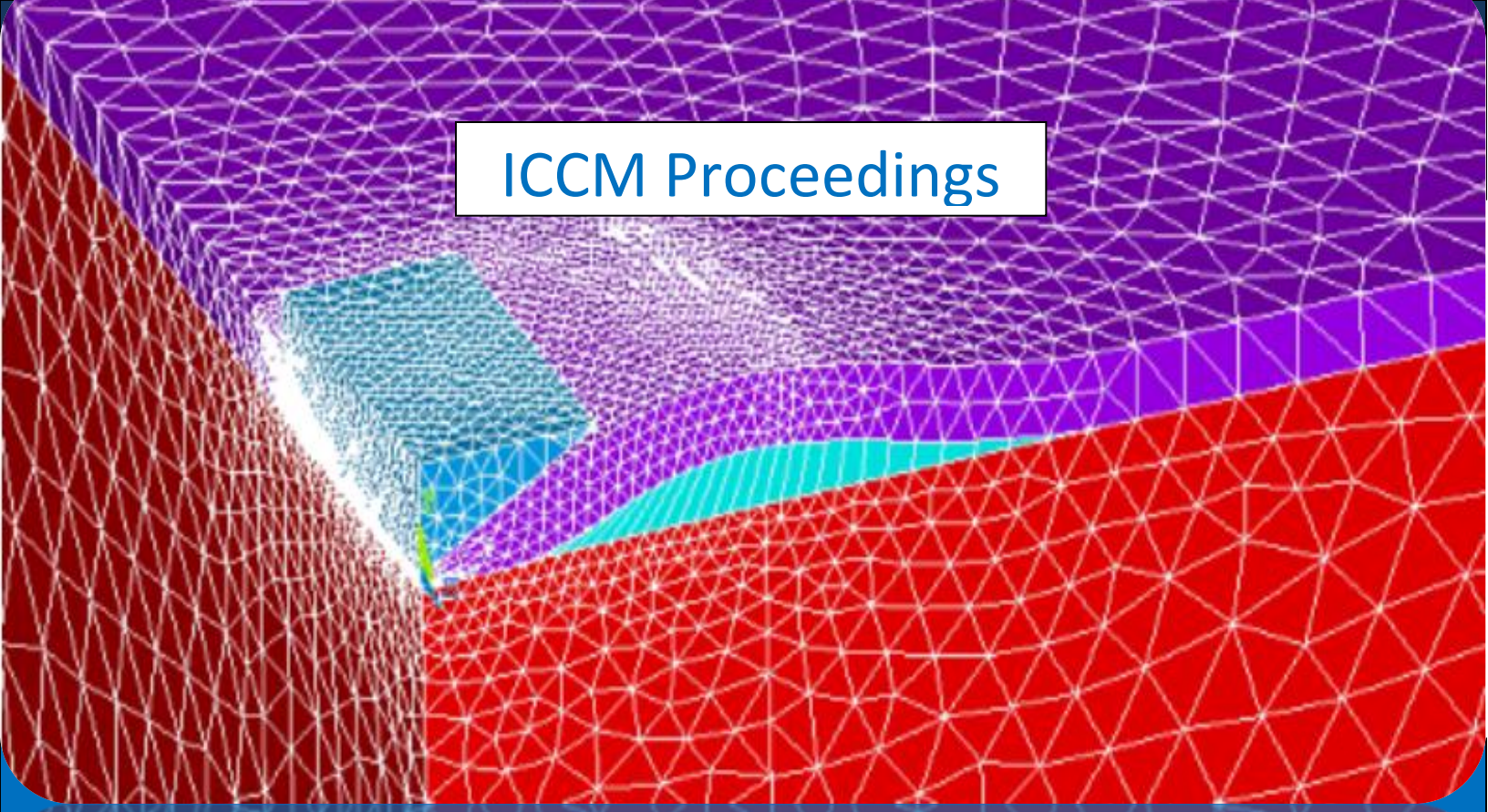

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Proceedings of the International Conference on Computational Methods

(Vol.5, 2018)

9th ICCM, 6th-10th August 2018, Rome, Italy

Editors: **G. R. Liu, Patrizia Trovalusci**

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Edited by

G. R. Liu
University of Cincinnati, USA

Patrizia Trovalusci
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PREFACE

On behalf of the organizing committee and the co-chairs, we would like to welcome you to the 9th *International Conference on Computational Methods* (ICCM2018) at the Auditorium Antonianum, Rome, Italy, between August 6th and 10th, 2018. The conference aims at providing an international forum for scholars, researchers, industry practitioners, engineers and graduate and undergraduate students to promote exchange and disseminate recent findings on both contemporary and traditional subjects in computational methods, numerical modeling and simulation, and their applications in science and engineering. It accommodates presentations on a wide range of topics to facilitate interdisciplinary exchange of ideas in science, engineering and allied disciplines, and helps to foster collaborations.

Computational Modelling and Simulation are fundamental subjects in engineering and sciences. They can be applied to many of the primary engineering disciplines, including Aerospace, Bio-medical, Civil, Chemical, Mechanical, and Materials Engineering among others. Computational Modeling and Simulation covers a broad range of research areas, from conventional structural and mechanical designs, failure analysis, dynamic and vibration analysis, and fluid mechanics up to cutting-edge computational mechanics, nano-micro mechanics, multiscale mechanics, coupled multi-physics problems and novel materials. This is reflected in the variety of fields featured in the conference topics.

The genesis of the ICCM series dates back to 2004, when the first ICCM2004 conference was held in Singapore founded and chaired by Professor Gui-Rong Liu, followed by ICCM2007 in Hiroshima, Japan, ICCM2010 in Zhangjiajie, China, ICCM2012 in Gold Coast, Australia, ICCM2014 in Cambridge, UK, and ICCM2015, Auckland, New Zealand, ICCM2016, Berkeley, California, USA, ICCM2017, Guilin, Guangxi, China. The present ICCM conference in Rome, Italy encompasses about 330 oral presentations organized in 64 Mini-Symposia and general sessions, including 3 Plenary Lectures, 14 Thematic Plenary Lectures, and several Keynotes.

The ICCM conference is unique in the sense that it showcases the current developments and trends in the general topic of Computational Methods and their relationship to global priorities in science and engineering. We would like to express our gratitude for the contributions of all ICCM2018 participants and presenters at this international event. We gratefully acknowledge the contributions from the International Scientific Committee, Mini-Symposium Organizers, and expert reviewers for their efforts and assistance in the organization. Special thanks go to Dr. Nicholas Fantuzzi for his efficient assistance to the scientific organization of the Conference and his patient handling of bureaucratic issues. We thank also the volunteers and the local staff in helping out in the organizing and running this important event.

