be razed to the ground in order to generate the clean, empty space required. So the architect in modernity, in her or his most successful and ideal version, is exactly this: a generator of concepts that can follow them all the way until they get realized. Alberti's ideas survive – largely intact – to the present day.

2. Architect and master builder / craftsmanship

Of course, that was not always the case. Before the Renaissance, in the place of the architect was the Master Builder. The master builders were artisans, like stone masons and carpenters, that were eventually rising to the status of the master builder; that is acquiring more responsibility or a leading role in the building process, usually because of their proficiency in their art (Murray 1969). Therefore the proficiency or virtuosity of the master builder in relation to the actual process of 'building' was of great importance.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

ber of technological innovations of that period: Around 1400 for example, paper starts to get used for drawings and until the 1500 its use is generalized. Until the 1600 the use of pencil for drawing is also generalized. At the same time, from the 14th to the 16th century we have the invention of linear perspective and geometric projections. It is those technological innovations that allow Alberti to formulate his new conception of the architect. All of them make possible the generation of drawings that can accurately describe the three-dimensional form of a building. Therefore they accommodate the possibility for someone to design a future building represented on paper accurately enough to direct the builders to realize it. Whereas before, the designer had to be, not only constantly present during the construction, but more importantly a skilled builder as well. In those situations the design was emerging out of the building process and it did not precede it. Manuel de Landa in a similar observation notes: "*Craftsmen did not impose a shape but rather teased out a form from the material, acting more as triggers for spontaneous behavior and as facilitators of spontaneous processes than as commanders imposing their desires from above*" (DeLanda 2002, p. 135). Of course the change from the master builder to the architect was a gradual one. Up to the 1700 the master builder was still the dominant model except for special cases, such as big public projects. But with the advent of the industrial revolution and the introduction of mechanized mass-produced objects, and therefore building parts, the transition is largely intensified until the master builder becomes a model of the past and the architect arises as the main figure of the design process. The domination and idealization of the role of the architect as the creator is further intensified and reaches its high point, as mentioned before, in the 20th century.
In that process of transformation some of the main characteristics of the master builder lost their importance or became irrelevant to the profession of the architect. Craftsmanship was one of them: The individual skills necessary for the production of the elements of a building that before modernity were an integral part of the design process. With the advent of modernity the architect started to distance himself from the art of crafting and with the industrial revolution this transition was fully realized: mass production left little space for the unpredictability and intense individual labor that craftsmanship required. But not without some notable exceptions.

3. Arts and crafts

In 1849 John Ruskin publishes his book "The seven Lamps of Architecture". The book marks a significant moment in the history of architecture during modernity as it puts forth a polemically critical stance towards the architectural principles that defined the era that started with the renaissance. Ruskin in his book calls for a more spiritual, even mystical, version of architecture, largely in contrast with the changes that the industrial revolution was bringing to architectural production. While his book served as a 'summary' of the principles behind the 'gothic revival' of that period, it also formed the theoretical basis – or better: starting point - for the arts and crafts movement and the theories developed by William Morris.
The arts and crafts movement therefore, had at its basis a fundamentally 'anti-modern' approach. William Morris' theory was initially based on the observation that art since the renaissance was becoming increasingly disassociated from its social surroundings. He explicitly notes that "*it is not possible to dissociate art from morality, politics and religion*"(Morris 1911). In his quest to reconnect art and architecture with its social surroundings he

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

emphasizes the importance of craftsmanship and makes the use of machinery in architectural production - especially as taken to an extreme by the industrial revolution - his main opponent. He unambiguously states: "*As a condition of life, production by machinery is altogether an evil*" (Morris 1911, p. 335). This radically critical stance towards mechanized production however took later on in the development of the movement a less polemical approach and the form of more 'refined' expressions. Morris himself was eventually led to finally admit that machines can be used "*as an instrument for forcing on us better conditions of life*"(Morris 1911, p. 352). Along the same line of thinking, Charles Robert Ashbee, a central figure in the later part of the development of the movement, writes characteristically: "*We do not reject the machine, we welcome it. But we would desire to see it mastered*" (Ashbee 1894). Besides Morris' stance towards the machine however, the central point of the arts and crafts movement was exactly the concept of craftsmanship. The direct relation with the material and the virtuosity needed in order to manipulate it and form it. In other words an approach that shares many things in common with pre-modern practices that go all the way back to the medieval times. And it is exactly this relation to craftsmanship that places the arts and crafts movement at odds with the principles of modernity; and consequently brings the concept of the author under question. Morris is again very explicit: "*That talk of inspiration is sheer nonsense, […] there is no such thing: it is a mere matter of craftsmanship*"(Pevsner 1975, p. 23). For Morris and the arts and crafts movement therefore, the result of the design process (or any artistic process for that matter) comes out of the direct harnessing of material through craft; it is not a 'grant' idea that is first conceived and subsequently materialized but rather what emerges from manual, material labor.

4. A different reading

Following our line of thought up to that point, it becomes clear that the arts and crafts movement was based on principles in direct opposition with those of modernity; in essence the arts and crafts can been seen as an anti-modern condition that was soon to be left behind as architecture moved into the 20th century and modernity found its 'ideal' architectural expression in modern architecture. It might come as a surprise then that for the literature of modern architecture, and especially for the mainstream approach to the history of the modern movement, the arts and crafts movement is considered as one of its main precursors.
In fact this approach, that the arts and crafts contained the seeds for modern architecture, was not widely accepted until 1936 when Nikolaus Pevsner publishes his book 'Pioneers of Modern Design". In that book Pevsner argues that the seeds for modern architecture can be found in three previous approaches: The Art Nouveau, the work of 19th century engineers and the arts and crafts movement and especially the work of William Morris. The first chapter of the book is dedicated to the arts and crafts and traces a line from William Morris to Walter Gropius: "*The history of artistic theory between 1890 and the First World War proves the assertion on which the present work is based, namely, that the phase between Morris and Gropius is an historical unit. Morris laid the foundation of the modern style; with Gropius its character was ultimately determined*" (Pevsner 1975, p. 39). After Pevsner, the arts and crafts movement continued to be considered as one of the predecessors of modern architecture, even for much more recent historians. In Kenneth Frampton's History of Modern Architecture for example, the arts and crafts hold again the place of the first chapter (Frampton 2007). The paradox that emerges - the arts and crafts movement as both an anti-modern condition and as a precursor to modern architecture, the ultimate expression

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

of modernity in the field of architecture - might be difficult to decipher if we consider modernity and forces that are opposed to its principles as elements that exist independently. We can follow however a different approach: Antonio Negri and Michael Hardt in their book Commonwealth place specific importance into those moments of antimodernity exactly in that sense. They talk about modernity as a dual condition where modernity and antimodernity, the mainstream and the opposition, coexist in a purely dialectical relationship where one is necessary for the existence of the other: "*Modernity is always two. […] a power relationship: domination and resistance, sovereignty and struggles for liberation […] forces of antimodernity […] are not outside modernity but rather entirely internal to it.*" (Hardt & Negri 2011, p. 67) For Negri and Hardt modernity and antimodernity are always operating together. If we follow that line of thought it might become easier to understand how a clearly anti-modern condition as the arts and crafts movement can be seen under a specific point of view as something that led to a condition that can be identified as modern; like the modern architecture movement.
It is important however to identify those moments of antimodernity as such, since they can contain the beginnings for alternative ways to think about our current condition where modernity seems to become more and more a thing of the past. Negri and Hardt in their work move on from the dialectical relation of modernity to anti-modernity and go on to define our current condition as what they call altermodernity. Altermodernity according to them has its roots in antimodernity but is free of dialectics. It is not based on an opposition to something else. It is a positive state, based on affirmation. It carries within it however the traces of antimodernity or those moments of resistance or opposition to the mainstream: "*We intend for the term 'altermodernity' […] to indicate a decisive break with modernity and the power relation that defines it since altermodernity in our conception emerges from the traditions of antimodernity – but it also departs from antimodernity since it extends beyond opposition and resistance*" (Hardt & Negri 2011, p. 103). It is in that sense that examples as the arts and crafts movement might become useful to us today.

5. Arts and crafts revisited

It would be reasonable to argue that today we can trace elements of change that are transforming the way we design and understand architecture in a way similarly fundamental with the transformations that happened during the transition from the 'pre-modern' tradition to what we can today identify as modern. Or, at least, we have in place a new technology whose consequences are as profound as those of the generalization of the use of paper and pencils or the invention of projective geometry: *the digital computer,* or more precisely digital media in general.
And through the computer, maybe surprisingly, architecture and design gets reconnected to the idea of craftsmanship or, in other words, to a direct relationship with the manipulation of matter. Firstly, that happens at the level of digital craftsmanship or in relation to the manipulation of "digital matter". Working in the computer with three-dimensional design software brings the designer in a direct relationship with the different kinds of geometrical representation that they employ. Diverse representations like nurbs, polygons, subdivision surfaces or splines, in effect 'virtual materials' (DeLanda 2002), require different ways of working, and most importantly thinking, while at the same time they yield very different results. Consequently, and maybe surprisingly enough again, virtuosity in the manipulation of matter, albeit digital in this case, becomes again relevant. The ability of the designer to

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

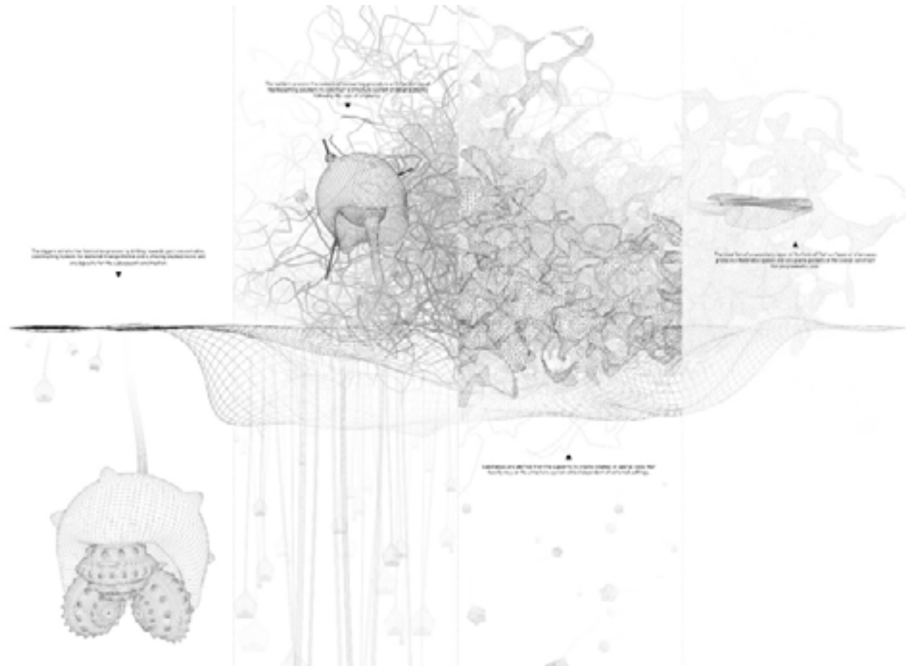


Figure 1.
Involuntarily Real. Corrupt Gold graduate studio, Spring 2014, School of Architecture, Washington University in St Louis. Student: Zhiyang Wang Instructor: Dimitris Gourdoukis.

use her or his tools along with her or his specific choices of those tools defines in a very direct manner the final outcome and therefore becomes increasingly important. In that sense, some of the main characteristics of the arts and crafts movement reappear in architectural production, initially – and ironically since they are now totally based on a machine – in a purely digital form.

And yet, that is obviously not enough. In order to be able to talk again about craftsmanship in relation to materiality in architecture a connection needs to be established between the digital world and the actual material world. This is happening - or can happen - through digital fabrication. Architects today have direct access to the machines that are able to translate a digital model into an actual object. They have access to the machines and the software that control them. Learning how to use them is part of their academic education. Therefore they reconnect themselves with the material aspect in a direct way. Only that now this connection is mediated through *protocols*. That is, through the framework that allows the computer to communicate with the machine and therefore the framework that allows the translation from a digital, virtual object to a physical one. More specifically a protocol "*refers to the standards governing the implementation of specific technologies*" (Galloway 2004). Anywhere that there is any type of communication between two or more different devices, a protocol is always in place to facilitate this communication, with the TCP Internet Protocol that is responsible for the functioning of the Internet being a prominent example. In our everyday life there are hundreds of protocols constantly at work. The current state of our society would be impossible to function properly without them. Therefore in contemporary societies protocols are the means to control

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Figure 2.
Conveyor. Corrupt Gold graduate studio, Spring 2014, School of Architecture, Washington University in St Louis. Student: Youngjae Lee Instructor: Dimitris Gourdoukis.

