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Digital Revolution in Current Architecture: Towards a New Architectural Expressivity

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History of Architecture teaches us how tight is the relationship between innovation and changes in architectural expressivity and design through the centuries. These innovations may occur in the own territory of architecture, e.g. with the introduction of new materials or building technologies, or they may be classified within disciplines external to architectural subject, but which can have considerable repercussions on it.

This is very evident if we look at the changes occurred to architecture during the whole XX Century, until the explosion of digital revolution in 2000s which irremediably has changed designer's scenario. Gradual but significant changes have occurred in expressivity and in conception of architectural space and its organization since Post-War, derived by a combination of influences, from innovations in materials and technologies, to the social questions and reconstruction matters, that have produced new dynamics of urban transformation (Frampton, 2007).

However, in recent years main trend of contemporary architecture seems to take advantage of the innovations occurred in the field of science and technology in the broadest sense. About this, Ignasi de Solà-Morales (1997) says that *'having abandoned the discourse of style, the architecture of modern times is characterized by its capacity to take advantage of the specific achievements of that same modernity: the innovations offered it by present-day science and technology. The relationship between new technology and new architecture even comprises a fundamental datum of what are referred to as avant-garde architectures, so fundamental as to constitute a dominant albeit diffuse motif in the figuration of new architectures'.*

Indeed, the advent of computer in Architecture in the early '90s generated a new way to conceive design, that is consequently reflected on the aesthetics of last period architecture. But, by giving a look at buildings, it is evident that we are dealing not with a *style*, but rather with a multiple expressive trends present at the same time and in different places. It is not any doubt that we are inside a revolution of methods, processes, thinking (Pellitteri and Riccobono, 2012). Nowadays we can talk of *Post-Digital Age*, because the first effects of this revolution are strongly evident on global scale (Spiller, 2009).

Goals of this research were to understand the real influence of digital technology in architecture, what this influence has produced on the architectural language,

which are dominant trends of contemporary architecture and which is their cultural background. Hence, it seem fundamental beginning our treatise with a brief history of architectural computing.

Historical and cultural background: computer and architecture

Starting from the invention of the first electronic calculator, ENIAC (Electronic Numerical Integrator And Calculator) developed by John von Neumann in 1946, we owe to Ivan E. Sutherland the first application which can perform drawing functions (Sutherland, 1980). *Sketchpad*, a software that experimented new forms of interaction between operator and computer by using a light pen and a CRT monitor, was developed in 1963 and is considered the precursor of the CAD (Computer Aided Drafting) software (Fig. 1).

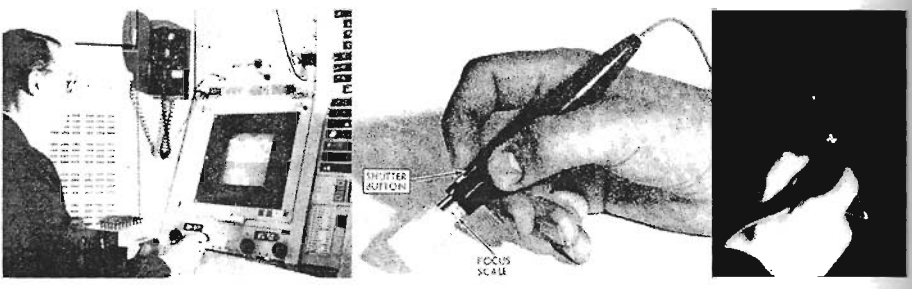


Figure 1. Sketchpad in use (credits: I. E. Sutherland)

A key date for architectural computing is the 1982, when John Walker, founder of Autodesk, released of the first commercial version of Autocad® and then the CAD software began to enter into the designer's practice. The main problem was linked to prohibitive costs, mainly of hardware and consequently of software. At first it was unclear which kind of real contribution could be given to profession by programs. We have to wait until the early 90is before the CAD software is partially used into the studios. Their contribution was only related to the potential of representation, making faster the drawing process and unnecessary the *old* set squares. The screen of computers were used as a paper sheet, designing and drawing in a traditional way, and later, creating three-dimensional images which undoubtedly augmented the designer's possibilities of space exploration.