Finally, we would like to warmly thank you for the contribution of our authors and participants in making ICCM2018 in Rome a very prominent scientific event. We believe the ICCM2018 has become a special event that widens the bridge between West and East in our worldwide community for computational methods.

We are looking forward to your participation and continued engagement for the future ICCM conferences, and contribute further in the development of computational methods.

Professor Patrizia Trovalusci
Conference Chairman, ICCM2018
Sapienza, University of Rome, Italy

Professor Gui-Rong Liu
Honorary Chairman, ICCM2018
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Computational Methods in Architecture from theories to architectural design

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Abstract

Almost thirty years have passed since the mid-eighties, when the digital has burst into architectural design and production. From the initial experiments and theoretical enthusiasms, practiced in geographical, political and cultural different contexts where traditionally there was a strong relationship between design, technology, administrative institutions and industries, we have achieved some widespread and standardized results in software industry, processing, production, profession, spanning from experimental computational applications to Building Information Modeling. What will be the next conceptual steps and tools and in which specific fields it seems that the use of Computational Design be strengthened? This paper tries to reassemble the wires between the experimenters' generation, their earlies disciples strongly engaged with theoretical works, and the awake of the historians on the digital and the computation design in architecture.

Keywords: **Computation, Architecture, design.**

A retroactive awareness

Almost thirty years have passed since the mid-eighties, when the digital has burst into architectural design and production – after the personal computers spread at large scale – allowing today to read within a historical perspective the most significant past experiences and to detect issues anticipating how technology will continue to influence architecture in the near future. Since then, the use of computer technology in the design and in the building process of architecture has considerably grown.
The deanship (1988-2003) of Bernard Tschumi at Columbia University of New York, Graduate School of Architecture Planning Preservation signed a further phase of architectural postmodern culture, based on technological innovations, – digital design (research on form, style), widely disseminated by architectural journals and magazines as Architectural Design, and computing sciences applied architecture (BIM, prototyping, 3D printing, form-finding, parametricism) – competing with similar experiences already started at MIT (Negroponte, Media Lab 1985) and Harvard Laboratory for Computer Graphics and Spatial Analysis (Eric Teicholz, Jack Dangermond founder of ESRI), established in 1965.
From the initial experiments and theoretical enthusiasms, practiced in geographical, political and cultural different contexts where there was traditionally a strong relationship between design, technology, administrative institutions and industries, we have achieved some widespread and standardized results in software industry, processing, production, profession, spanning from experimental computational applications to Building Information Modeling.
In this new field of research – at that time – a giant as Frank Gehry certainly made digital design as the fundamental tool for linguistic exploration and for research on the construction methods to produce architecture. Gehry has played a decisive role for several decades positioning his practice – hardly imitable – between the development of digital design and the spread of software and assessment systems with the foundation of Gehry Technologies, at first getting patents and than selling the company which keeps still his name.

During the last fifteen years, after an initial phase of individual engagements (scholars, groups and institutions), the research results were spread establishing teaching courses and programs, with a special emphasis provided in cutting-edge schools: Digital Research Lab at Architectural Association London, Sci-Arch Los Angeles, Angewandte Wien, MIT Boston, Columbia New York, Cornell Ithaca, ETH Zurich. But recently courses focused on topics as Algorithmic Architecture and scripting, Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technologies emerged also in other architectural schools not traditionally engaged in these researches (Stuttgart, Chalmers, Cardiff, etc) with the intention to expand or reinforce their academic programs.
However, after an in depth analysis related to the institutional and industrial relationships and academic networks you would understand how decisive were the linkages and nexus between institutions, market, academia, simplifying the discourse between clients and researchers, politics and visionaries. For example, how important the relationship between Ian McHarg and Jack Dangermond (founder of ESRI and McHarg's former student), was for the work on "map overlay" concept in landscape discipline and the development of GIS. How consistent was the work of Harvard Laboratory for Computer Graphics with the American Census Bureau and the geographers' digital research at territorial scale. How strategic was for the American architectural profession to instruct young architects in the use of digital 3D software to standardise the drawing production for the construction industry passing by the organization of the drafting, designing, making physical models, drawing work in the architectural office and the acquisition of a specific software license. Therefore, also the strong commitment of Nicholas Negroponte, Leon Groisser and Jerome Wiesner (MIT president) with the defence research, the National Science Foundation and private corporations. In a seven year found raising period, infact, the Negroponte's Architecture Machine Group collected 40 million dollars – in which 40 corporations pledged their pre-commercial research budget – with the support Dean Lawrence Anderson who sought to challenge traditional architectural pedagogy: the Beaux-Arts teaching method exercised what he called a "residual influence [that] remains as an incubus that dampens our enthusiasm for any panacea"[1]. Not to talk about Buckminster Fuller and his geodesic domes and the interest on them of the American Army.

Imitation-Modeling

What will be the next conceptual steps and tools and in which specific field the use of Computational Modeling in architecture will be strengthened?
From the point of view of Italian Architecture schools their an increased challenge to enhance the integration of computation design in their curricula since enormous revolution occurred establishing the mandatory use[2] of Building Information Modeling, within five years, in every public tender.
It could be useful to recall that in 2005 the School of Architecture "Ludovico Quaroni" of Sapienza University of Rome organized a Symposium[3] on the education of architects with a special panel titled "Digital innovation in architecture", chaired by Antonino Saggio, which hosted Patrik Schumaker, Vasili Stroumpakos, Manuela Gatto, Mark Goulthorpe, Ed Keller, Karl Chu, Claudio D'Amato, Lucio Barbera and Giuseppe Longo [2] a mathematician from the CNRS Ecole Normale Supérieure, Paris. Longo had been invited to offer an overall comment to the researches of the architects making extensive use of computing design. His perception was almost tough after participating to the panel presentation of the experiments presented, concerning biology and computing processes 'applied' in/to architecture during the Roman symposium – especially the "Responsive Environments" by Schumacher and the "Human Genome Project" by Karl Chu. Longo observed that: "In contrast to the problem of intelligibility in the sciences of nature, for you

[1].See Radical Pedagogies: http://radical-pedagogies.com/search-cases/a13-architecture-machine-group-media-lab-massachusetts-institute-technology-mit/

[2]. New Public Works Code, active since 2019.

[3]. Dean Lucio Barbera organized the Symposium "Becoming Architect in the XXI Century" from January 20th to 22th 2005. Proceedings, Anna Irene Del Monaco (edited by) Becoming Architect in the XXI Century, Casa Editrice La Sapienza 2006.

[architects], it seems to me, that the role of the mathematical instrument – now information technology – is that of *aid to invention*, in this very complex game between science and artistic fantasy that is precisely the architectural design of a 'thing that is not there'. And 'this' determines a radical difference from the point of view of the relationship with information technology and its tools, in particular, and at the same time the problem is even richer in its internal logic deserving a reflection. The extraordinary novelty we are confronted with is the fact that today we have a machine that is the result of a very complex historical-evolutionary path. This machine was not there, in the same way that 200 million years ago there were no mammals on the face of the earth."