Figure 3.
3d milled model. Fabrication Protocols / Digital Crafting seminar, Spring 2014, School of Architecture, Washington University in St Louis. Student: Jeffrey Glad Instructor: Dimitris Gourdoukis

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

6. Fabrication protocols

In the case of digital fabrication, protocols come in the form of specialized software that reads a digital model and translate it into machine code so that the machine can fabricate it; software that is of course designed and implemented by specific companies. In order for those software packages to be general enough to accommodate the many different – and often unpredictable – cases that the different users will inevitably have to handle, they have to rely on *standardization*. In other words they have to define standards as to the ways that the different processes will happen and therefore be implemented. For example software that prepares models for three-dimensional CNC milling offers a limited number of predefined ways to generate the tool paths, based in most of the cases on a concept of efficiency in relation to the movement of the machine. Accordingly, software that enables digital models to be 3D printed performs the translation from 3d model to machine code based on standards that are largely defined according to optimization principles in relation to the time required fir the 3d print or to the efficiency of the material used.

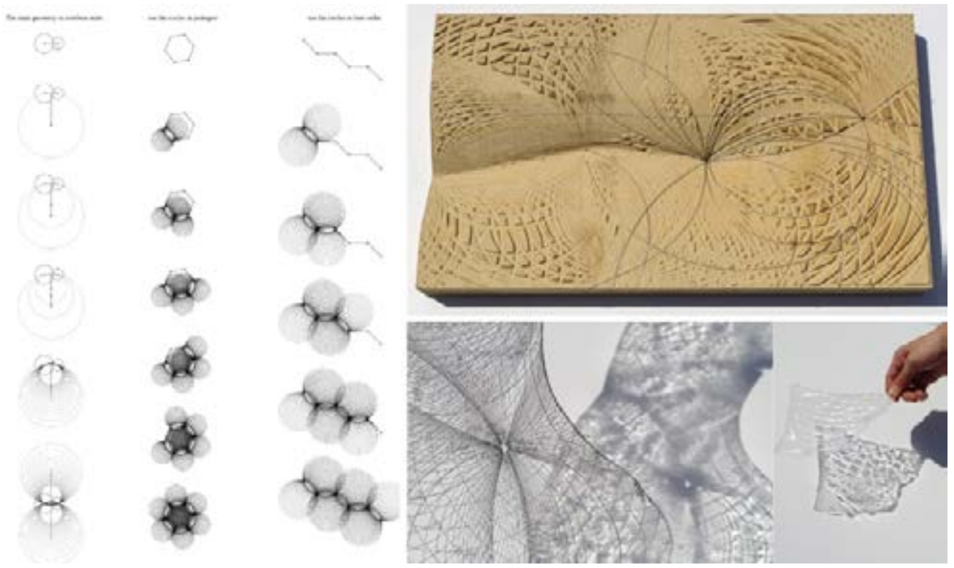


Figure 4.
3d milled model and Vacuum formed surface. Fabrication Protocols / Digital Crafting seminar, Spring 2014, School of Architecture, Washington University in St Louis. Student: Nasim Daryaee Instructor: Dimitris Gourdoukis.

At this point however another paradox is emerging: It is those fabrication protocols, the means to control, that are offering to the architects the chance to reconnect with materiality and craftsmanship while at the same time, through standardization and simulation, are taking away the properties of unpredictability and emergence that are inherent in processes that are harnessing materiality. In other words, the designer might be able again to work directly with materiality and use it as a means to design, but at the same time the tools that offer this possibility are taking out individuality by favoring standardization over individual experimentation. A paradox that is inherent in protocols at large: While they tend to be

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

While they tend to be democratic in the sense that they try to include everyone and everything (a protocol does not care about what kind of data is communicated, it just makes sure that the communication happens and hence does not discriminate content) in order to achieve this they have to rely on standardization, and therefore become almost fascistic in that sense: "*The contradiction at the heart of the protocol is that it has to standardize in order to liberate. It has to be fascistic and unilateral in order to be utopian*" (Galloway 2004, p.95).

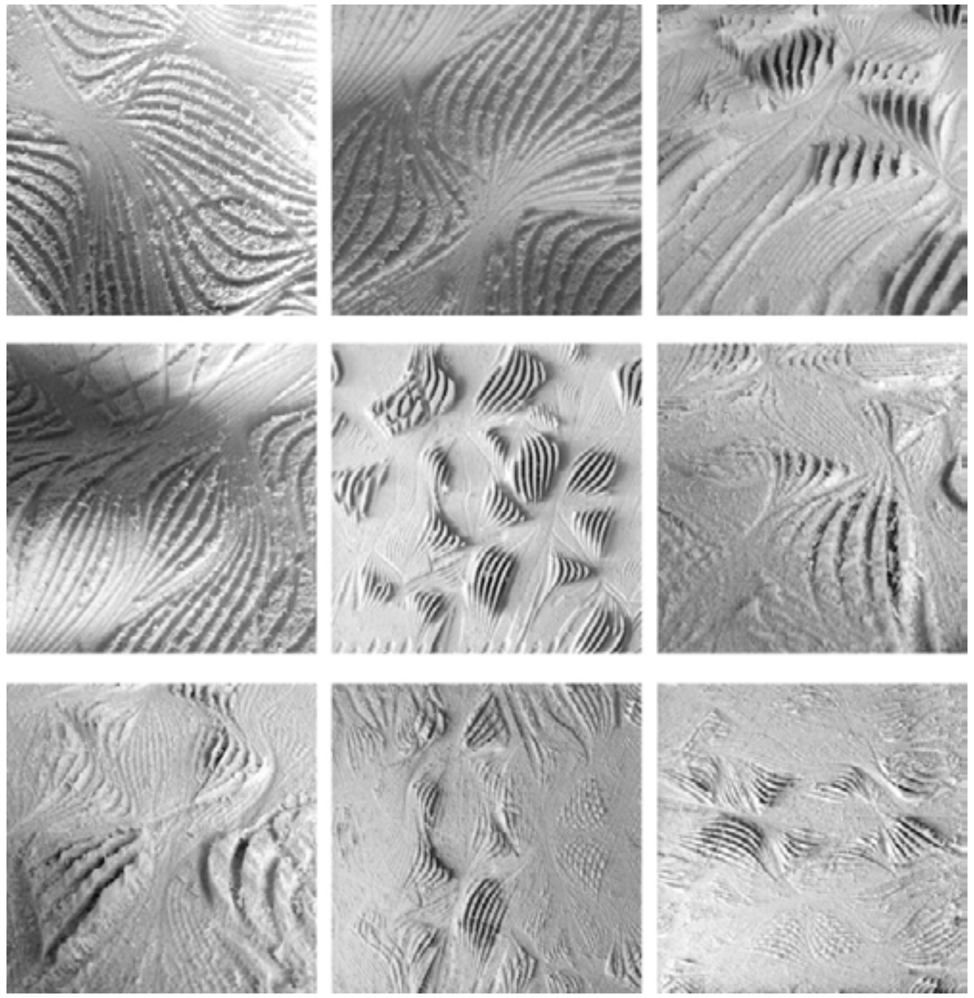


Figure 5.
3d milled models. Fabrication Protocols / Digital Crafting seminar, Spring 2014, School of Architecture, Washington University in St Louis. Student: John Patangan Instructor: Dimitris Gourdoukis

The common working 'pipeline' consequently when working with digital fabrication methods is that an architect or a designer submits a digital model and the protocol / software does the translation according to the preset standards, most often by following some idea of an optimal solution. Of course there is always a process of trial and error taking place, albeit one that is in most cases carried out through that standard, present option provided by the software. It is at this point that the opportunity for a meaningful reconnection of

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

design to craftsmanship can actually be realized in a fundamental way. The real challenge for architecture in this case is to try to harness those protocols and instead of following the preset standards to try and invent new ways of operating the machines. Otherwise the machines remain out of the control of the architect and they become just tools that functions in a manner that in most cases the designer does not understand and, most importantly, does not control. In essence the process of following the standardized way with digital fabrication serves the designer to the extent that it helps her or him to realize a preconceived architectural idea.

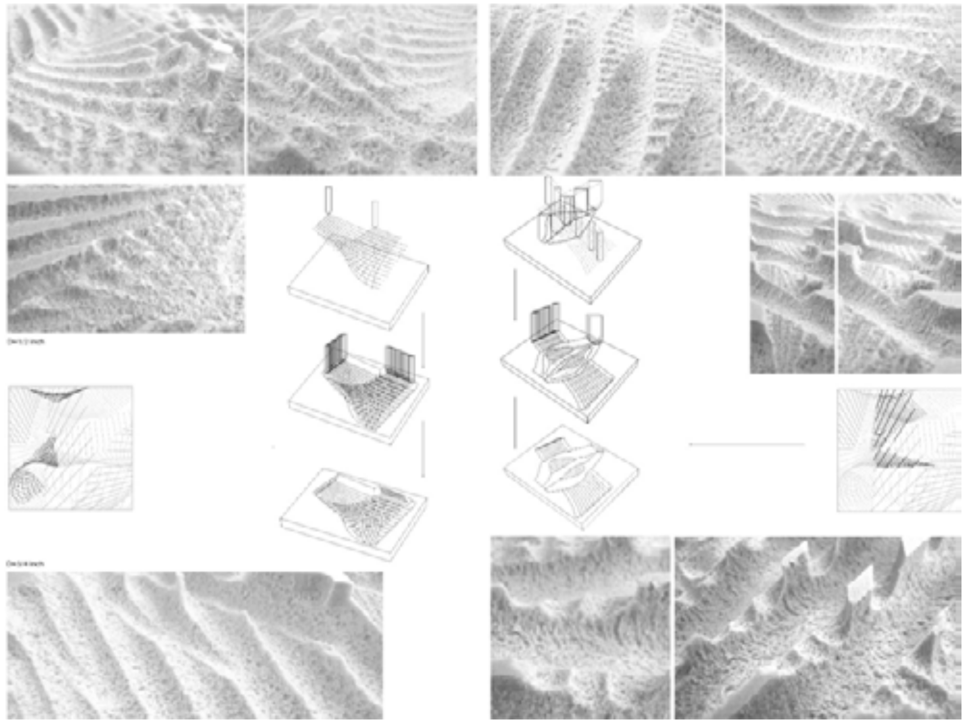


Figure 6.
Toolpaths and 3d milled model. Fabrication Protocols / Digital Crafting seminar, Spring 2014, School of Architecture, Washington University in St Louis. Student: Fan Wu Instructor: Dimitris Gourdoukis

Figures 3-9 illustrate a simple example of the above-described method, through student work from a seminar class taught in spring 2014 at the School of Architecture at Washington University in St Louis. Aim of the seminar was to explore the concept of digital craftsmanship and how fabrication protocols can be harnessed by the designer in a very simple case: that of a 3-axis CNC milling machine. The students were asked, instead of modeling something in the computer and trying to fabricate it, to directly design the machine's tool-paths and in that way to create a design process through the experiments they were conducting with the machine. Following that line of working no preconceived idea for the final outcome existed at the beginning of the process. Instead, the produced result emerged out of the direct interaction with the machine. Design intent, limitations posed by the machine and possibilities arising out of its use, and the properties of the material were operating in parallel and at the same level resulting in a bottom-up production of the final

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

outcome. The process for all the projects was characterized in most cases by similar steps: The first attempts led to fabricated outcomes that looked like failures. But through several iterations, that led to an understanding of how the machine operates and how it can be directly controlled through line drawings, the outcome was characterized by increasingly refined results. During the refinement of the technique, properties of the produced models were observed and they subsequently became the driving force of the process. Design intent was not imposed on the process and on the material but was rather continuously formed through the interaction with them.

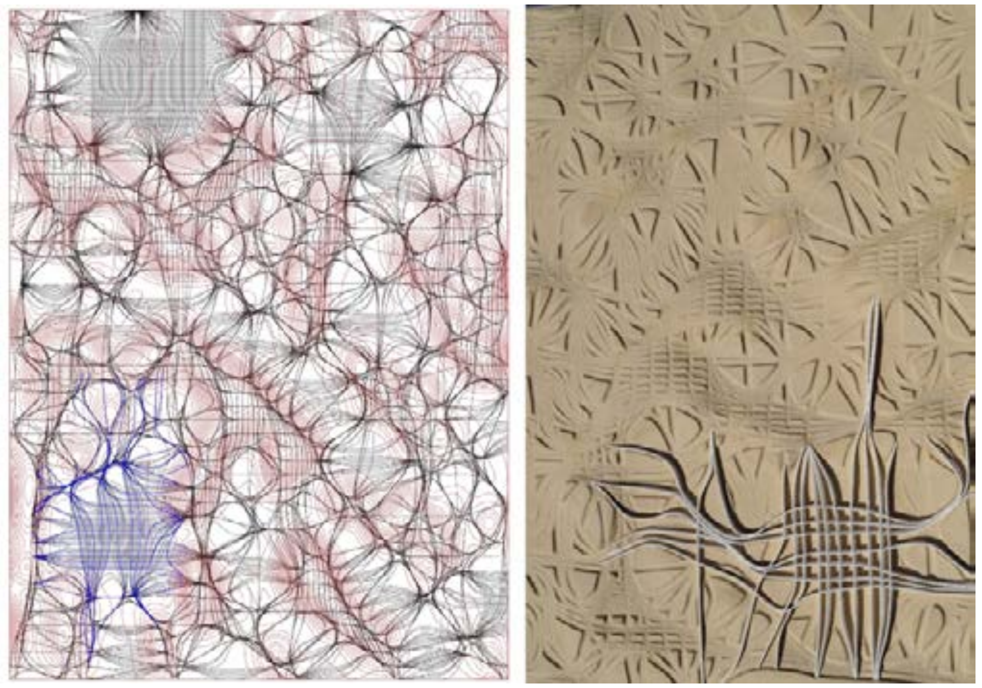


Figure 7.
Toolpaths and 3d milled model. Fabrication Protocols / Digital Crafting seminar, Spring 2014, School of Architecture, Washington University in St Louis. Student: Jeffrey Glad Instructor: Dimitris Gourdoukis.