This happened to profession, while at the same time academic research confronted itself with the great possibilities for architecture offered by computation. Indeed, exactly in this period there was the birth of the first CAAD associations, as eCAADe (Education and research in Computer Aided Architectural Design in Europe), ACADIA (Association for Computer Aided Design in Architecture), CAAD Futures, etc., with the main aim to organize annual conferences where to share knowledge about architectural software and experimentations with it. Even if the main contribution was given by academia, also practitioners and software developers participated to the congresses, mainly in order to take advantage of the most interesting studies which could become parts or add-on of programs.

The next step was to understand that the potential of the CAAD was not related only to the architectural representation, but also to the ability of control and management of the design. The use of these programs has undoubtedly expanded the representation possibilities of the architectural object. It has also triggered a revolution in design methodology linked to almost endless possible experimentations with the architectural space. Geometrical concepts and principles are foundation of the current and popular software for graphics, which allow a three-dimensional control of forms. From concept to modelling, or sometimes from modelling to concept, the step is increasingly short, because in real time the designer can have the perception of the whole process at the base of the construction of the architectural space. Hence, in the late '90s some avant-garde architects tried to bring computation inside design process with the goal to develop a new design methodology linked to a new way to intend the architectural space, which had to be more connected with other science, like Mathematics and Biology. Of course projects as the Moebius House by Un Studio or the HtwoO Pavilion by NOX (Fig. 2-3), both built in 1997, are expression of that intent and are pioneers of the *new* architecture. But their conception and then the construction were possible only thank to the new possibilities given by CAAD, so as geometrical control in the realization phases and CAD-CAM interface, which allowed the use of personalized shapes for envelope components, metal profiles, glasses or formworks.

Figures 2-3. The Moebius House by UNStudio in Het Gooi, Netherlands and the HtwoO Pavilion in Neeltije Jans, Netherlands by NOX.

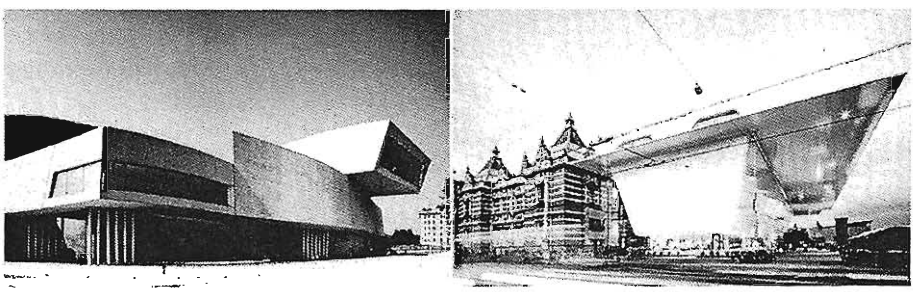
After these pioneer projects, the triumphal entry of computing in architectural design became evident; everyone is able to recognize that something is changed and that new expressivities are derived from software use. Despite various claims in academic publications, software publicity, manifestos and architectural criticism, it is unclear what these influences entail and what is their significance (Riccobono, Koutamanis and Pellitteri, 2013). It seems that the only way to recognize digital influences is what designers or some critics declare. Then, there is an absence of research on what direction architecture is taking under the influence of computation and on which trends are absolutely prevalent.

Research Methodology: case-studies inclusion criteria and analysis

To carry-out this research, we chose to avoid opinions (either from academia or from

practice) and focused instead on the actual *products* of architectural practice, by analysing sixty recent building clearly influenced by digital methods or techniques. The analyses were conducted in a uniform, objective manner and collected in a feature-based structured case base that allows a wide variety of queries on the identified features.

The case-studies were chosen from the high end of contemporary architectures. They are buildings well known in the academia and among practitioners and experts, realized in the last 15 years. Moreover, this difficult selection among projects published more or less everywhere on architectural magazines was carried out also taking in consideration the claim or publicity earned among not-experts and simple users. E.g. the construction of buildings like the maXXI Museum in Rome or Stedelijk Museum extension in Amsterdam (Fig. 4-5) had generated diffuse polemics on newspapers, critics from public, apologies from municipalities and institutions and so on.



Figures 4-5. maXXI (2010) by Zaha Hadid in Rome and Stedelijk Museum extension (2012) in Amsterdam by Benthem Crowel.