Longo was making reference in his discourse to the Turing machine, a mathematical abstract concept, an indispensable clarification to architects referred to the non "scientific" (intelligibility) approach in their simulation (or imitation) "games". In particular Longo in one of his paper [3] had already discussed this arguments taking of the double pendulum digital simulations. If you click "restart" relaunching a virtual pendulum – as Schumacher's did in his "Responsive environments" presentation – with the same initial data it tends to cover all the possible trajectories (a chaos aspect) "but with a real physical pendulum, not a virtual one, in a dynamic (non-linear) system – because of the thermal fluctuation, the density of trajectories –, "once reinitialized, the systems never take the same trajectory. [...] Specifically, we will see that the digital machine proposes causal structures and the breaking of symmetry which generate them as being the central structures of the intelligibility of nature. This will enable to point out a distinction between 'imitation' and 'modeling' in terms of simulation or formalization, and therefore enable to highlight the limits and the potentialities of digital simulation. Such a machine is the culminating point of a very specific process which begins with language, but which is mainly influenced by the birth and development of the alphabet: the digital machine is at first an alphabetic machine, and then a logical and formal one". This argument would deserve a consistent and wide discussion in architecture, especially the distinction between imitation and modeling – imitation resemble causality, Longo claims – and which is, more or less the distinction that some scholars as Achim Menges [4] raise quoting Rob Howard. As Menges (and Howard) belong to a ideal group of researchers – "a research tradition" – which understand the necessity to distinguish the process of designing to build (o "fabricate") towards the necessity to design for in search for authoriality [5, 6], to which the Zaha Hadid and Coop himmelb(l)au approach to architecture belong: "In parallel to the development of Computer Aided Design, which is characterized by the transfer of long-established, representational design techniques into the digital realm, research into generative Computational Design has been conducted for many decades. In the 1960s design programs such as GRASP (generation of random access site plans) developed by Eric Teicholz at the Harvard Laboratory for Computer Graphics, explored ways of generating rather than drawing design solutions and evaluating their performance (Howard 1998)."

Going back to Longo's comment on the Turing machine and recalling its conceptual newness, it is interesting to read that "in short, it is an invention which is both extraordinary and contingent to our culture, which is marked by the birth of the alphabet, of Cartesian rationality, of Fregean logic, of Hilbertian formalism" […] The 'principles' which are inherent to Physics (modern Physics), an interval and the inevitable variation, below the threshold of measurement, suffices to vey quickly produce a different evolution. The analysis of the equations within the continuum leads to an understanding of the random aspect of chaos, whereas computational imitation makes it disappear completely, but the discrete nature of its data types."

Longo's assumptions remind us the idea of Antoine Picon when asserts that it is the information based society which invented the computer and not *viceversa* [7] – showing in his lectures a picture of the Prudencial Company (financial, insurance, retirement, investment company) at the turn of the nineteen century – and that the concept of diagram in architecture has failed – mentioning the lost promises of working on fluxes diagrams by UN Studio –, being in the end more the development of a Beaux Arts approach than something different and that, looking at a different aspect, the Building Information Modeling system imposes the idea of "who is allowed to do what and not the implementation of the idea of a fluid world".

Not just a happy accident !

The way of approaching 'imitation' and 'modeling' put the work of an entire generation of academic-architects under a different perspective and recalls the objective meaning of the term "Computer Aided Architectural Design..." which literary could mean "aid to invention" and provide some advice to follow especially when we teach and make analogies, comparison with the natural, physical and abstract realities.
The generation of Frank Gehry, Peter Eisenman, Zaha Hadid, Coop Himmelblau, Future System, although starting the use of computer in their fifties or sixties – and in many cases with them having no direct personal skills in the use of computer –, made a significative use of computer aided design to enhance the possibility to draw, design, conceive, assess and build their architectures. Albeit it was also a generation intersecting the computational early tools with the Deconstructivist Architecture discourse, as Philip Johnson implicitly demonstrated with his exhibition at MoMA of 1988. This is the case of a generation of architects "that told to the computer what they wanted to have!", affirms Greg Lynn in a conference at the Architectural Association of 2013 [4]; the results was not "just a happy accident", like often happen to unconscious native digital students which act out of cultivated awareness – Lynn continues. It is the case of a generation of architects which found the way to transfer the information of their drawings into to the frame space structures system in order to build their projects. Each of them found in digital architecture a way to "complete" their intellectual impulse toward construction. Eisenman, following his theoretical impulse, did not disdain "the idea of genetic based architecture" and fed up a generation of younger practitioner and thinkers (included Greg Lynn), and built the uncompleted Santiago de Compostela project. Hadid (a graduate in mathematics before architecture) wished to escape the condemnation of being a paper architect. Gehry got the artistic intuition (the most advanced intellectual stage) to select the right tools for his formal research and was able to make business with them too.

Archaeology or pre-consciousness?

It is highly significant that Greg Lynn, who has been a young collaborator of Eisenman and Gehry during the eighties and nineties, and one of the first hour prophets of morphogenetic design (see his Embryologic House Project), has recently written a book entitled *Archaeology of the Digital* linked to an exhibition at the Canadian Center for Architecture which he has curated with a retrospective programmatic understanding – and that leaves us very much thinking if we "pre-consciously" remember the early work by Peter Eisenman "Cities of Artificial Excavation" although Eisenman commented that archaeological is better than antiquarian. Lynn can be considered together with Hani Rashid and Lise Anne Couture, Ben van Berkel and Caroline Bos, Farshid Moussavi and Alejandro Zaera Polo, Jesse Reiser and Nanako Umomoto, Patrik Schumacher, a generation of academics strongly engaged with digital architecture which have made of that domain their avant-garde language, intellectual tool and generational strategy to enter the architectural business (academic and professional) which Antonino Saggio with the IT Revolution in Architecture and other books [8] had been monitoring in the last twenty years for the Italian and non-Italian scholars and readers. Many of these architects delivered an early or late book manifesto. In particular Patrik Schumacher [5, 6] had been ambitiously theorizing in 2010 with *The Autopoiesis of Architecture,* Farshid Moussavi wrote the book *The Function of Ornament* [9] in 2006, and van Berkel and Bos published in 1999 *Move (3 volumes)* [10].
In *Archaeology of the Digital* Lynn analyses four architectures of the eighties classifying them by the following categories: 1 Design using procedural processing; 2. Transforming robotic structures; 3. Structural optimization and expression; 4. Optimization of the digital medium. Besides the book the exhibition at CCA curated by Lynn in Canada included additional drawings, physical models and the interviews to the four authors delving into "the genesis and establishment of digital