At this point Ashbee's quote mentioned above about the machines and their use gains a new, updated for the 21st century, meaning. In order to avoid the standardization and the homogeneity produced at large by the new technologies, their rejection would hardly be a solution. Instead through the affirmation of their properties and characteristics, control over them can be achieved and subsequently mastering them and transforming then into design tools becomes possible.

8. Conclusion

As computation gets more and more connected with the construction and inevitably gets related to materiality, it becomes apparent that it is essential to consider how this connection is happening. There is an approach that follows the example of modernity: One that is driven by the principle that new technologies can be used to serve the initial intention of the architect / designer. Therefore they come after the definition of the design

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Figure 8.
Toolpaths and 3d milled model. Fabrication Protocols / Digital Crafting seminar, Spring 2014, School of Architecture, Washington University in St Louis. Student: Leslie Wheeler Instructor: Dimitris Gourdoukis.

intend and they operate on a different, second level that is hierarchically depended on the first; that of the design concept. In that context it is understandable that material science becomes important. Materials can be designed in order to fit and serve the needs that arise from a design proposal. New materials can be created and can be programmed to perform in a way that will answer in a very specific design problem that is predefined by the designer. Alberti would have been pleased.
But there is also another possible way: One that works from the bottom up and where the scope does not preexist but rather emerges as a result of the things discovered and, especially, invented in the way. Such an approach has a direct relation to some of the ideas that were prominent in the arts and crafts movement: the result of the design process, and maybe more importantly the meaning that it conveys, is not the outcome of an initial, preconceived idea; it is not based in what Morris rejects as inspiration (and can take many names like idea, concept etc.), but it is rather a result of craftsmanship, both digital and analog. Only when mediated by protocols, and when the designer is the one in control of those protocols, that approach can achieve an altogether new meaning where it is no longer defined as an opposition to something else. It is no longer an anti-modern condition operating always in a dialectical relation with modernity in Negri and Hardt's terms; instead it becomes a positive approach that can operate on its own, forming a new proposition for the alter-modern condition.

9. Acknowledgements

All the student work presented in this paper was created during the Spring semester of 2014 while the author was a Visiting Assistant Professor at the School of Architecture at Washington University in St. Louis, USA.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

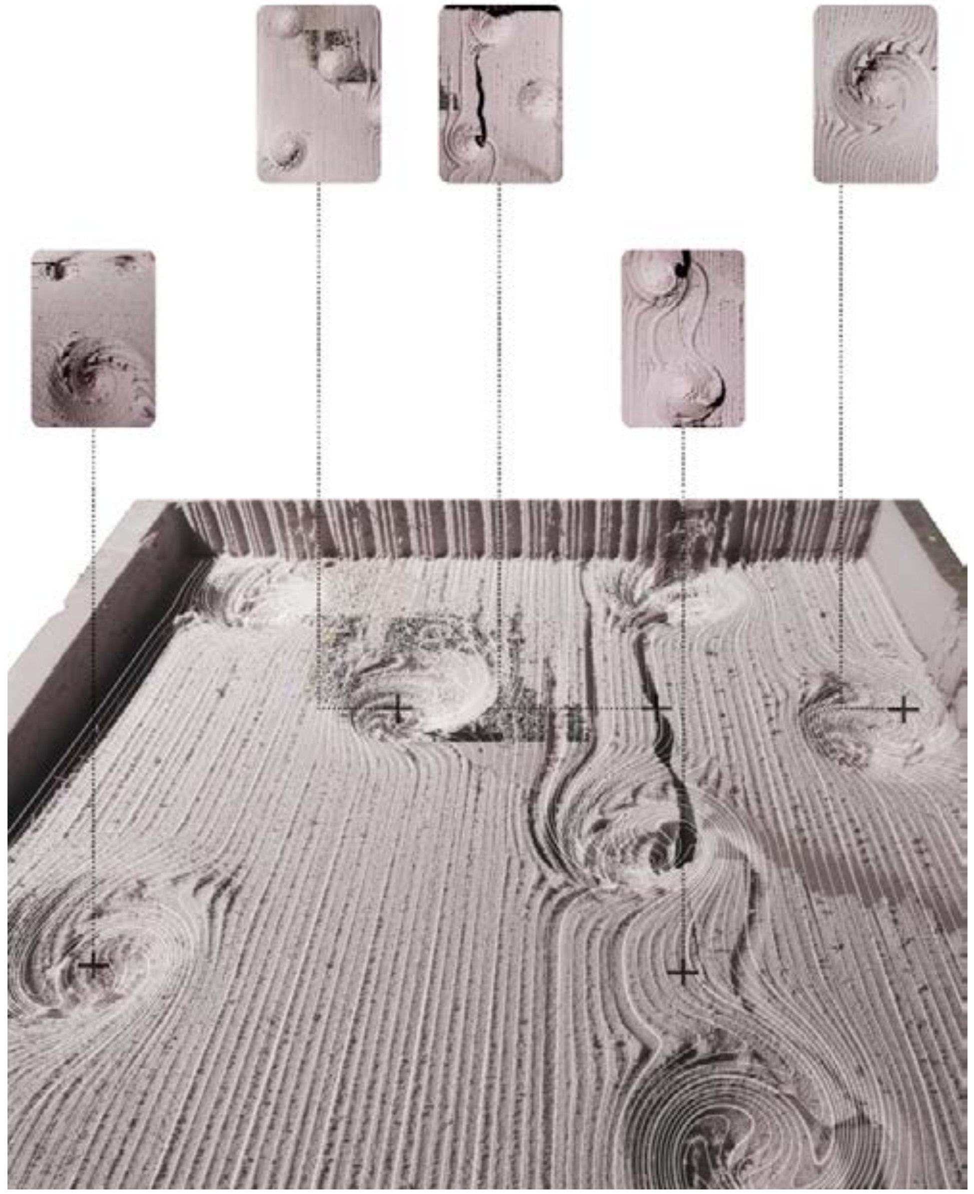


Figure 9.
Toolpaths and 3d milled model. Fabrication Protocols / Digital Crafting seminar, Spring 2014, School of Architecture, Washington University in St Louis. Student: Leslie Wheeler Instructor: Dimitris Gourdoukis.

References

Alberti, L.B., 1997. On the art of building in ten books 7th printing., Cambridge, Massachusetts: The MIT Press.

Ashbee, C.R., 1894. A few chapters in workshop re-construction and citizenship.,

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

London, Boston: The Guild and School of Handicraft; D. C. Heath. Available at: http://catalog.hathitrust.org/Record/001757782 [Accessed June 10, 2014].

Carpo, M., 2011. The Alphabet and the Algorithm, MIT Press.

DeLanda, M., 2002. Philosophies of Design: the Case of Modelling Software. In Verb: Architecture Bookazine. Actar, p. 280.

Frampton, K., 2007. Modern Architecture: A Critical History Fourth Edition., London ; New York, N.Y: Thames & Hudson.

Galloway, A.R., 2004. Protocol: How Control Exists After Decentralization, Cambridge, Mass: MIT Press.

Hardt, M. & Negri, A., 2011. Commonwealth, Harvard University Press.

Morris, W., 1911. The Collected Works of William Morris: The story of Sigurd the Volsung and the fall of the Niblungs, Longmans, Green.

Murray, P., 1969. The Architecture of the Italian Renaissance, Schocken Books.

Pevsner, N., 1975. Pioneers of Modern Design Pelican Edition., New York: Penguin Books.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Material and virtuality

Anders Kruse Aagaard // Aarhus School of Architecture // Denmark.

Abstract
Through tangible experiments this paper discusses the dialogues between digital architectural drawing and the process of materialisation. The paper sets op the spans between *virtual and actual and control and uncertainty* making these oppositions a combined spaces where information between a digital world and a physical world can interchange. The paper suggest an approach where an overlapping of virtuality and the tangible material output from digital fabrication machines create a method of using materialisation tools as instruments to connect the reality of materials and to an exploring process.
In this paper investigations in sheet steel form a substance of concrete experiments. The experiments set up shuttling processes in between different domains. Through those processes connections and intermingling between information from digital drawing and materiality is created. The dialogues established through these experiments is both tangible and directly connected to real actions in digital drawing or material processing but also the base for theoretical contemplations of the relation between *virtual and actual and control and uncertainty.*

Keywords
Drawing; Fabrication; Virtual; Steel; Material; Processing

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Research context

The experimental substance in paper consists of a series of experiments carried out in sheet steel. The experiments are a part of a larger mass of experiments also including concrete and wood. The combined mass of experiments form the investigating basis of the PhD project *Bespoke Fragments*. In this paper only a selected type of the steel experiments will be described in detail. However the scope of the overall project will be presented to situate the work in a correct and understandable context

The project *Bespoke Fragments* seeks to explore and utilise the space emerging between the potentials of control through digital drawing and fabrication and the field of materials and their properties and capacities. Within this span the project is situated in a shuttling between the *virtual* and the *actual*, investigating levels of *control* and *uncertainty* originating from these.

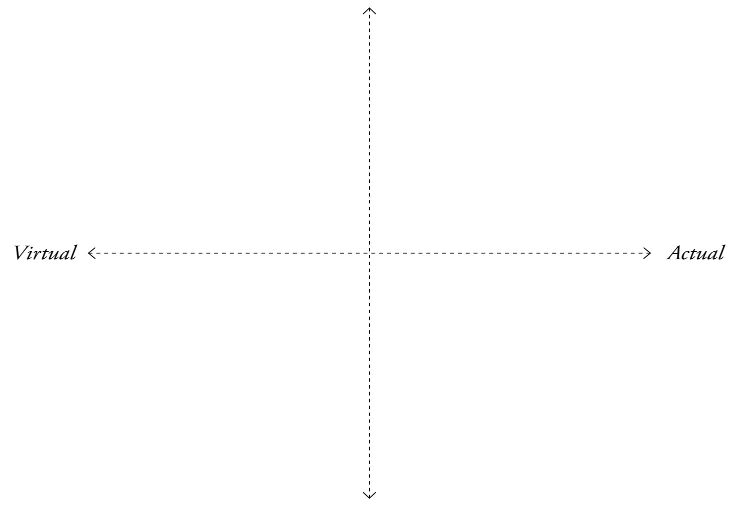


Figure 1.
The Virtual and the Actual, Control and Uncertainty. The experiments operate within this field constructed context using digital and physical tools and materials

Throughout the experiments – both the ones introduced in the paper and in the overall project – the term *fragment* plays a role in the genesis and the intended conception of both the digital and physical production. Firstly it handles the understanding of scale related to – especially – the physical artefacts. They are to be seen as 1:1 existences both in their form and their behaviour. They should be perceived directly and not be interpreted in relation to another scale. They, however, should neither be perceived as concluded objects. Rather they are to the seen as openings, preludes or *fragments* that potentially could be a part, a component or part of a component in a larger context or construction.

Through tangible experiments the project discusses materiality and digitally controlled fabrications tools as direct expansions of the architect's digital drawing and workflow. The project sees this expansion as an opportunity to connect the digital environment with the reality of materials – and use realisation and materialisation to generate architectural developments and findings through an iterative mode of thinking about the dialogue between drawing, materials and fabrication. Consequently the interest and mind-set behind the project and the experiments builds upon contemporary and earlier discussion about the relation between (digital) drawing and making in architecture.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

"Bringing with me the conviction that architecture and the visual art were closely allied, I was soon struck by what seemed at the time the peculiar disadvantage under which architects labour, never working directly with the object of their thought, always working at it through some intervening medium, almost always the drawing, while painters and sculptors, who might spend some time on preliminary sketches and maquettes, all ended up working on the thing itself which, naturally, absorbed most of their attention and effort"

(Evans 1997).