Furthermore we have chosen not to include projects that exist only on the paper because this does not permit analysis and evaluation of many aspects, e.g. tectonic issues. Buildings are from all over the world, since the effects of digitization on current architecture have been not dependent on urban and geographical contexts, and moreover they were not chosen on the basis of typological or functional criteria, but digital influences are evident e.g. both in a theatre and a house.

The database

Then, we chose to collect all the case-studies in a database, where each building is described by a number of predefined parameters. This decision is linked to the kind of analysis we wanted to carry-out, where each feature is correlated to the others. This gives us the possibility to apply a combinatorial approach and to analyse the existing relationships among several elements in a building's description, to visualize them and to interpret the results. Moreover, organizing information in a database forces us to think in a concrete way, less vague than textual discourses, according to a rigorous logical scheme, where several aspects and their interrelationships can be made explicit.

The data collection is split up in two parts. The first one is more descriptive, including categories such as. *Building Name* and *Designer(s)*, identified as primary keys, *Location (city), Country, Date from* and *to, Client, Type* and *Context.* The description is completed with pictures and design drawings and by dimensional data. We can see the main database interface in Figure 6.

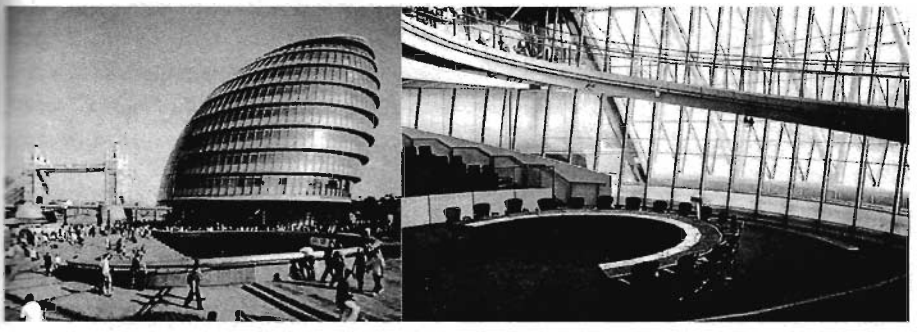


Figure 6. An example of a case-study sheet from the database.

The second part is analytical. We deal with the close examination of case-studies, studying projects both from the geometrical and compositional point of view. Firstly we have to study the taxonomy of each project, through the recognition of its *Geometry, Morphology* and *Geometric Primitives* used in a design. Then the analysis continues with the recognition of the *Compositional Concepts* (Arredi, 2006), that underlies the arrangement of primitives in a design and the recognition *of Compositional Operations* (Di Mari and Yoo, 2012), used to refine the first form and to compose the final configuration. At this point it should be spontaneous to ask which is the link with digital features.

Indeed, the database is articulated through a complex system of sub-tables, where we can add further information: about *Primitives*, we will clearly identify if they are digital-derived or not - i.e. NURBS Surfaces or free-form solids belong to computational domain; moreover we have mapped which kind of geometry is associated to each primitive. While at level of *geometry, morphology* and *composition concepts* we cannot introduce criteria related to *digitality* (Negroponte, 1995), because we are dealing with abstract concepts. At level of *Operations* we could previously define which were born in the computational domain (i.e. Folding, Boolean) and which not. In this way, we can absolutely link the morphological features of a project with its conceptual part and we are able to understand which was the contribution effectively given by digital media.

The last part of analysis is devoted to map the conceptual criteria on the basis of each design. Despite some projects could seem affine looking at their formal configuration, materials and overall style, their concepts could often start from very different point of view. We can recognize these conceptual strategies only by tightly studying what designers say in projects description and indentifying, e.g. which software were used to conceive design. Hence, we have defined a vocabulary of the