[4] Greg Lynn - Conversation about Digital Archaeology, Architectural Association 2013-10-10; https://www.youtube.com/watch?v=U2ujuFMYkzA&t=4077s

tools for design conceptualization, visualization, and production at the end of the 1980s and the beginning of the 1990s. Conceived as an object-based investigation of four pivotal projects that established distinct directions in architecture's use of digital tools, the book highlights the dialogue between computer sciences, architecture and engineering that was at the core of these experiments". The four architectures that Greg Lynn selected are discussed in his book considered also the specific software and methodology, drawing techniques used for their design and eventual construction, probably in search for a "pre-conscious origin of the digital", as Peter Eisenman affirmed in the interview released for the publication and for the exhibition [11]. 1)The Peter Eisenman's Biozentrum (1987) (Figure 1) to which Lynn worked as a young architect, was drew by the software Form Z integrating the digital drawings by a craft assessment system (layer copies of the variation of geometries superimposed, produced and mailed by Fed Ex every day from a laboratory located elsewhere). 2) The Chuck Hoberman's Expanding Sphere (1992) (Figure 2), in which the author used his own scripts hand-written – he owns 18 patents. After graduation Hoberman worked at Honeybee robotic and got acquainted with transformable objects. The software Hoberman used was AutoVIZ, a former language from Autocad. Hoberman had been the first in architecture to use the CnC manufacturing and 3d printing. The aluminium components of the Expanding Sphere were CnC cuts and the drawing presented, rarely at that time, by computer hidden line. 3) The Shoei Yoh's unbuilt Odawara Municipal Sports Complex (1990–91) (Figure 3). Shoei came from manufacturing and is the structural engineer that Toyo Ito collaborated with for Sendai Mediatheque. The project uses space frame structure, a parametric construction technique that later on become a standard. It is the only project built by the group with the use of the trass. 4) The Lewis Residence by Frank Gehry (Figure 4), Lyndhurst, Ohio (1989-1995). For this project SOM did the Autodesk 3D model and structural analysis. From that experience on Gehry decided he wanted to manage and control the 3D assessment phase and looked for the right tools to succeed. The physical wooden model was completed by the wax/velvet cloth and pin bars. Then the house was redesigned for further exhibition and for the CCA's exhibition by the CATIA's inelegant spline surfaces. After starting using CATIA, Lynn affirms, Gehry started sketching like the spline surface. CATIA models had to be completely re-drown in Autocad, but there was a fidelity in the measure and geometries. Referring to the time in which the four projects were conceived Greg Lynn comments that after "five years later it was a total different story". Before there were a lot of correspondences back and forth from the two kind of techniques (digital and analogical): "Either these techniques were abandoned or diverged. At that time the speed of computer was slow. Analogical and digital methods were equal in speed, so that producing physical models and sheet analysis was sometimes more speed than a computer model."

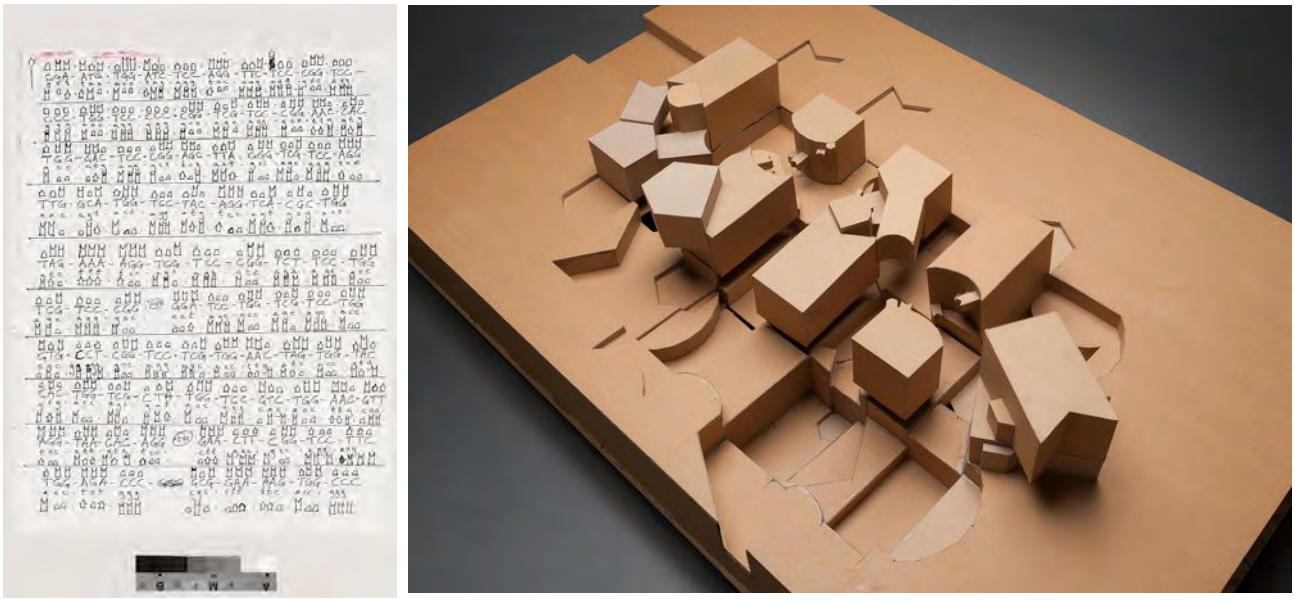

Figure 1. Peter Eisenman's Biozentrum (1987)