The above quotation is from Robin Evans essay *Translation from drawing to building* from 1986. While his realisation and concern is probably still valid in almost all architectural practises the current landscape of architectural tools is indeed changing. Digital drawing and design tools have either replaced or supplemented sketching and drawing by hand. Alone however these new tools still – with Evans's words – put the architects at the disadvantage of newer working directly with the object of their thoughts. Interestingly a new set of tools seems to find the way into the architect's toolbox. In today's field of, especially, architectural academia and education – but also practise – the importance of *making, fabrication and realising* seems more and more pronounced. Many directions and opinions have already emanated. Digital fabrication tools extend beyond the computer and bring new perspectives to Evans's reflection on the relationship between *architect, drawing and building*. Working closer to the materialisation of thoughts has the possibility to be common practice for future architects. This project positions itself in continuation of Evans thoughts and tries not to situate the architect as the builder, but to bring the materials, the matter, close to where the architect is working and shaping.

Digital lines

Today's digital drawing is well implemented and used in any of the architect's processes. From the early sketching and concept development to the final construction drawings. Digital drawing is serving both as a highly controllable and flexible tool, being able to produce precise and interchangeable information.

In the recent decade a fast evolution in digital fabrication has taken place. Going from a solely code controlled environment, industrial grade digital fabrication tools such a water jets, CNC routers and industry robots can now receive programmed information originating from digital drawing. Industry grade digital fabrication machines hold the capability to process real materials with quality and precision.

Compared to lines done by hand digital lines and CAD software can create contours and surfaces so complex that one can no longer be certain of their spatial coherence (Cache, 2010 pp. 60-61). Digital lines are at the same time very well defined and very detached from actual spatial relation. Thickness of surfaces does not exist and scale is not a defined concept. They are total reproducible within their own domain and the data describing them can easily be transferred to a production context. However the difference between what they are inside a computer and what the do within a production compromising the reality of materials calls for situations where realisation is not a representation of an idea but a dialogue between virtual and actual (Cache, 1995).

The link between digital drawing and material processing bring the material existence

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

closer to the act of drawing and through that reinterprets the meaning of the drawing. While the making of the drawing can be parallel to the making of a traditional representative drawing, the content of the drawing shifts. The architect can still be in control of the lines, but where the traditional lines are representatives or notations for the outlines of formal or material borders or transitions, the lines drawn with the intention of digitally informing the fabrication becomes either direct or indirect tool paths for the actual material processing.
The possibility of a close linkage between drawing and realisation is thanked to great advancement in the field in the recent years. The combined outcome of the spread and progress of both software approaches and hardware collectively have built a very well developed domain for designing and workflows to push digital information into reality (Sheil, 2005 p. 24)

Material specificity

The project is implicating three different materials; wood, steel and concrete. Those three materials have been selected because they together form a varying range of material properties.
The wood is naturally solid with a heterogeneous material structure. The grains running through the wood are defining the material behaviours continuously. Steel is a homogeneous material that is often processed in its solid state and from standardised formats. On the contrary, concrete is mainly processed in its liquid state, offering a homogeneous matter that actively uses its mass to flow into formwork.
The range of materials is well known and all established in the world of building practice and architecture. They are often used in different dedicated situations where they perform in often repeating, standardised and well-proven ways. Despite their controlled use and refined formats they all offer inherent autonomous material properties and capacities.
Materials properties are defined as objective characteristics that can be listed. Capacities, on the other hand, are *relational.* A capacity to affect always goes with a capacity to be affected (Delanda 2007). Properties cannot be overlooked, but the relational character of capacities becomes of distinct interest since the behaviour of this project is to affect material with tools and information from the digital domain. Delanda's coining of the definition of material properties and capacities is used in the following investigations to connect actions made in the digital domain and in the material domain.

Dialogue between digital and material

The point of departure for this project is the observation of the digital drawing as an initiator for working directly in and investigating materials and material behaviour. The control of fabrication tools through precise drawing opens up a new approach to materials in an architectural context. The drawing that controls the tools becomes specific for this to happen. And the knowledge and intention behind the drawing becomes specialised through the understanding of the fabrication processes and their affect on the materials. This creates drawings that are representations not of form, but of fabrication information that embeds directly into materials (Ayres 2012). An important aspect of this operation is that the processing not only creates form from the material, but also intermingles with the material's inherent properties and capacities and through specific control creates new capacities.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

These capacities might be affected by internal properties, external situations and/or affect situations. A dialogue between the digital domain and the material world is at the same time an alternating dialogue between control and uncertainty – specific control can lead to unpredictable behaviour. The notion of uncertainty is here parallel to David Pye's coining of the concept of workmanship of risk (Pye, 1968, pp. 20-24). Pye explains the difference between the workmanship of risk and the workmanship of certainty through comparing writing with a pen and printing. Where the result of printing is predetermined the act of pen writing involves as risk comparable to that of the creation of unique craftsmanship. The result of neither craftsmanship nor pen writing is fully controlled – predetermined – but both unveil uncertainty through a controlled direction or intention.
The drawing also becomes the carrier of the creation of material capacities. The drawing is created in a *virtual* space. *Virtual* is in this context understood as spaces of possibilities where parameters are variable and changeable and not definite or inalterable. In *virtual* space conceptual, formal and design decisions can still be made and respond to whatever situation that might exist or arise. When drawing embeds not form, but capacity, into the material through fabrication, the emergence of *virtual* space is no longer limited to the computer's digital world, but extends into the materials' world. According to Deleuze (Deleuze, 1991 pp. 96-98) *virtual* is not opposed to *real* but opposed to *actual*. *Real* is opposed to possible. For Deleuze pure possibility is not a productive condition. This Deleuzian perspective and differentiation is made operative in following experiments through the contradistinction of control and *uncertainty* where a situation of mere uncertainty is similar considered problematic. At least a fraction of intention, control and reality is needed to produce a beneficial situation. Deleuze's distinction between real and actual also makes the situations of virtuality in reality tangible.
The experiments described in this paper is interested in the type of drawing that let's the design space – the virtual space – include the materials and a possibility for decision making and exploration with the materials. This intention calls for certain ways of regarding the act of drawing. While no digital drawings – including coded and parametrical drawings - are excluded in this combining of the digital and the physical into a virtual space, it is crucial that the establishment of the digital design creates potential for investigation in the material domain and is not limited to the realisation of a definite. Seen this way, the type of digital drawing, applied in the following experiments might relate more to a classic relation between the drawing and the materialisation than more recent digital strategies – BIM for instance - regarding where design decision can be made. A classic architectural drawing set creates a direction for a realisation, but leaves many decisions to be solved through the information of the construction and materialisation. Comparable is the intention for the dialogues between the digital drawing and the materials in this explorative context. However, where a classic architectural drawing set relies on the reading, conventions and the esoteric understanding of the drawing in order to produce realisation, the digital drawing pursued in the paper talks directly to the physical world.
In these dialogues, knowledge of material behaviour, tool possibilities and concrete materialisation results directly contribute. Therefore a continuous production also becomes a constant evolution as a shuttling between the virtual and actual start to benefit from each other's specialities. Information from reality into the digital can happen through the humans facilitating both sides. Some information might be experienced based – for instance through transformation and assembly of processed element. Other might enter the domains through digital photography, measuring or digitisation through 3D laser scanning and metrology.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

The project's intention is to investigate the relations described above. Through concrete experiments the project is developing work that in different ways positions and relates itself in the dialogues between the *virtual* and the *actual* and between *control* and *uncertainty.*

Experiment strategy

This paper specifically outlines and explains investigations made with sheet steel. The experiments were carried out with the intention of forming a workflow and a producing experience close to the material and production. Consequently even simple elements of the workflow were carried out and hands-on knowledge about the fabrication tools was gained. To understand fabrication tools conceptually and how they abstractly can blend with design processes is the first step towards an integrated practice. But without deep knowledge of both the tool, the machine and the understanding of the working relationship within the specific processes control of the technology, and hereby an opportunity of designing, is not obtained (Callicott 2001).
The construction of the experiments builds upon the idea that the appreciation and utilisation of uncertainty comes through mastering and control. To operationalise uncertain moments and events happening from the steel, a contrasting control needed to be applied. This allowed a workflow where controlled intentions, intuitive actions and openness to uncertainty could exist.

Unfolding potentials

The experiments started out as an intuitive series of not contemplated material test where different approaches to folding, stretching and bending where tried out. Deliberately almost all experiments trajectories involved an act of transformation after the processing of the steel itself.
Hereby the fabrication did not become a transfer of form from computer to material, but an embedding of capacity into the materials. The subsequent transformation at the same time gives the architect a way to re-enter the process. If transformation and assembly is not decided ahead of fabrication it leaves a design space open and allows direct interaction between design development and the processed materials. The movement from digital to material does not become an abrupt actualisation but something that happens through an elongated virtual process. This way elements of control, decision making, discovery and reconsideration is distributed throughout the whole process. The designing becomes '…a creative and experimental process that occupies the full extent of architectural production…' (Sheil 2012).
Experiments were established around a feedback-oriented workflow. A drawing was created, drawing informed fabrication tool – a water jet cutter – through CAM software, fabrication realised in steel according to drawn geometry, steel was transformed on the basis of the given capacities into a shape, shape underwent evaluation – geometry based, structural based and material behaviour based – and evaluation fed into the next drawing (Fig. 2). This workflow might seem linear but given that multiple versions and experiments happened coherently it altogether appears as a network of different events and discoveries, all informing each other continuously.
Through the workflow the experiments closed in on the material properties of the sheet steel and unfolded a number of techniques and design spaces through which material capacities could be developed.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

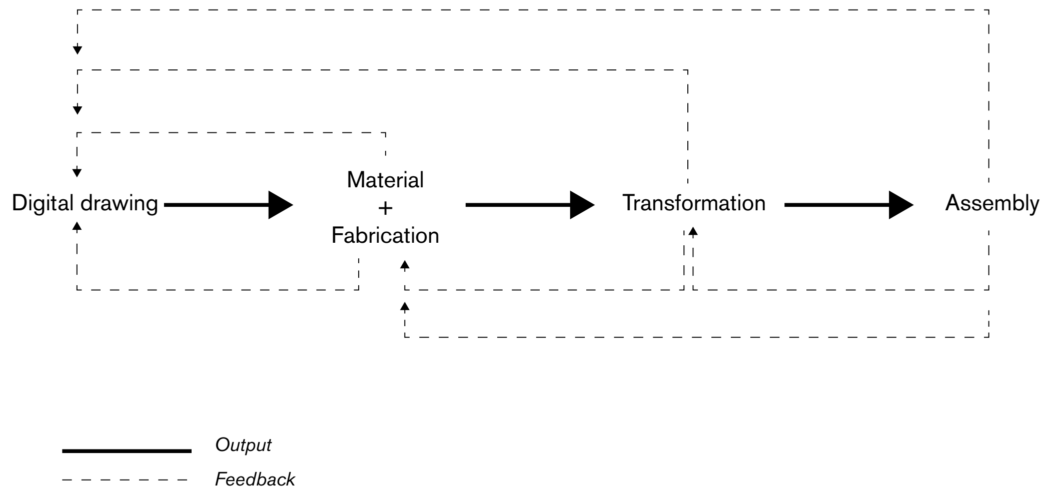


Figure 2.
A workflow based on constant feedback and output creates constant dialogue.