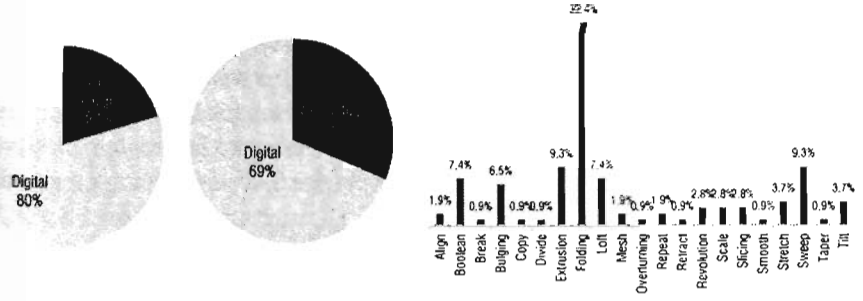
recurrent conceptual strategies derived by the use of digital technologies, describing and explaining each category in all specific aspects. Each architecture was classified according these several categories and also we have considered that some buildings might have more than one classification. Among the categories identified, we find *Blob*, term coined by Greg Lynn, which refers to digitally designed buildings that have an organic and bulged shape, as an amoeba, and *Grid*, traditionally a Cartesian structure that generates static and rational shapes, but that with computational deformations became instrument for designing forms and spaces unpredictable and changeable. Other categories, which here we limit to list, are: *Fluidity, Flows, Diagram, Pattern, Artistic Fact, Deconstruction, Folded Surfaces, Mathematical Derivation, Natural Derivation, Performance* (Pellitteri and Riccobono, 2012).

Results and interpretation

The results are derived from the setting out of several queries, through which questioning the software in order to quickly visualize the results and combinations in form of graphs, tables, reports, etc. Firstly we have queried the database to show the related prevalence for each category, setting up some simple queries. Referring to *Geometry*, we note the high prevalence of the *curvilinear* one (66%); moreover there is an high percentage of *geometrical morphologies* (70%). This shows a strongly trend towards designs with curvilinear configurations, but with a rigid geometrical control allowed by the almost endless possibilities of manipulation and deformation of the shape allowed in digital representation. On the other hand, concerning *Primitives*, which are distinguished in *prevalent* and *additional*. We found an high prevalence of digital primitives (61%) in the first order but not in the second order (only 30%).

This is an important result because it suggests that, by developing design concept, the starting point - expressed in terms of primitive - is in prevalence digital, while primitives in the second order, used to refine conceptual idea or to complete design composition, are conventional and not digital-derived. It also shows that with the introduction of architectural computing, during conceptual phase, designers have substituted the value of the *sketch*, which for centuries was the first sign to express an idea almost always unclear in the same designer's mind with the primitives currently available in each architectural software (Dorta et al., 2008). Now practitioners start with a parallelepiped or a sphere and then work on it by refining, deforming, cutting, etc.

After, we have analysed those *compositional operations* that we can easily recognize in the general design configuration. Even in this case, we have split up the category in first order, according to those operations that unequivocally were prevalent, both in dimensional and figurative terms, and second order, where we have recognized all instrumental actions that generally were used to refine the shape to reach the right consistency with design idea. Also here it is evident that a high percentage of designers have used operations totally digital. Digital operations are prevalent in both levels, primary, where generally *Folding* appears the one most used, and secondary (Graph 1).



Graph 1. Compositional operations, digital attitude and prevalence per parameter.

Formal concepts are abstract and pervasive criteria, all along existing in designer's scenario, like *alignment, symmetry, articulation,* and for this reason we cannot define any of them strictly *digital.* However, the popularity of concepts like *plasticity* (11,5%), *complexity* (11,2%) and *unity* (9,3%) suggests an emergent trend towards buildings with a unique envelope, which very often is treated as a complex surface with a curvilinear configuration that may refer to a sort of artistic plasticity. This seems a dominant motif in current architectural scenarios, evolution of organic and expressionist trends from the first half of the twentieth century – what could be termed *Digital Expressionism* (Riccobono, Koutamanis and Pellitteri, 2013).