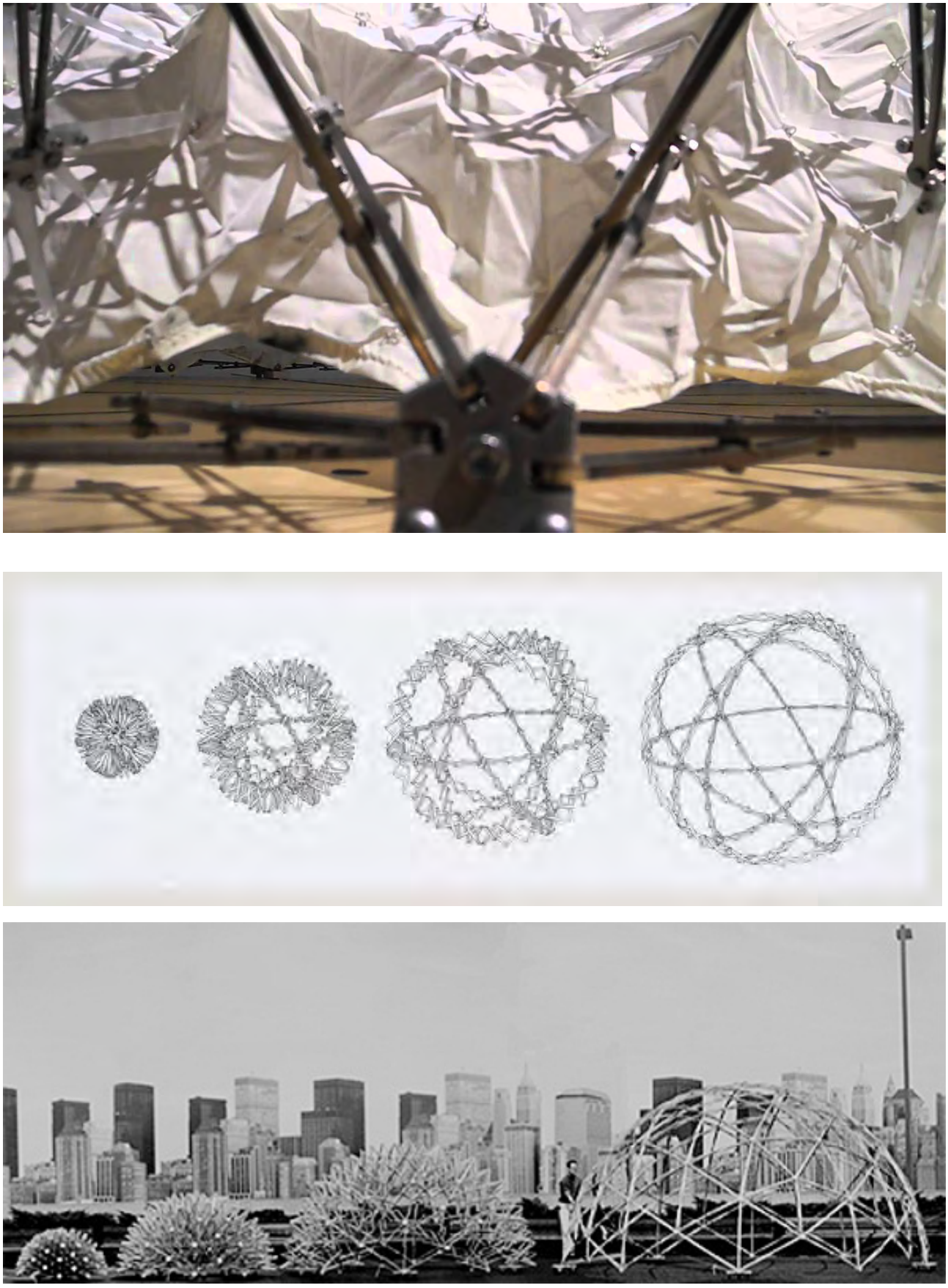

Figure 2. The Chuck Hoberman's Expanding Sphere (1992)

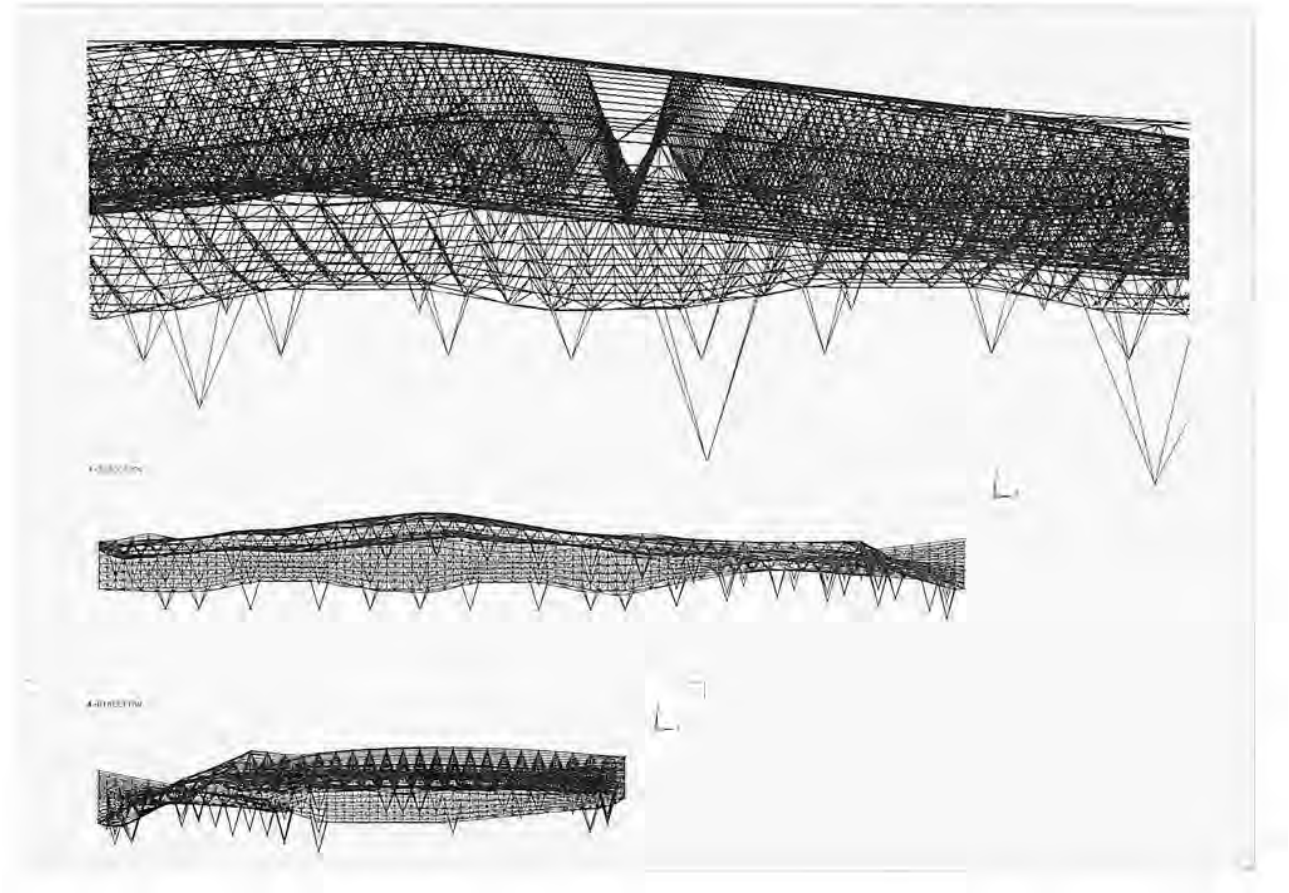

Figure 3. Shoei Yoh's unbuilt Odawara Municipal Sports Complex (1990–91)

Figure 4. The Lewis Residence by Frank Gehry, Lyndhurst, Ohio (1989-1995). The pin bars, plexiglass and wax/velvet cloth model and the CATIA spline drawing.