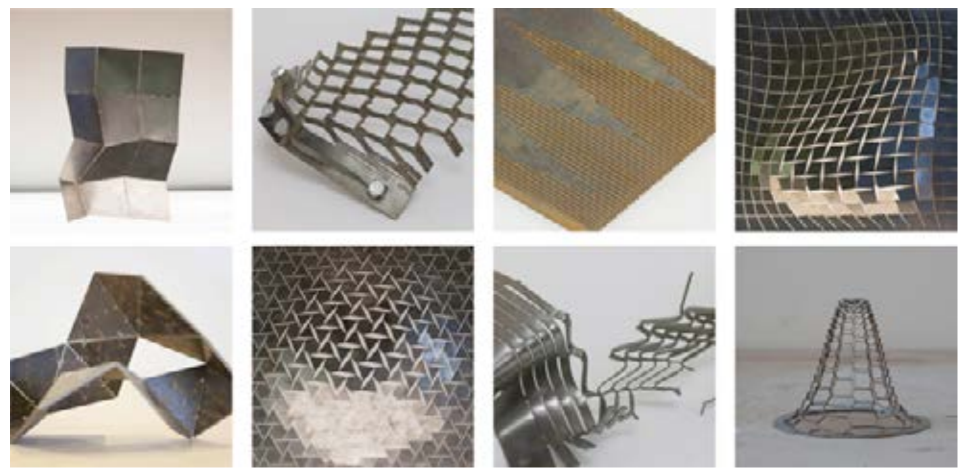


Figure 3.
A selection of experiments in sheet steel

Mesh focus

Through the explorations in sheet steel a focusing on stretched metal was mesh developed. The particular fascination by this technic should be found in two reasons. First the impressive structural potential created through the cutting and transformation of thin steel into stretched mesh. After the water jet followed instructions originating from digital drawing a force of up to 5000N is applied to the material. Local transformations in the mesh create plastic deformations (Fig. 4). These deformations are extremely strong and create stiffness to the areas where they are applied. The process from geometrical design, through production to straightforward material properties bridges the span between virtual and actuality.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

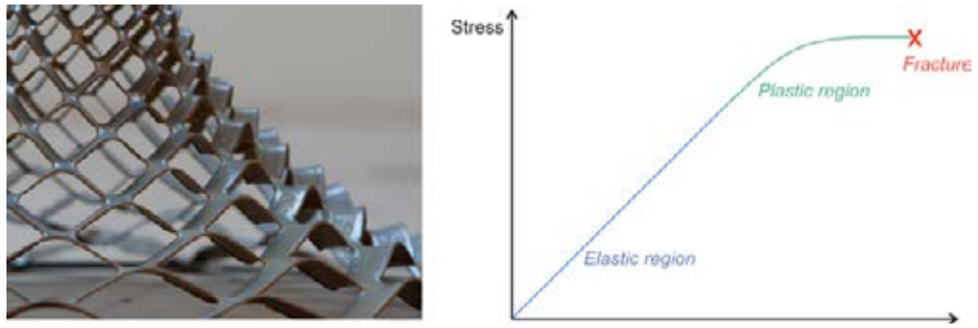


Figure 4.
The transformation of cut steel into mesh results in local plastic deformation. ("Deformation (engineering)," 2014)

Secondly the stretching involves and number of contributions to the dialogue between control and uncertainty. The creation of the mesh itself involves a number of crucial points where control of the material is necessary to realise the intended. The meshes are naturally depending on the design and configuration of the drawing. The water jet follows the control from the drawing and prepares for forthcoming transformation. The transformation itself requires precise control of the deformation (Fig.5). Both force and direction need attention if not uncertainty is allowed to take over. Even with precise metering of force no stretch turned out exactly the same. Inherent differences in the thin sheet steel had an impact on the final result. And sometimes uncertainty took over despite of the intention of control (Fig. 3).

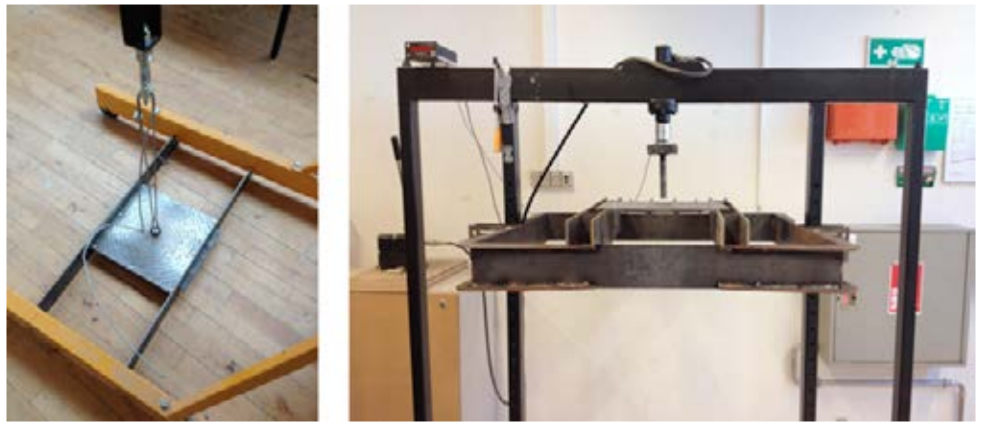


Figure 5.
Two iterations of equipment for stretching steel into mesh.

On the contrary to the industrialised production of metal mesh, this set up investigation combines creative freedom with the power of a water jet cutter. Geometry and tool paths can take many forms, experimental stretching can be tried out and the meshes can change size and character within the found material and tool limits.
Initial experiments started out with a mapping of mesh sizes and sheet metal tolerances. Stretching methods and techniques were explored and roughly brought under control

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

(Fig. 6). From here different strategies and geometries were tested out. Linear and point stretching are more or less controllable including asymmetrical and amorphous shapes. Crooked and multi-directional stretching however includes a fair amount of uncertainty.

Figure 6.
Early mesh construction. Steel is almost under full control.

Levels of control

The quantity of steel experiments ensured an overall, however scattered, knowledge of different geometrical and transformable approaches to sheet steel. They established different ways of transferring drawn intention into material. With a workflow established and a well-developed mesh investigation more conceptual implementation of the knowledge started.
The steel mesh creates an exiting contrast to the floppy 0,5 mm steel from where it grows out. The structural capabilities of the meshed areas emphasises the level of control and precision that is encased in its production. Mesh and unprocessed steel outlines the levels of control that can be applied to the material through the explored processes. In between these extremes the folding, bending and other deformations on basis of drawn geometry is found. With these varying levels of control combined drawing sets can be created. Not solely on the basis of form or intended material behaviour, but as a strategy of embedding different levels of control into a piece of material and use this distribution as a devising factor (Fig. 7).

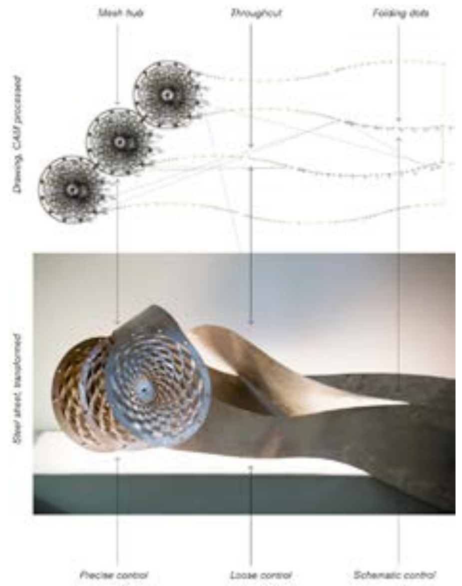


Figure 7.
Distribution of control into material through drawing

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Towards architectural components

Taking the world of architecture into account the developed approach to steel sheets is applied to a set of structure types. The created artefacts are related to human scale, creating an intention and suggestion of a 1:1 use of the method. Other than being human size this series of experiments tries to incorporate certain architectural and structural occurrences. For instance; the beam, a shift from vertical to horizontal or varying structure density (Fig. 8). Since the method and technic not conceptually allows complete preceding designs the above description should be seen as intention that impacts the decision making wherever the architect directly appears in the process.
The produced artefacts are considered experiments along with their predecessors. However their genesis is also an experiment in itself. The process is a collage of contrasts and the results incorporate a new level of reality into the project.

Figure 8.
Selection of structures.

Back to virtuality

So far the created artefacts disciplined origins from the dialogue between the computer's digital domain and the specific material properties and capacities. The dialogue however has a clear direction moving from the digital starting point towards realisation and our perceived world. I may zigzag and shuttle back and forth on the way but the increasing materialisation and actualisation through the process is predominant.
The method with which the artefacts are being developed is characterised by a continued consent of the unplanned and autonomous. Therefore no exact description, drawing or simulation of the artefacts exists. The final results only exist as themselves, a physical output compromised of created and utilised information from drawing, fabrication and

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

material. The artefact hold highly controlled portions, which precisely correspond with intention, in some areas. Other places they consist of curves or folds that is either a dialogue between drawing and material or composed only by the material itself. Steel sheets curves the way they like to curve without any predefined external instruction set.
Within the transformation processes and formal output a lot of qualitative information is embedded. The natural curves might contain useful courses and the relationships within and between artefacts might hold interesting spatial information. In both cases the workflow preclude the possibility to extract this information from the data basis from where it origins – the drawing, codes…ect. To access and operationalise this information for further development the artefacts need to feed back information into a virtual domain, where plasticity exist.
Digital photography allows a subjective way of collecting information through the digital picture plane. 3D laser scanning takes the digitalisation to another level and combines millions of measured point with photographs to create a digital point based world on the basis of reality.
3D laser scanning makes it possible to directly jump from one extreme to another. Existing reality with indefinite amount of indefinable information can be digitised into points. Points have no area, volume or any other property than its relative position in a digital space. The point cloud is the extreme of sole digital existence, yet its relation to reality is easily perceived. Like reality the digital point cloud contains almost endless information that, in it self, is practically non-operative. Selection, processing and decision making is required to obtain usefulness. A virtualisation, a translation or processing, of the point cloud is needed for it to be more than just an endless amount of documentation.
The steel artefacts were intuitively arranged in an already existing space and digitised with a 3D laser scanner. An immediate outcome is the possibility to discuss and analyse the real world through the scan using existing architectural constructions and articulations. A representational, architectural section (Fig. 9) can be created and a parallel to the architectural drawing can be established. Within this experiment that option is important since the materialisation was created without any traditional drawing material. This now exists, chronological backwards. The processed steel now causes spatial, architectural representation. Architectural representation did not cause the processing of steel.

Figure 7.
3D laser scans create a digital section through reality

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Because of its comprehensive nature, the point cloud do not function very well as direct operational information. The enormous amount of points does not instantly transform into useful geometry. But relevant information can be extracted accordingly to an intention. Again this is a matter of control. Full control of the digitised actual world might not be fertile at all. But specific, selected control in places of specific importance might be easily operational. A strategy for an operationalisation of the point cloud can be to single out points of special potential for further processing. This can be for the creation of splines or NURBS surfaces or other virtual existences. These transformations take the digitisation of the actual into being a process of defining variables instead of a passive documentation. This creates a linkage going from real actuality to digital virtuality.

With the use of modern metrology equipment the digitisation and virtualisation can however be combined to an interconnected action. Digital metrology arms can combine exact point definition and point cloud scanning (Figure 10). This makes the process of establishing the virtual an action that takes places in a tangible shuttling between the physical world and the digital. The virtualisation itself becomes a space of possibilities and choices.

Figure 10.
Combined scanning and metrology equipment. Digitisation and virtualisation as an interconnected process.

In this experiment, points along the curved steel where digitised and used as information for the creation of virtual splines in digital space. This way the material behaviour caused the creation of digital curvature (Figure 11).
With annexation of the curved steel into virtuality this project is put on pause. However the splines have the potential of initiating the next set of experiments and discussions. Easily they can become information for new drawing and production – and they probably will.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

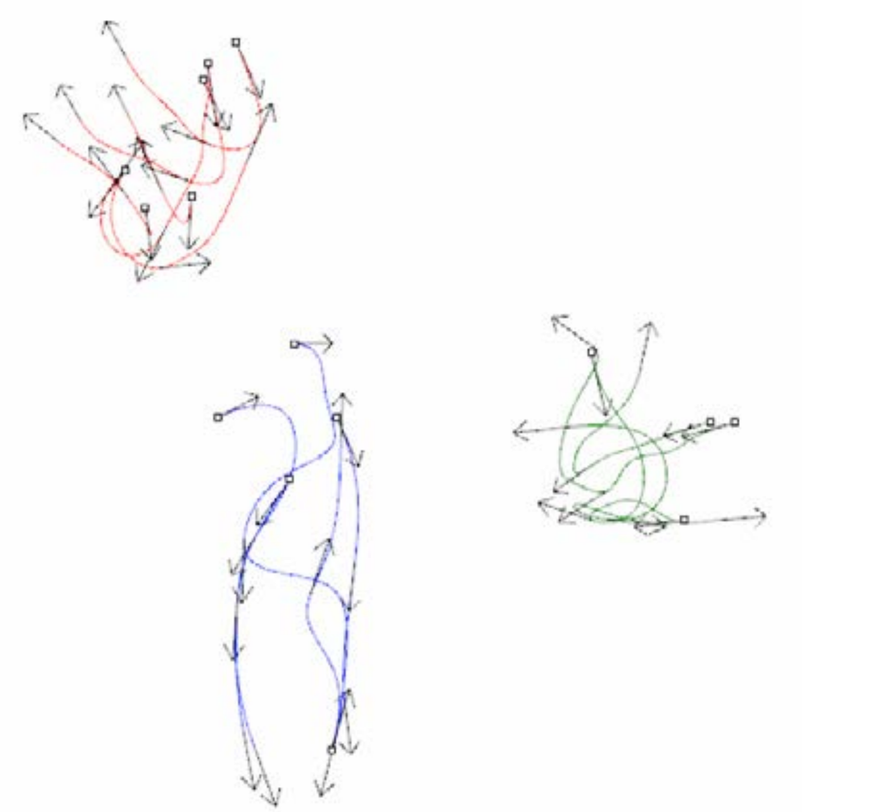


Figure 11.
Splines made from digitised points. Reality feeds back information to the virtual. Splines correspond with structural arrangement from figure 9.