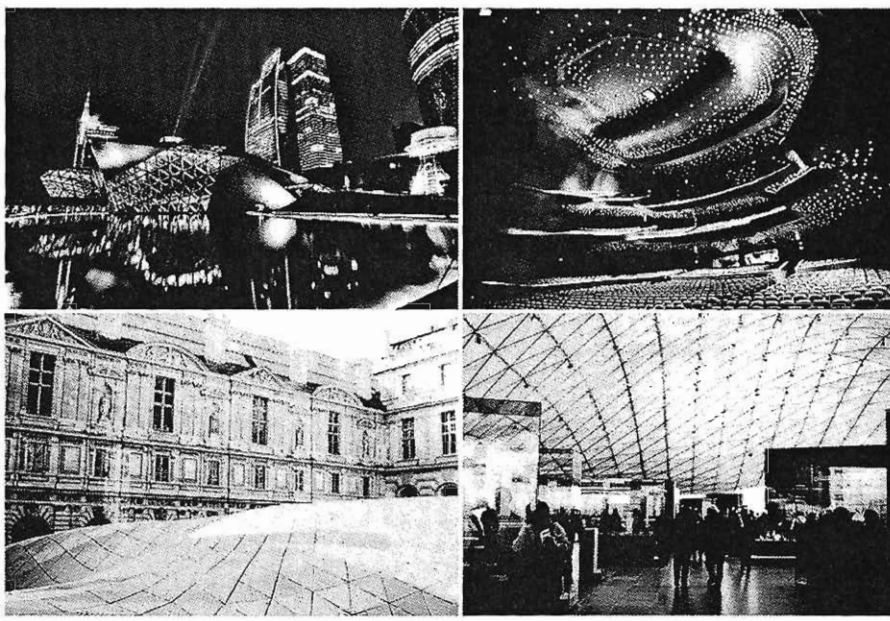
About conceptual strategies, we have observed the prevalence of *Blob,* accompanied by the important recurrence of *Artistic Fact, Diagram, Fluidity,* but there is no strong prevalence of any category, insomuch as make us able to assert that there is a substantial balance among the several trends.

New and old trends in the digital-influenced architecture

The results effectively confirms the strong influence that software has had on architecture, until the precious suggestion that the design is totally developed in the computational space, but also we have got results about morphology and conceptual strategies. Now it seems then interesting to conclude this treatise by interpreting information that we learned until now and by defining which trends are the most relevant and more represented in current architectural scenario.

- *Digital Expressionism.* As we asserted before, the main change caused by digitization of architecture is related to advances in representation field and its consequences. Indeed the easy three-dimensional control guaranteed by software has meant a change in the ways of exploration and conception of architectural space. Since the origins, prerogative of architectural design have always been the extensive use of visual methods and techniques in composition (Koutamanis, 2000) and each radical discovery in representation field had always constituted a revolution in the architectural design thinking. Nowadays it seems that morphological approach to architectural design takes over and the architectural design starts often from the curvilinear manipulation of shape, pushing to the limit the potential of software

to search for often unusual spatial configurations. It does not mean that curvilinear geometries and complex surfaces were not used and not experimented in the past; rather this trend seems the right continuation of the expressive tendencies born in the Post War, with personalities as Eero Saarinen, Hans Scharoun, Felix Candela. The main difference with respect to the '60s is the extreme facility to conceive free forms, without minding about their geometry in the first stage, and to progressively refine the configuration according to aesthetical, structural, functional needs. This is undoubtedly a pro, but it is a contra at the same time: facility and speed can make designers loose the way, not considering aesthetical, contextual and tectonic factors (Fig. 7-10).



Figures 7-10. Above, the Guangzhou Opera House (2010) by Zaha Hadid and, under, the Louvre Islamic Arts Department by Mario Bellini Architects (2012).

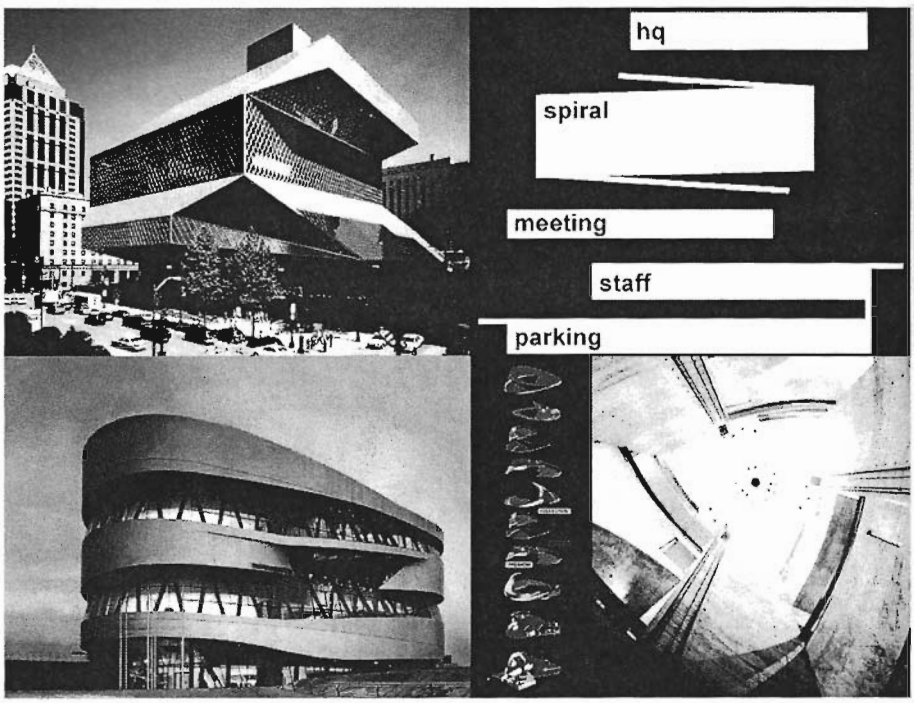
▪ *Hi-Tech evolution.* When digital media appeared in professional practice, some architects with a strong technological approach had adapted their design methodology to new software. Starting from the optimization of one or more parameters to increase building *performance*, the new software for architecture allows the creation of autonomous forms, arising from the optimization of different parameters. You can choose to focus on the structural, the climate - environmental, but also the social and procedural aspects, and many others. On the contrary, the final shape can be achieved also due to the modification of a primitive by starting e.g. from a sphere, a cube, a parallelepiped and progressively modifying it, deforming it by following approximations, until it reaches the best possible configuration. This trend was called by some critics *Performative Architecture* (Kolarevic, 2005), even if it not properly a *new* attitude. In fact, looking at the protagonists of this kind