The awake of historians

The fact that the generation of "young" enthusiasts experimenters of the nineties in the last decade is focused on theoretical works on Archaeology (Greg Lynn, self-consciousness, quoting Eisenman again) or Autopoiesis (Parik Schumacher) and that some historians of architecture have begun to reflect on the phenomenon of digital architecture – some of which establishing that it is in a phase of "Second Turn"– tells us many things. Recently, Mario Carpo (professor of Reinassance and history of cultural technologies) and Antoine Picon (professor of History of Architecture and technology) have been doing a significant work in conducting their researches on digital architecture from an architecturals historian point of view and providing focus on different aspects, at least producing a counterpart effect with respect to the mainstream culture.

However some years ago also James Ackerman, a great historian of Renaissance architecture and Palladio's scholar, writing his contribute after fifty years to the proceedings of the Triennale Milan 1951 "La divina proporzione" (with Le Corbusier and Wittkower as chairman) introduced significant arguments. He observes that after the Modulor the "golden section" disappears from the architectural discourse and, at the end of the twentieth century, proportional systems based on plane geometry and straight spaces begin to "give way to the fluid forms of the architects-engineers contemporary of Le Corbusier": Pier Luigi Nervi, Edoardo Torroja, Felix Candela, Buckminster Fuller, Heinz Eisler. The arguments proposed by Ackerman confirm furthermore the reason why Mario Carpo and Peter Eisenman are so involved in the digital architecture discourse. In particular, the passage in which, starting from the definition of Wittkower of Renaissance architecture (Andrea Palladio, Sylvio Belli) as architecture based on number, seems to be significant, Ackerman articulates the reasoning inside and outside the scope of the 1951 conference: " But in the field of musical composition the limits of the simple Pythagorean consonances had been surpassed for more than a century. From the beginning of the 15th century, polyphonic music composers had introduced what theorists followed to define dissonances (as was shown by Robin Evans in the brilliant essay "The Projective Cast: Architecture and its Three Geometries"; it was to demolish the belief that 'ideal forms are ... in themselves, ideally beautiful')." [12] Then, in addition to addressing the work of Frank Gehry, whose "buildings with an evolved formal vocabulary [...] have made the definition of proportion" more complex, and to mention the experiments of Greg Lynn, who promoted a type of planning based on the concept of calculation and topology, the American historian highlights the theoretical and design work of Preston Scott Cohen, in particular, the book *Contested symmetries and other predicaments in architecture*, which reopens to a line of research that supports the survival of the idea of proportion.

In 2011 Mario Carpo published *The Alphabet and the Algorithm* [13] for the Writing Architecture series, a project of Any Corporation, Cynthia Davidson editor and brilliant wife of Peter Eisenman, who certainly appreciated Carpo's highly-qualified consistent engagement with both Renaissance and Digital Design. The synopsis of Carpo's book clarify what in our discourse get us reconnected to the Long's arguments on "imitation" and "modeling": "In *The Alphabet and the Algorithm*, Mario Carpo points to one key practice of modernity: the making of identical copies. Carpo highlights two examples of identicality crucial to the shaping of architectural modernity: in the fifteenth century, Leon Battista Alberti's invention of architectural design, according to which a building is an identical copy of the architect's design; and, in the nineteenth and twentieth centuries, the mass production of identical copies from mechanical master models, matrixes, imprints, or molds. The modern power of the identical – Carpo writes – came to an end with the rise of digital technologies. Everything digital is variable. In architecture, this means the end of notational limitations, of mechanical standardization, and of the Albertian, authorial way of building by design".

A significant advice already came from ACADIA members. CAD technology, had already be introduced in the postwar era and adopted in architectural practice beginning in the 1970s, affirmed Yehuda E. Kalay [14] – founding member, and past president, of ACADIA (Association for Computer Aided Design in Architecture), and former co-Editor-in-Chief of Automation in Construction – already in 2004, "CAD [goes] beyond the improvements in drafting, modeling, and rendering for which it is commonly used. Computer-aided architectural design (CAAD) is capable of modeling and manipulating objects (not merely their graphical representations), reasoning about and predicting performance of design solutions, generating new design solutions through algorithmic and other methods, managing vast amounts of information, and taking advantage of opportunities offered by the Internet for collaboration across time and space and for design of the virtual 'space' of the Internet itself."

Moreover Carpo came out recently with anther book, *The Second Digital Turn,* whose synopsis shows the further conceptual steps proposed by the Italian historian: "Almost a generation ago, the early software for computer aided design and manufacturing (CAD/CAM) spawned a style of smooth and curving lines and surfaces that gave visible form to the first digital age. […] this is because the design professions are now coming to terms with a new kind of digital tools they have

adopted – no longer tools for making but tools for thinking." In March 2018 the author presented the main contents of his late book in a lecture [15] to a non-architects audience (Google's employs) at University College London and used the metaphor of fishes, potatoes and dogs. " Frank Gehry started with a fish!" the historian explained, talking of the fish streamline sculpture by Gehry built along the Barcelona waterfront and of the "spline" working methods of CATIA which impressed the streamline also to other Gehry's projects, from the Bilbao Museum up to the Foundation Cartier. Carpo discussed also about the spread of softwares as Rhino, Maia, Form Z, cheaper than CATIA, in the teaching courses and in the profession and the fact that today computers are faster and cheaper, and that big data and environment are emerging issues to be considered. So that, according to him, the style produced by the software used in the most recent years shifted from fishy (Gehry's CATIA) to doggy (Heydar Aliyev Center, Baku by Zaha Hadid Architects), a less sophisticate streamline developed by a very simple algorithm. Unlike "fishes", "potatoes" and "dogs" belong to the free-forms category and have no sophisticated mathematics embedded inside their geometries. The reason why Carpo consider the current condition a "second turn" depends on the fact that for architecture the technical bottleneck is always determinant. Architecture is always at the mercy of the tools that make it happens, and his authoritative discourse upholds what I tried to demonstrate in a comparative study between composition in music and architecture [16] too.
The Italian born historian was particularity bright in clarifying during his London talk that architecture is a liberal-art and not a scaffolding art and that even though drawing is a notation system used to eventually build "architects can enter the spirit of the game better than other professionals, since they uses simple software and have the building phase as a feedback loop, although computing is not their game but your (google's people) game..."