Recapitulation and future research

The starting point of this paper – and the project underlying – is a method to the use of digital fabrication in an exploring architectural process. The goal of the approach is not to use digital fabrication as a tool set to realise digital, architectural ideas, but as instruments to connect the reality of materials and to an exploring process. The project sees the virtual domain as the approach to exchange information back and forth between the materials and the architect's intention.
As it, hopefully, becomes clear through in the exposition of the experiments, the relationship between control and uncertainty becomes important to the way the experiments and the project takes shape. This dialogue is related directly to the discussed relation between virtual and actual. The paper aims to focus on the opportunity of linking materiality to the digital drawing in a coherent way. It is the conception that material properties and capacities hold potential with which projects and experiments can develop. Consequently the aim is not to trump the material with superior control, but create a context where all can contribute. For this to happen, this paper suggests the method of distributed control and the encouragement of uncertainty. Without any control material would stay passive. It would not be affected or have the capacity to affect. As seen in the experiments, specific

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

control through the digital domain into the materials can trigger possibilities and allow for uncertainty to offers itself through the material's behaviour.

As explained, the experiments examined in this paper only represent a component in a larger project. The project also involves wood and concrete. The approach to these materials is similar to the steel in the way that it establishes dialogues between digital design intention and control factors and the materials. Wood and concrete offer very different material qualities than steel and hold completely different sets of capacities.

However the future step for this research project is to establish exchanging information between the materials and their different realities. This also means more complex, intermingled virtual situations where specific or universal control for different or all materials can be handled. The creation of digital splines from curves created in reality is an obvious example of a starting point for a multi material strategy. One material can create actual information that is virtualised, gets transformed, processed and becomes fabrication information for another material that again can meet the original material in reality. Together they now can create new information that becomes nutrition for further dialogue and development.

A far-reaching and more ambitious end of the subject of this paper is to fertilise and nourish architectural practices and design approaches where the digital domain and the reality of the material world are in mutual conversation. The development in digital fabrication machinery and supporting software is enabling the output of digital design tools to much more than picturing and passive actualisation of ideas. Design and realisation does not need to be split up affairs or a one-way process. A design practice of inclusive approaches, encompassing the full extends of both digital and material possibilities seem to have potential for architectural development.

Hopefully the intention and overall approach of the project comes through in this paper. It is the belief that both the interest and method presented here will be refined in the further investigation to come.

References

Ayres, P 2012a, 'Makers of Architecture' in B Sheil, 55-02 a Sixteen*(makers) project monograph, Riverside Architectural Press, Toronto.

Cache, B., Carpo, M., Barrett, C., 2010. Projectiles. Architectural Association London, London.

Cache, B., Speaks, M., 1995. Earth moves: the furnishing of territories. MIT Press, Cambridge, Mass.

Callicott, N 2001, Computer-aided manufacture in architecture: the pursuit of novelty. Deformation (engineering), 2014, Wikipedia Free Encycl.

Delanda, M 2007, 'Opportunities and Risks', Domus, No 901, pp. 192–193.

Deleuze, G., 1991. Bergsonism. Zone Books, New York.

Evans, R 1997, Translations from drawing to building and other essays, Architectural Association, London.

Pye, D., 1968. The nature and art of workmanship.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Sheil, B., 2005. Transgression from drawing to making. Archit. Res. Q. 9, 20–32.

Sheil, B 2012, Manufacturing the bespoke: making and prototyping architecture, John Wiley and Sons Ltd., Chichester, U.K.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Propositional architecture and the paradox of prediction

Stig Anton Nielsen // Department of Architecture, Chalmers Technical University // Sweden

Abstract
If Architects had a tool to predict future demands, modification of the built environment could meet the changing behaviors and emerging phenomena in society. Research on existing building stock, in relation to prediction is reviewed. And an entirely new type of architectural tool is proposed.
The algorithm, capable of making predictions in unstructured environments, is presented, and the basis and the idea of the algorithm are described. The discussion focuses on possible applications for this new tool, and the paradox of prediction is debated. Finally, improvements to the computational system are proposed.

Keywords
Building Stock; Prediction; Forecasting; Build Environment; Algorithm; Computation.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

1. Introduction

What if we could predict trends, rising phenomena and future necessity in our built environment? What if we could trace behaviors and forecast the needs for the future? What if we had a tool for proposing architecture, able to point out potentialities and suggest additions, subtractions and modifications?
Our societies nowadays change faster than ever, and as both long term and short term demands change, our physical surroundings need to adapt in a rate where real-time feedback is too slow for the time-consuming process of building. There are few ways to react to this issue. One is to make use of the existing building mass and only focus on the smallest most time-utility effective modifications. The other is to start modifying before the need actually arises; a preemptive strategy, which requires prediction. Prediction easily becomes either a technical engineering issue or a philosophical issue. This changes with the grade of fuzziness versus determinism of what we must predict. The article does not discuss the philosophical aspects of prediction, rather assume prediction from a cognitive viewpoint, where experience creates the basis of forecasting - through the ability to remember similar situations and project their continuation.
As society, culture and especially demographic setting change, many aspects of the architecture should follow. As an example, families get smaller, more people live alone in the same size apartments as 50 years ago, and density drops causing change in the urban scale. Drop in density makes it harder to run efficient public transport, and small-scale local shopping demise. If the existing housing mass would continuously adapt to the need, mixed use could nurture social integration, less transportation, and lower general consumption. Much of this adjustment could be achieved through subdivision infill buildings or merging of existing property (Anne Power, 2008). In addition, enormous amounts of industrial spaces have been left empty as the situation for industry in Europe has changed over the last 35 year, however reliable data are missing in order to form coherent refurbishment plans, and in addition it is not high on the agenda of the architecture community, as architectural education, by and large, focuses on (new) building designs (Hassler, 2010).
If we are able to predict phenomena for large-scale environments, the proposals for modification could be anything from subdivision of living spaces, opening of ground floors, addition of balconies, infill houses, or demolitions to create parks, and urban spaces. Basically including all scales of modification to the built environment, through both subtraction, addition, and modification. The importance lies in being able to propose modifications, in the rate of which the demand changes.

Figure 1.
This simple robust structure from 1924 was serving initially as garage, but has since been modified to fit several different needs. Through the 80s and the 90s the building has served as a shop for outdoor apparel. (Brandt, 1994)

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Figure 2.
As the downtown Akron, Ohio, grew closer to the grain silos of the Quaker Oats Company, it was decided to transform the structures into a hotel, now known as the Quaker Hilton. (Brandt, 1994)

2.1 Related work on prediction used on the existing built environment

Kohler and Hassler sums up the research on refurbishment and the building stock, and describe the different strands. In addition, I will mention some research done by engineers. One area is the energy refurbishment research, where buildings are divided into groups based on various parameters such as annual consumption, surface area, age, function and inhabitants, with the aim to make overall predictions of energy consumption for coming years. Hassler comments on these models, saying that rather than predicting the results of refurbishment, the need is to form a strategy for future refurbishment (Hassler, 2010).
Research by Stepney that looks more general, and includes social, environmental, and cultural consequences of demolition in comparison to refurbishment, without actually doing a prediction, highlights a complex landscape of causal effects - ranging from local through political, social and global consequences. She concludes:
"It is unclear how energy use will work out in practice. So, an approach grounded in the realities of our complex built environment seems more hopeful than a theoretical, long-term and largely uncosted plan to build and demolish on unprecedented scales within our seriously constrained environment."

(Stepney, 2008)

Another strand is the traditional research in conservation that focuses on conservation of historically significant buildings. This refers - depending on country or region- to as little as 1-2% of the building stock (Hassler, 2010) and one of the discussions in this field is to what extent the original functions of the building should be maintained in opposition to suggesting and refurbishing for new functions and possible uses.
Kaklauskas and his colleagues make a full multi-criteria analysis, where all criteria like cost, aesthetics comfort and quality are quantified in tables. They are basing the system on set of weighted criteria, which would probably change weight or value depending on the environment in which the refurbishment is taking place (Kaklauskas, 2004).
Yet other research into prediction of the building stock development, has focused on energy consumption and uses production statistics and implicit trend models to predict the future behavior of the stock. Those studies look at average trend curves from the entire environment, in single separate dimensions and project many years into the future, with

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

large margins (IEA, 1995).
However, sustainability, heritage and refurbishment have both to do with the past and the future of our built environment. While architectural heritage is concerned with sustaining culturally valuable buildings for the future, refurbishment is about adapting the built environment to future needs of its inhabitants, so that new sets of demands can be met. But, how do we determine what the demands are, and what attributes of heritage we should attempt to keep? Do we keep cultural values and resources through conservation, preservation or protection? Maybe it is done through maintaining utility and nurturing active use of our built environment. An approach could be to use existing potentials in combination with future trends, occurrences and phenomena.
If that is the case, attention is no longer on the design and formal expression and aesthetics of the physical matter in the environment. Rather, the subject can be seen as constituted by the events and occurrences in the environment. A matter composed by events, activities and episodes.
"An episode is a collection of events that occur relatively close to each other in a given partial order."

(Manilla, 1997)

Events make up episodes, which are perceived less through conventional spatial metrics and categories, more through our human sensorial apparatus and cognitive sense making. Episodes are often considered to pass over time, but when understanding them as series of events, time is not preconditioned, it may or may not be regarded.
The article seeks to understand the paradoxical consequence of using prediction in architecture and speculates on ways of implementing prediction as a tool for proposing modifications to our built environment. The chosen research approach, is referred to as Propositional Architecture and is described in the paper "Propositional Architecture using Induced Representation"(Nielsen and Dancu, 2014). It uses sensor technology, cognition, and augmentation combined, in order to achieve an ongoing stepless refurbishment of the existing building mass. The approach consists of a few steps. A: data collection from the environment, B: machine cognition, learning, prediction, and, C: proposition, visualization, and embodied representations for quick implementation. The paper outlines the factual and theoretical basis for this approach, and discusses three experiments, each one of which deals with steps A, B and C.

2.2 Machines understanding events

Already in the 90s, when sensor technology was recognized as one of the important emerging technologies, the ability to process sensor data in software became an important area of development (Toko 2000, Laughlin 2002, Murphy 1996). Nowadays sensors are heavily enhanced by more advanced software methods such as 'Sequential Pattern Mining' and 'K-means clustering', Self Organizing Maps, and others (Gershman, 2012, Cabanes, 2010). The combination of these different types of algorithms, can result in systems performing machine learning and cognitive processes. Systems that can reveal hidden relations in large unstructured data, learn to recognize consumer patterns, objects in images, handwriting, or faces.
Through using different algorithms in combination, this (accumulate) algorithm can propose the occurrence of future phenomena, provided that it has an amount of experience. That means that the algorithm can be assigned to a higher level than analytical machines or design machines, namely that of initiative and proposition. The algorithm permits the identification of behaviors and thus it is able to propose what is necessary in the future. The ac-

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

cumulate algorithm might permit us to build and modify for future events and phenomena.

2.3 A new type of computational aid for architecture and the built environment

Machines throughout the past century have increasingly managed design; perspective perception apparatus for hand drawing and parallel drawing machines for geometrically constructed perspectives. In the last few decades, computer aided design machines have evolved, and the late twenty years computerized parametric machines have come about. The parametric machines allow architects to manage complex geometry, data and relations, and some simulation models already simulate notions of events and occurrences in the environments they model. Such technologies enable architects on a level of design and development of ideas that are already conceived.
If we change the focus from handling geometry to the task of handling behaviors and events in matter, maybe we can use computational and sensory machines for the very conception of ideas. The computation and technology in this research is not for the design of existing ideas, rather aiding in the very conception of ideas. Propositional Architecture could point out potentialities in the environment and suggest modifications.
A learning algorithm is proposed that is able to detect phenomena and make predictions on events in any given environment, real-time. The algorithm can be fed any input data, in any number of dimensions, and the algorithm can easily adapt to any timescale.
The algorithm searches its memory and when pointing to a part of the memory, it indicates that there is a certain phenomenal similarity between the current and past experiences. Representation of the projected memory can be in any form of medium, but this is the prediction.
These are the steps which is performed in continuous repetition:

A: Collect and memorize multiple types of data from the environment.
B: Produce an internal representation of events and phenomena. (This representation constantly shifts depending on the character of the data.)
C: Compare the current series of events to all previous series of events and find behavioral similarities, and recurrent phenomena.
D: The forecast takes the 'soon to come' events from the most similar previous phenomena, and projects it into the future.