of methodology, we find Norman Foster, Nicholas Grimshaw, Renzo Piano, who were the same protagonist of the so-called *Hi-tech* trend in the '80s. Hence, it seems we are looking at a natural evolution of a trend, that through the possibilities of digital design has pushed until the limit the building technology, creating an old expressivity in terms of material - almost always steel structure with glass walls - but new regarding to the envelope's shapes (Fig. 11-12).

Figures 11-12. Swiss RE Headquarters (2004) in London by Norman Foster and the Singapore Gardens by Wilkinson Eyre (2012).

▪ *Diagram Architecture.* This trend is not born with digital technologies, but with their huge diffusion the sense and use of architectural diagrams was modified. Let's start from the term: *diagram* in architecture it is usually thought of as *graphic tool* (Bijlsma, 1998), that is the translation of a series of possible relationships between the parties in a drawing, but it can't be attributed either to the type, nor even to a sketch. The term derives from Greek *dià* (through) and *grámma* (something written). Although it is usually made up of points, lines and surfaces organized in two-dimensional or three-dimensional patterns, it may include data, legends, text, and then relate different aspects at the same time, crossing data, connecting functions and needs. Digital diagrams, often integrated in some software or add-on, have become an operational concept tools. Design tools as well as a means of reading. Indeed, it is often happened that what was initially mapped as diagram, e.g. for function or users movement, in the final phase of project become the base of formal configuration. This way to proceed is very common in designers like UN Studio and Rem Koolhaas (Fig. 13-16), but we have not to forget that the first to use digital diagrams, conceived as deformed grids, was Peter Eisenman, one of the most important architects of avant-garde and *deconstructivist.*

The analysis of our sample verifies the claims and assertions made by their designers and architectural critics: digital influences play an important role both in the overall form of the designs and in critical details, primarily with respect to visual impact and secondarily concerning performance and construction, or better the augmented capacity to manage building process, above all in presence of complex projects. It is clear that the influence of CAAD software on design was profound and also it modified other existing trends in pre-digital architecture, insomuch as we recognized



Figures 13-16. Above, the Seattle Public Library (2004) by Rem Koolhaas and, under, the Mercedes Benz Museum (2006) in Stuttgart by UNStudio.

that *new* digital trends have solid basis on what architecture produced *before*. The only factor that join all these tendencies is the evident return of *curvilinearity* in architecture, even if the conceptual starting point is often very different in each case.

To conclude, we think that a new frontier could be represented by younger architects who have had the benefit of early exposure to the computer and formal education in design computing (even if it is restricted to practical skills). Then it is unavoidable that digital influences on architectural design will keep increasing, but what is probably unpredictable is which kind of expressivity will be reached by them, who will have a complete comprehension about how obtaining and controlling forms, but with a lack of understanding about why, with which aims and mental concepts. And also this is the risk that current architecture is taking under the strong influence of digital technologies, which often overpower designer's minds.

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