Geometries, families of solutions, fabrication

However geometry is at the base of every discourse. Also Mario Carpo recalls that his main arguments are related to the shift of quantification from algebra to calculus. Euclidean geometry, a quantification and proportional system, was typical of Greek and Roman architecture, while numbers and arithmetic are the proportional system specific of the neoclassical architecture. Then, Carpo remind us that with Pierre Étienne Bézier there is the culmination of western mathematic, after the work of Descartes, Leibniz, Newton which were able to notate conics but not complex geometries like Gehry's "fishes" – Jean Louis Cohen has started to study Frank Gehry from an architectural historian point of view [17]. Other relevant contributes to the question of contemporary geometry, fabrication and construction are elaborated by ETH Zürich research teams as he Block Research Group (BRG), also established at ETH Zürich hosts led by Philippe Block and Tom Van Mele, whose experiments were hosted at the Venice Biennale 2016 (Figure 5). Their research focuses on the analysis of masonry structures, graphical analysis and design methods, computational form finding and structural design, discrete element assemblies, and fabrication and construction technologies, geometry based approach. The Block Research Group of ETH Zürich works are somehow on the track already traced by Pier Luigi Nervi and Sergio Musmeci (Figure 6). Another significant contribute from the ETH Zürich is the book *Architectural Geometry* [18] edited by Helmut Pottmann, Andreas Asperl, Michael Hofer, Axel Kilian and published by Bentley Institute Press – Bentley is the company releasing Microstation, a software used, for example by Forster and Partners. Shajay Bhooshan, graduate from AA London and Lead Designer, Zaha Hadid Architects Computation and design group, is completing his PhD with Block Research Group office and has been a bridge for experimenting collaboration between ETH and ZHA office. There is another interesting contribute coming from Southern USA: Ronald Rael and Virginia San Fratello and their practice Emerging Objects (Figure 7) together with their teaching activity at UC Berkeley and Arizona University demonstrate the impact of computation on a different kind of architectural and construction tradition and materials as clay and hearth [19, 20].
Ali Farzaneh and Elif Erdine chaired an interesting conference [21] at the Architectural Association London within the Symposium "Advancements in Design Computation" on February 2016. They

invited Antoine Picon (GSD Harvard), Achim Menges (Stuttgart University), Francis Aish (Foster and Partners). Picon focused on the importance of the concept of "materiality" – not "materials" – to understand digital architecture, in the sense of Condillac's treatise on the sensations (senses and matter), and of Boulle's relations between human subjects and the material worlds [22, 23]. Achim Menges's [24] – raised within the Emergent Technologies group at the AA London, developed and inspired by the morpho-ecologies of Michael Weinstock – design approach is also focused on "materiality" to what extent you can push the limit of design toward material systems. Menges reveals to be among the most promising experimenter in the future, for the philological clearness in the research of coherence between the use of the material, the structural geometrical conception (derived form the material morphogenetic character) and its fabrication (Figure 8). His work is highly inspired by nature, biology, material behaviour (spider works: pneumatic inflations; lobster shells' cavity and fabrics) and by the possibility to synthesize the capability of a machine to imitate the "modelling" not the form o a spider or a lobster, etc. (Figure 9).

Figure 5. Block Research Group. Above: Construction prototype for ultra-thin concrete roof; Down: vaulted form made up from two layers of a new type of compressed earth blocks, Durabric, developed by the LafargeHolcim Foundation for sustainable construction.

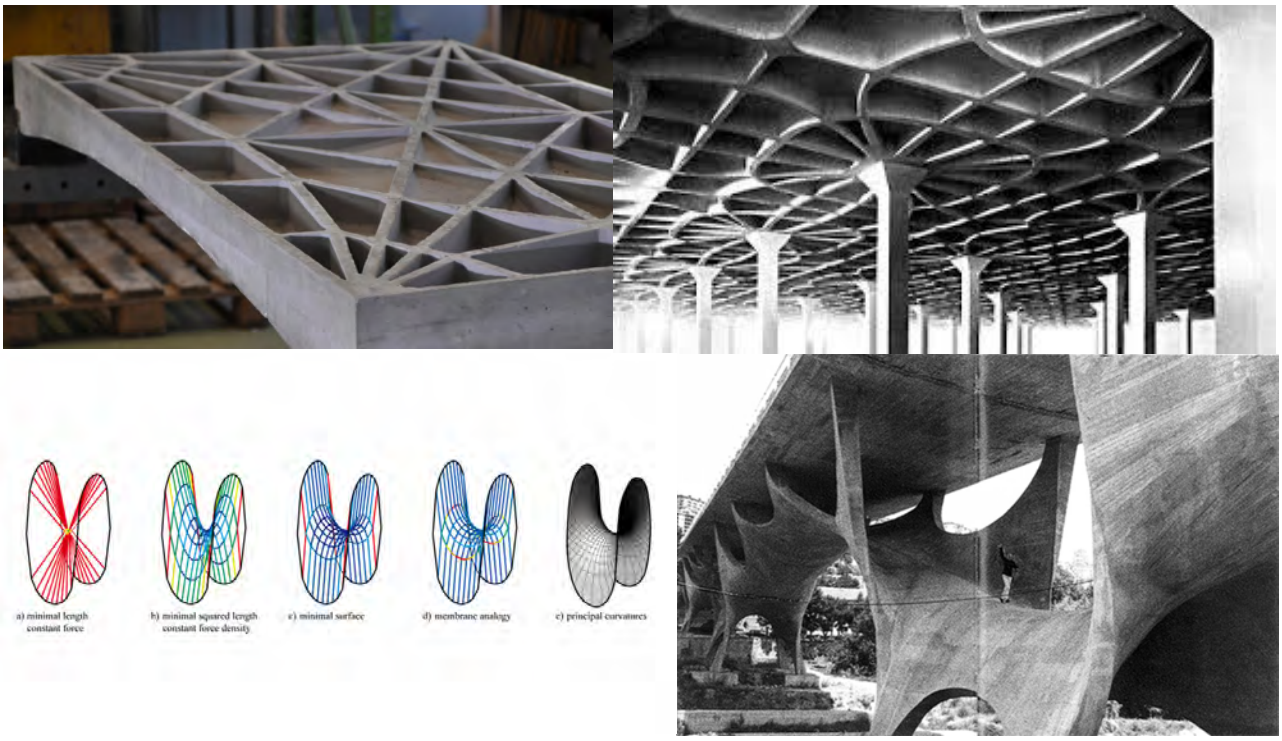

Figure 6.up-left: 3D-printed floor system by Block Research Group; up-right: Industrial warehouse "Lanificio Gatti" (1951-1953) by Pieri Luigi Nervi, structural concrete. Down-left: Comparing form finding methods by Block Research Group; down-right Ponte sul Basento (1971-1976), by Sergio Musmeci.

In the same conference after the advanced experiments by menges, Francis Aish from Foster & Partners, presented a number of project revealing the other side of computation potentiality applied at the top level professional world: to accelerate the design process. In particular the Dresden Railway station project in 1997 and the Beijing New Terminal Airport for the 2008 Olympics are a demonstration of how to shorted the time during the design decision. In Dresden's project the canopy system and form-finding system were integrated arriving to a solution in less than one hour. The roof of Beijing Airport represents a low-tech intense project: 3,5 years to design and built the entire airport and 1,5 years to complete the roof by a space frame structure system with 5,000 workers (Figure 10).