3 Forecasting method

Most of the simple forecasting methods are based on running averages, linear regression, trends, or curve-fitting models, all included in linear prediction. Non-linear prediction is also rich presented as frequency identification or Fourier transform analysis for more complex curves (Antunes, 2001) or statistical methods using, for example, the Bayesian theorem (Gershman, 2012). Also neural networks have been used (Dorffner, 1996), but these methods suffer from the problem of long training time.
The algorithm presented in this article can be placed within the group of 'Advanced time-series forecasting methods', and the most similar approach can be found in the article 'Rule discovery from time series' (Das, 1998).
In this case, where the changing factors are spatially distributed and it is in fact not clear what exactly we need to forecast, this work takes an approach favoring robustness and speed, while still being able to have a real-time graphic representation.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

If we assume for a moment, that all events and phenomena are constituents of other smaller or larger events, then if a certain sequence of partial events takes place, we should be able to remember it and project the next few parts of that event, provided that we have experienced a similar series of events before. This means that we need a system, which can separate the occurrences in the environment into different partial events, and then compare the current sequence of partial events to all the similar sequence of partial events in memory. Laplace describes determinism like in the quote below, but he assumes that we must know, through science, all meaning of the individual parts in the entire universe, but we may just need to look for similarities to previous occurrences, without knowing the meaning of the events.
"We ought to regard the present state of the universe as the effect of its antecedent state and as the cause of the state that is to follow. An intelligence knowing all the forces acting in nature at a given instant, as well as the momentary positions of all things in the universe, would be able to comprehend in one single formula the motions of the largest bodies as well as the lightest atoms in the world, provided that its intellect were sufficiently powerful to subject all data to analysis; to it nothing would be uncertain, the future as well as the past would be present to its eyes. The perfection that the human mind has been able to give to astronomy affords but a feeble outline of such an intelligence."

(Laplace, 1820)

The idea of the algorithm is that, if several aspects of the environment are observed throughout a period of time, a memory of the events taking place is built, and if the most recent series of events is found to be similar to a previous series of events, then we may presume that the continuation of the current situation is similar to the continuation of the event from the memory, so that it becomes the prediction.

3.1 Experience built from multidimensional data

One sensor can support many simple tasks, but for the data to be usable, it must be both calibrated and context aware. Through the technique of sensor chaining, multiple same type sensors can perform without calibration, only with context awareness. Instead of calibration they make use of their different readings set in relation to their different contexts. Context awareness, high precision and adequate reaction speed are required of sensors used for sensor chaining (Nielsen, 2012). Sensor Fusion, on the other hand can significantly reduce the need for both precision and context awareness for the individual sensors, as this technique makes use of various criteria, or what we will refer to as 'dimensions'.
If you cannot find the sensor you need in any manufacturer´s catalogue then you can probably make your own - in Software. This is the basic premise behind sensor fusion. The idea is that if you combine the data from a variety of different sensors, you will be able to measure parameters for which no single sensor exists" (Laughlin, 2002)
With sensor fusion systems, a rough calibration is useful, and this is how we might understand the system described in this paper. This algorithm can be seen as a sensor-fusion system, using sensor chaining throughout time. We look at each unit of time as a multidimensional data point, and compare its values to all other time units in order to determine which are similar and which are different. We employ a simple K-means clustering algorithm to determine the differences throughout the time-data points. This is the basis for creating a sequence.
The K-means algorithm, commonly used for signal processing, is clustering the n-dimensional observations into any given number of clusters, where similar observations are grouped together. If we had two-dimensional observations plotted on paper, we could

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

divide them in two different clusters. Then we could calculate the average centerpoint for each cluster, and then find out for each point which centerpoint it is closest to. Then recalculate a new position of each centerpoint based on the average of the points belonging to the cluster with that centerpoint.

Increasing the number of clusters could still be visualized, but when we increase the number of dimensions for the data points, we can no longer visualize them after 3-dimensions. However the K-means algorithm uses the same approach, calculating the distance over n-dimensions, and comparing the Euclidean distance between clusters and data points to tell if the point belongs to one or the other cluster, even for a very large number of dimensions.

When looking at the time-data-points in the order which they are recorded, a sequence can be derived where each new element is given the name of the cluster to which the time-data-points belong and a length which is determined by the number of consecutive time-data-points belonging to that same cluster (Figure 3). We call one such element 'subsequence'. This method is a strong discretization of the data, but by continuously redistributing members of the clusters, it is constantly reinterpreting its understanding of the data in accordance with the latest experiences. So if no particular phenomena take place, -say all sensor input has only minor changes, the distribution will still occur. One might say it adapts to the degree of complexity in the environment.

The last step is to look through that sequence and find a series of subsequences similar to the most recent series of subsequences, -the 'now'. Once a good match is found from the previous event sequence, we can look at how that earlier event unraveled and propose that same course of events to pass again. A similar approach is described and used here (Das, 1998). For this purpose I made an algorithm performing '*recursive temporal data mining*'.

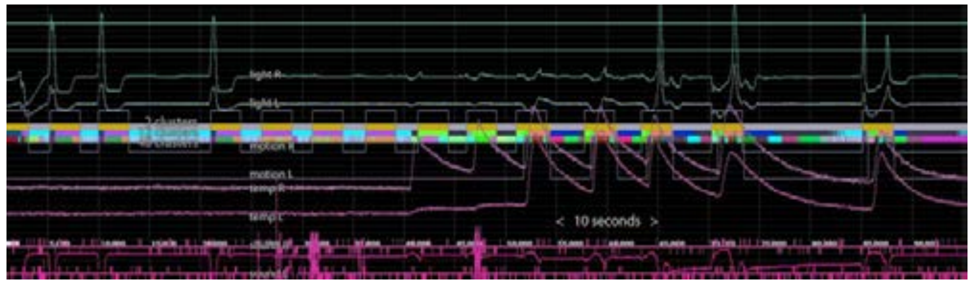


Figure 3.
Sensor readings are plotted over the duration of about 100 seconds. The data is analyzed, and vertical time sections with similar sensor readings are clustered. The result is shown as the poly-colored bar across the middle. Same color time sections have similar sensor readings.

3.2 Temporal Data Mining

Temporal data mining is a widely applicable field, and most real world data can be viewed as sequences of events, which can be used as input for temporal data mining. This algorithm makes use of recursion to find the best matching previous event. As the bottom part of figure 4 indicates, the recursion starts once for every previous subsequence with the same name (or color). In order to investigate the similarity between the current sequence and the sequence back in the memory, one step backwards in both sequences is made, and if the subsequence has the same name, the recursion is called again. By summing up the lengths of sub sequences and giving penalty when the length of the sub sequence pieces

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

mismatch in length, the longest, matching sequence can be found.

As already mentioned, there are literally hundreds of different algorithms published within the field of data mining, rule mining and sequential data mining. They are mainly different in optimizing speed for searching large data sets, which is in part because the task of finding any sequence with any length, and any number of its occurrences, is a task that increases exponentially in size with the increase in data. Often the algorithms need to be appointed a size of window, from which the sequences can be mined, and a criterion of support may also be defined. The window separates the task in smaller chunks, and the support defines how much to look for patterns (Fournier-Viger, 2014).

Because this algorithm only searches through memory in relation to the latest sequence, and because it uses recursion, the mining takes just few milliseconds. Additionally, for the recursion to be robust to noise in the sequence, that is built in a criterion of noise tolerance. It works like a jump with penalty. If the next sequence piece does not match, the second is queried, if that also doesn't match the third is queried. This maximum number of jumps is a variable, a noise tolerance. And the penalty is deducted from the sequence length index, which determines what sequence is chosen for the forecast.

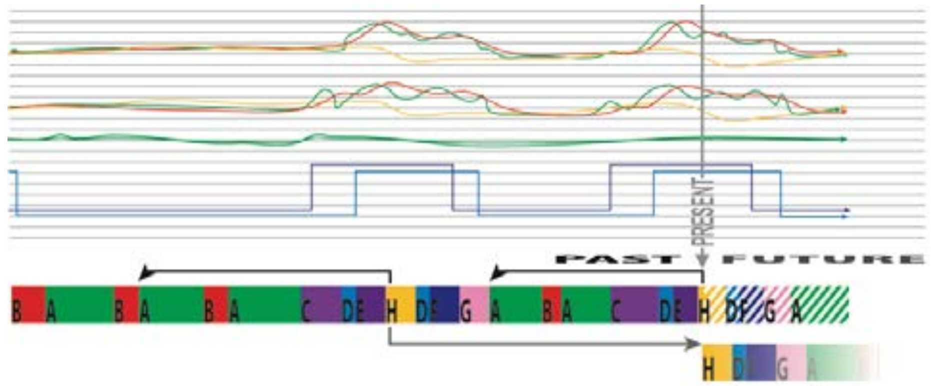


Figure 4.
Top; The input dimensions of various data assigned to each time-data-point. Bottom; Recursive temporal data mining, and the projected sequence making the prediction: HDFGAB.

3.3. Pseudocode:

1. Add new data point to memory - assigned with incoming data dimensions
2. Reorganize cluster names for data points using k-means clustering
3. Write whole sequence of subsequences using cluster names from k-means
4. Start recursion for each previous subsequence equal to the current subsequence -return the longest matching sequence
5. Forecast from the end of returned sequence
6. Continue until better sequence is found
7. If memory is full, start overwriting oldest memory
8. Repeat from 1.

4. Example of use

The algorithm was tested on an outdoor area of ETH, campus Hönggerberg. The area is providing access for pedestrians between the campus buildings and the busses, connecting

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

the campus to the city. The input dimensions are, in this case, given the color of the pixels indicated by grey squares in figures 5 and 6, and the memory was recording a span of about 5 minutes, before starting to overwrite old memory. The prediction is illustrated as a series of green traces showing what pixels are going to change in comparison to the normal image. Figure 5 is not a real prediction because the algorithm was shown the same exact video twice, but it demonstrates how the algorithm shows the most similar previous series of events, namely the exact same previous events. Figure 6, on the other hand, was shown a continuous video of all events in the area, and although it is obviously not able to predict the situation, it is able to find a series of similar events, where several of the pedestrians are seen in the same areas simultaneously.

This is obviously a very difficult situation to predict because the environment has little or no causal behavior, and almost none of the events are related, but rather spontaneous and chaotic.

Figure 5.
Testing and demonstrating the capacity to predict. The algorithm was shown the video twice, and the second time it was able to use the first as prediction. Prediction is displayed in green.

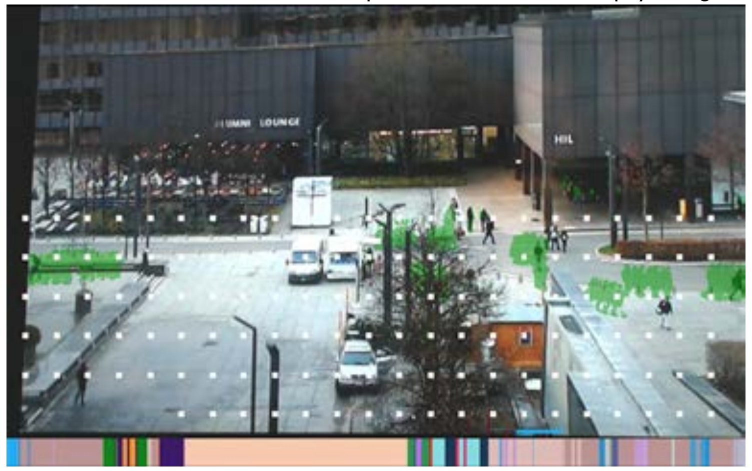


Figure 6.
The algorithm is shown a long video, and the chosen moment is when the algorithm finds a similar series of events. Prediction is displayed in green.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

5.1 Paradox of prediction

How do we verify a prediction if we intentionally change the environment in which it were to play out? And should the prediction be created from memory of modification based on prediction?

The questions suggest two different ways of using the algorithm, one where the memory is based on past cases of refurbishment, it would, given the data from a vast amount of other cases, be able to suggest the most similar outcome, and provide data on more aspects such as built time, cost and other detailed data from the past case(s); for example, if memory was made up of a number of refurbishments in different locations, where each was tracked over time with essential criteria. Then when another refurbishment is started, the most similar can be found and predictions can be based on that previous refurbishment. Of course as the refurbishment progresses, the prediction would change, as other better fits might be found. That way future potentials might be seen earlier and exploited better.

The alternative is without using past refurbishment as memory, instead using occurrences of events and trends in the environment, in order to produce designs that support the events. This could, for example, be shifts in functions of a certain area. In case we have multiple dimensional data over time with information about how inhabitants and industry behave in the city, then recurring events of movement to a new part of the city can create the sequential memory. The algorithm will be able to make a prediction of which inhabitants are likely to move within a given time.

If input dimensions are imperceptible, might we predict on imperceptible phenomena?

If we make use of dimensions imperceptible to humans, we might identify series of events that are otherwise imperceptible. What Immanuel Kant describes as noumenon. Predicting may work the same or better, it needs to be experimented with (Rescher, 1972).

How can we provoke reactions for faster learning of relevant phenomena?

An example is the unfamiliar water faucet, one might not know what happens when it is turned versus levered. The approach to learn is to affect it. In this way, after a few operations, it is learnt which operation supplies water pressure and which operation regulates temperature, but gaining this experience, is impossible through just passively observing the faucet.

Interplaying with the environment might increase the rate of which learning information, sufficient for prediction, can be gained. But this points back to the first question in this discussion.

5.2. Improvements to the forecasting method

How could we improve the choice of sequence?