To conclude, Picon and Carpo have a similar opinion toward the impact of Artificial Intelligence in architecture. The French historian says: "in twenty years from now we will have much more sophisticated software that we will enable to produce a lot of solutions (families of solutions) [25] and there will be a problem of choice, which is also one of the fundamental way to understand information [21]. The Italian historian maintains: "computational design is already a fascinating testing ground for Artificial Intelligence since the staff we do are simple and cheap and software we use are elementary and we do physical things, so the feedback loop, the verification stage, is faster probably than in other professions." [15]

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Figure 7. Ronald Rael and Virginia San Fratello, Emerging Objects: "Cabin of Curiosities" (4.500 ceramic tiles) Oakland, 2018; "Bloom Pavillion", 3D print cement (This structural system was inspired by the *Iglesia Cristo Obrero* of Uruguayan architect and engineer Eladio Dieste and Jefferson's serpentine brick walls at the University of Virginia, while the precise form was inspired by Richard Serra's *Torqued Elipse.*)

Figure 8. Achim Menges. Above: Elytra. Filament Pavilion (Robotic Pavilion) for V&A Museum, London; Down: Component Membrane AA London, 2008.

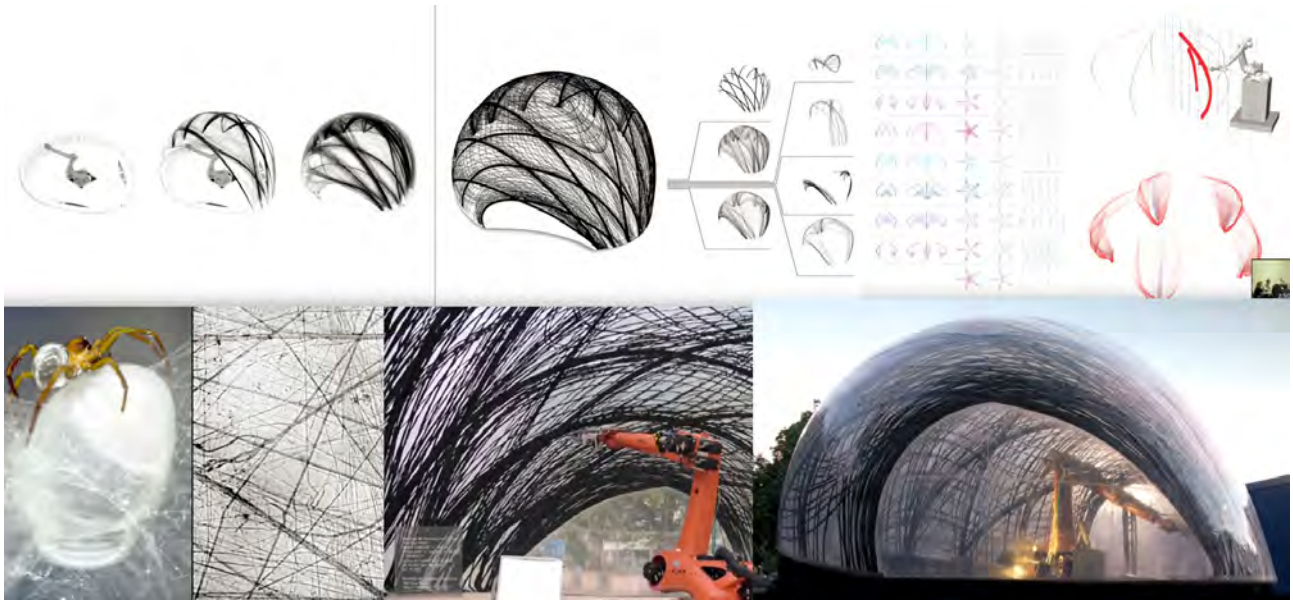

Figure 9. Achim Menges, ICD / ITKE Research Pavilion inspired by the submarine nest of the diver spider.

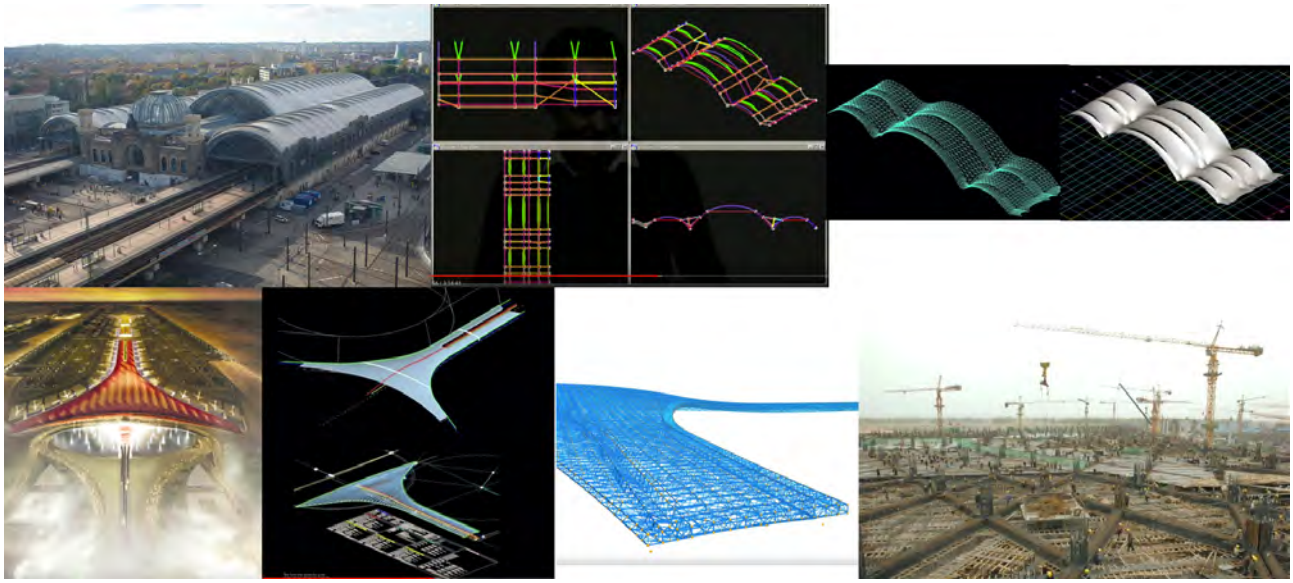

Figure 10. Foster & Partners (Francis Aish): Above: Dresden Railway Station, 1997 Refurbishment; Down: The Beijing Capital International Airport, 2008