One of the most important aspects of the prediction is to choose the sequence to use for prediction, and it is obviously already dependent on the differentiation of time data points and the granularity of the sequence. The approach of finding the longest possible set seems like a reasonable strategy for the very diverse forecasting environment.

How might we improve the input dimensions?

Another very important criterion is to choose relevant input dimensions. These should be related to the situation relevant to the prediction. Essentially according to the idea of fusion sensors, improving the number of different sensorial aspects improves the robustness. Dimensions for which nothing happens will be non-influential, and only dimensions with no

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

causal relation to the situation of relevance can be creating noise. It would be relevant to construct learning filters which are able to 'sharpen the senses', thus reducing the influence of noise dimensions.

Such filters might be constructed through supporting the dimensions, which are active when recurring sequences are found, and inhibiting the dimensions that are inactive when recurring sequences are found.

Can we use Induced Representations as input dimensions?

The more qualitative the input can get the better, so if we were to supply the prediction algorithm with pre-analyzed data e.i. representations, as opposed to raw sensor data, the algorithm might perform well on different environments in parallel. For example city parts may be compared and occurrences from one city part can be used as memory for another.

6. Conclusion

The article presents an approach to architecture where, instead of the conventional architecture design approach, a tool for proposition of new interventions is presented; a shift from designing existing ideas towards that of proposing new ideas for intervention.

An algorithm which, provided multiple dimensional data, can make predictions of events and phenomena in highly fluctuating and diverse environments, and if applied correctly, it can identify and propose new ideas for interventions.

The algorithm is presented and described in detail. Possible unexplored applications for the algorithm as well as improvements are discussed and in the future research, aspects such as multiple layers of memory, as well as partial predictions should be explored. There seems to be both vast applications for prediction, as well as many opportunities for using the concept of Propositional Architecture.

Acknowledgement

This research officially started in September 2012 at Chalmers Technical University Dept of Architecture under the name 'Embedded Sensors'.

Alexandru Dancu from Chalmers Technical University, dept. of Applied IT joined the research mid 2013, resulting in a turn, and speed picked up.

In the entire year 2014 I have been Guest Researcher at Prof. Ludger Hovestadt, Chair for Computer Aided Architectural Design, Department for Architecture, ETH Zürich. Here the research took another turn into a deeper understanding of advanced computation. I would like to thank Prof. Ludger Hovestadt for opening a more versatile approach to computation, and Vera Buhlmann for a general understanding. I will also mention Atli Seelow for his help improving the chapter on related work, and my supervisor Monica Billger for advice. The project is funded by the project Architecture in the Making and Chalmers Technical University Department of Architecture.

References

Antunes, Cláudia M., and Arlindo L. Oliveira. (2001) "Temporal data mining: An overview." KDD Workshop on Temporal Data Mining.

Zhang, Zhiqiang, and Qiong Zhu.(2013) "Fuzzy Time Series Forecasting Based On K-Means Clustering." Open Journal of Applied Sciences 2: 100.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Mooney, Carl H., and John F. Roddick. (2013) "Sequential pattern mining--approaches and algorithms." ACM Computing Surveys (CSUR) 45.2.19.

Guenael Cabanes and Younes Bennani (2010). Learning the Number of Clusters in Self Organizing Map, Self Organizing Maps, George K Matsopoulos (Ed.),ISBN: 978-953-307-074-2

Gershman, Samuel J., and David M. Blei. (2012) "A tutorial on Bayesian nonparametric models." Journal of Mathematical Psychology 56.1: 1-12.

Laughlin, C., (2002) "Sensor Fusion + New Materials", editorial, Sensor Review vol 22#4 Emerals Group Publ. Ltd

Guenael Cabanes and Younes Bennani (2010). Learning the Number of Clusters in Self Organizing Map, Self Organizing Maps, George K Matsopoulos (Ed.),ISBN: 978-953-307-074-2

Manilla, H.(1997) "Discovery of Frequent Episodes in Event Sequences" Data Mining and Knowledge Discovery 1, 259–289

Toko, K., (2000) "Biomimetic Sensor Technologies" Cambridge Press

Laughlin, C., (2002) "Sensor Fusion + New Materials", p.7-editorial, Sensor Review vol 22#4 Emerals Group Publ. Ltd

Murphy, Robin R.(1996) "Biological and cognitive foundations of intelligent sensor fusion." Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on 26.1: 42-51.

Fournier-Viger, P., Gomariz, Gueniche, T., A., Soltani, A., Wu., C., Tseng, V. (2014). SPMF: a Java Open-Source Pattern Mining Library. Journal of Machine Learning Research (JMLR), 15: 3389-3393.

G. Das, K.-I. Lin, H. Mannila, G. Renganathan, and P. Smyth. (1998) Rule discovery from time series. In Proceedings of the 3rd International Conference on Knowledge Discovery and Data Mining.

Dorffner, Georg. (1996) "Neural networks for time series processing." Neural Network World..

Brand, Stewart. (1995) How buildings learn: What happens after they're built. Penguin.

Rescher, Nicholas. (1972) "Noumenal causality." Proceedings of the Third International Kant Congress. Springer Netherlands.

Kaklauskas, Arturas, Edmundas Kazimieras Zavadskas, and Saulius Raslanas. (2005) "Multivariant design and multiple criteria analysis of building refurbishments."Energy and Buildings 37.4 : 361-372.

Power, Anne. (2008)"Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability?." Energy Policy 36.12 : 4487-4501.

IEA (1995) International Energy Agency: Future Buildings Forum. 2nd FBF Think

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Tank Workshop, IEA, Paris.

Niklaus Kohler & Uta Hassler (2002) The building stock as a research object, Building Research & Information, 30:4, 226-236, DOI: 10.1080/09613210110102238

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Maria Voyatzaki is associate professor of architectural design and building technology at the School of Architecture of Aristotle University of Thessaloniki (Greece) since 2001. Her PhD at the University of Bath, School of Architecture (1996) supervised by Chris Williams and Edmund Happold investigated the design process of non-standard architecture entitled "An Insight into the Design Process of Unconventional Structures". Her research and respective published work focuses on the integration of an idea and its materiality aiming at enhancing the quality of architecture through this integration. She has taught for over 11 years in the United Kingdom and for a semester in Denmark (Aarhus School of Architecture). She has organised and participated in a great number of international student workshops and international conferences for architecture educators. She has been the editor of over 25 volumes of international conference proceedings. Her work is published in international journals and conference proceedings. She is the Coordinator of the European Network of Construction Teachers since 2001. She is a free-lance architect with experience in practices like Buro Happold. She is also the coordinator of a number of European funded programmes on architectural education, with the most recent one being the two-year funded Lifelong Learning Multilateral Project, continuum: from the school lab to the factory workshop that investigates new pedagogic protocols for teaching students on a file-to-factory logic. She is the Editor-in-Chief of e-archidoct (http://www.enhsa.net/archidoct/). She has been a Council Member of the European Association for Architectural Education (2000-2007). She lectures abroad and sits at design juries around the world. She is a chartered architect and member of the Royal Institute of British Architects and ARB. www.nomad-rnd.net and www.enhsa.net

Manolis Paterakis graduated from the School of Architecture of the National Technical University of Athens in 2005, and in 2012 he received a MSc in Design-Space-Culture from the same institution, where he also worked as a teaching assistant from 2007 until 2009. Since 2011, he is an undergrad student in the Dept. of Informatics and Telecommunications of the National Kapodistrian University of Athens, while pursuing a PhD research in the department of Architectural Technology at the NTUA Architecture School, in an attempt to find a common space between Architecture and Computer Science. His interests also include systems programming, UX design and front-end development for web platforms. He has worked both as a freelance architect in Athens having received distinctions in architectural competitions, as a web-developer and a programmer. From September 2013, he is working with the Integrated Systems Lab of the Institute of Informatics and Telecommunications at the N.C.S.R. "Demokritos" in projects concerning crowd-behavior simulation as well as web-based applications.

David Abondano graduated in architecture at School of Architecture ESARQ (2005). Afterwards he worked (2005-2010) in Carlos Ferrater studio (Office of Architecture in Barcelona) collaborating on the development of architectural projects and competitions, as well as co-authoring the chapter Ideographic Resources of the book Synchronizing Geometry (ACTAR, 2007). His independent architectural practice has been displayed in exhibitions such as the Lisbon Architecture Triennale (2007) and, Colombian Emerging Architecture (2009). ARC Group member since 2012, and with the grant of the FI-DRG 2012 from de Agència de Gestió d'Ajuts Universitaris i de Recerca, he currently carries out his Ph.D. thesis, "Transition Towards a Digital Architecture", within the program "Representation, Knowledge, Architecture", by School of Architecture La Salle. The doctoral research bridges the material, productive, and conceptual changes fostered by the industrial and informational technologies in architectural practice and theory. His intention is to provide a historical and sociocultural background that enables the understanding, and critical assessment, about the integration and employment of digital design and fabrication tools in architectural production. The results of his research have been published in scientific journals and conference proceedings.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Dimitris Gourdoukis is a PhD Candidate at the Aristotle University of Thessaloniki, where he is teaching classes on digital media and design. He studied architecture at Washington University in St. Louis (Master in Architecture, 2007) and at the Aristotle University of Thessaloniki (Diploma in Architecture, 2004). In spring 2014 he was a visiting Assistant Professor at the Sam Fox School of Design at Washington University in St. Louis where he tough a graduate design studio and a seminar on digital fabrication. He was a Lecturer at Washington University from 2007 to 2008, where he taught core digital media, advanced digital media and digital fabrication classes. In 2006 he founded object-e architecture (http://object-e.net), as a research platform on issues of architecture, computation and experimental design. He has won prizes in numerous international competitions. His work has received several awards and has been published, exhibited and presented at conferences internationally.

Anders Kruse Aagaard is an architect and PhD Fellow at Aarhus School of Architecture, Denmark. Anders graduated as an architect in 2012. In between his architectural studies he worked at architectural offices and also combined his master in architecture with graduate studies in philosophy and epistemology.
Both as a student and as an architect Anders's work has been focusing on materials and material processing. Both as aesthetic and formal expressions in design proposals and through investigative experiments during the design process. He has an interest in material qualities and material behaviours as well as the current and historic craftsmanship and knowledge connected to the materials. Before Anders started his PhD studies he was involved in the implementation of digital machinery at Aarhus School of Architecture and establishing of the material lab. He joined the teaching staff in Aarhus and coordinated seminars concerning materials and new technology. The introduction to digital production tools added a new dimension the material interest and eventually formed the topic for his PhD research.

Stig Anton Nielsen is PhD student and researcher within the field of Architecture, Computer Science and Robotics. His project attempts to combine notions from philosophy, architecture, artificial intelligence, material and non-material computation, as well as robotics, in order to manage and modify the build environment. In 2008 he graduated as Master of Architecture from the Royal Academy of Fine Arts, School of Architecture in Copenhagen with the project, 'Metro Mechanics'. The project was presented at conferences nationally and internationally.
In the years 2008-2012 he worked both at the at the successful and progressive architecture office COBE, as well as the internationally renowned research Center for IT and Architecture (CITA). At CITA he explored computation, large scale CNC fabrication, rapid prototyping and robotic assembly. During these years, he was involved in teaching at the Royal Academy of Fine Arts, and invited to host international workshops on his topic in both Warsaw, and Manchester. In 2012 he started his own project at Chalmers Technical University, Dept. of Architecture, and collaborated with researchers from Computer Science, in both teaching experi mentation, publication. Today Stig is conducting scientific consultancy for a robotics development firm, as well as guest researching at the chair for Computer Aided Architectural Design (CAAD) at ITA, ETH.

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

ISSN 2309-0103
www.enhsa.net/archidoct
Vol. 2 (2) / February 2015

Submission Policy

Archidoct is published two times a year, in July and January. The official language of the journal is English. Submitted manuscripts for review should not exceed 4500 words, including abstracts, references and image captions. The referring system will be the Harvard System. Text should be saved in a Microsoft Word or RTF file, while the supporting visual material (images, diagrams, sketches, tables and so on) should be sent as TIFF files with a resolution of at least 300 dpi. All visual material should be clearly indicated and numbered in the text, along with the respective image captions and credits. Additionally, all manuscripts should be submitted in A4 "camera-ready" .pdf format that gives an idea of how a finalized version looks like.

Archidoct only accepts manuscripts from PhD students. In order for an article submission to be considered for publication, the student must be a registered and active member of the ENHSA Observatory (www.enhsa.net/main/observatory), a PhD research portal created to facilitate communication and meaningful information exchange between architecture doctoral students.

Reviewing policy

The peer reviewers are all confirmed educators of architecture coming from different educational backgrounds, with different specialisations and expertise that share the common interest of their doctoral students: to encourage them to publish their work while improving their thinking processes towards academic research writings. Each submitted article is reviewed by two members of the journal's Scientific Committee anonymously.

Copyright policy

For all enquiries please contact the Editorial Board at **archidoct@enhsa.net**.

For further information please visit **www.enhsa.net/archidoct**