ShOCK!

Sharing of Computable Knowledge!

eCAADe 35

20 - 22 September 2017 Rome

eCAADe 2017

ShOCK!

Volume 1

Editors
Antonio Fioravanti, Stefano Cursi, Salma Elahmar, Silvia Gargaro
Gianluigi Loffreda, Gabriele Novembri and Armando Trento
Faculty of Civil and Industrial Engineering
Sapienza University of Rome

1st Edition, September 2017

ShoCK! – Sharing of Computable Knowledge! - Proceedings of the 35th International Conference on Education and Research in Computer Aided Architectural Design in Europe, Rome, Italy, 20th-22nd September 2017, Volume 1. Edited by Antonio Fioravanti, Stefano Cursi, Salma Elahmar, Silvia Gargaro, Gianluigi Loffreda, Gabriele Novembri, Armando Trento. Brussels: Education and Research in Computer Aided Architectural Design in Europe; Rome: Dep. of Civil, Building and Environmental Engineering, Faculty of Civil and Industrial Engineering, Sapienza University of Rome.

ISBN
9789491207129
978-94-91207-12-9

Publisher: eCAADe (Education and Research in Computer Aided Architectural Design in Europe) and Dep. of Civil, Building and Environmental Engineering, Faculty of Civil and Industrial Engineering, *Sapienza* University of Rome.

Cover Design: Ugo Maria Coraglia, Kareem Elsayed and Antonio Fioravanti.
eCAADe2017 Logo Contest winners: Mohamed Elgendy and Omar Hadid (1st prize); Valerio Perna (2nd prize).

eCAADe 2017

ShOCK!

Sharing of Computable Knowledge!

Volume 1

Proceedings of the 35th International Conference on Education and Research in Computer Aided Architectural Design in Europe

20th-22nd September 2017
Rome, Italy
Dep. of Civil, Building and Environmental Engineering
Faculty of Civil and Industrial Engineering
Sapienza University of Rome

Edited by
Antonio Fioravanti
Stefano Cursi, Salma Elahmar, Silvia Gargaro,
Gianluigi Loffreda, Gabriele Novembri, Armando Trento

Patronage and Sponsors of the eCAADe 2017 Conference

Patronage

Silver sponsors

Bronze sponsors

Technical sponsors

Acknowledgements

Authorities, colleagues, researchers, professors, students, professionals all of you are welcomed to the 35th eCAADe conference, in Rome the *eternal city*.

It has been a long time ago – 31 years – since the previous eCAADe conference was held in this Faculty, hosted by our University - "La Sapienza".
That time, Gianfranco Carrara, one of the eCAADe founders, chaired the 4th eCAADe conference in 1986. That time on, there was only one eCAADe conference in Italy precisely in Palermo in 1995 chaired by Benedetto Colajanni and Giuseppe Pellitteri. This Faculty – now Faculty of Civil and Industrial Engineering – inspired by Parisian and Austrian academic models, is quite old as it was funded by Pope Pius VII in 1817, so now it celebrates its Bicentennial!

But it is quite young compared to our mother University "La Sapienza" that was established by the Pope Bonifacius VIII in 1303.

The original idea of bringing the eCAADe conference back to Rome goes rather back in times, I remember it was in 2009 at eCAADe conference in Istanbul. You know things take their time in Italy, so only in 2013 my Faculty approved and on 21st March 2015 eCAADe Council granted us the permission to organize the 35th conference. Over the last years several people have helped us to make this conference happen. We thank the former Dean of Civil and Industrial Engineering Faculty, Prof. Fabrizio Vestroni and especially the present Dean, Prof. Antonio D'Andrea for their supports.

During the process of organizing the eCAADe 2017 we have had the privilege to experience the supportive, collaborative and frank atmosphere of eCAADe Council, whose members, no one excluded, have helped us with all organizational aspects.

Let us be touched in remembering for his humanity the former eCAADe President, Johan Verbeke, who recently passed away. We all are sad in this moment thinking is no more physically with us now, but at the same time we are grateful to have met him and exchanged ideas on equal terms as his habit. In spirit, he is present so we can tell him: Johan, special thanks for your open-minded support, we warmly thank you! We miss you, and we do not forget you!

How cannot we mention Joachim Kieferle a friend, who is also the eCAADe President, for his encouragement and unswerving support during the last years and his ability to cut up dead-

locks into pieces? A special thanks to the great Bob Martens for his ability in organizing complex tasks and simplifying processes – Dutch origin helps – his daily support was precious and helped us relentlessly. And a "suuppper" thanks to a "super" friend as Gabriel Wurzer for his optimism and silent help in difficult issues.

Also, we wish to thank all the other previous conference organizers, Henri Achten, Rudi Stouffs and Emine Mine Thompson, for sharing their experience and knowledge. A special thanks to more recent conference organisers Bob Martens, Gabriel Wurzer, Thomas Grasl, Wolfgang E. Lorenz and Richard Schaffranek together with Aulikki Herneoja, Toni Österlund and Piia Markkanen!

Quality is the vital issue concerning conference proceedings.

To improve it we used different means: *OpenConf* conference management system that easily ensured that none of the reviewers came from the same institution as the authors; through special relationships between Liverpool University and eCAADe thank to Martin Winchester's support we were able to overcome program bugs; a second and handcraft check of interest conflicts among authors and reviewers was made during the reviewing phase; a double-blind peer review process; and an accurate reviewers' selection. The selection was fair, and only extended abstracts with high grades were admitted to full paper phase.

Quality means also typographic quality control in two ways: for printing results and for respecting author's layout; so, thanks to the well-known *ProceeDings* formatting management system eCAADe could fulfil these two needs.

Authors uploaded their extended abstracts (length of 1000 to 1500 words, two optional images, 5 to 10 references) by 1st of February 2017; each abstract was evaluated anonymously.

Altogether, we received 309 extended abstracts from 46 different authors' countries, shortly after 5 were withdrawn. Each extended abstract had three blinded peer reviews so 912 reviews were accomplished in a short time and 188 papers were accepted for full paper submission. After a while 11 of these ones were withdrawn and eventually 155 papers were published in the eCAADe 2017 Proceedings.

Let us express our very grateful appreciations for all the 132 reviewers from all over the world for their constructive and thorough comments for each author. A special thanks to reviewers who spent their time to review more than 8 extended abstracts – Joachim Kieferle and Anand Bhatt - not to mention members of "Joker Reviewers' Team": Stefano Cursi, Salma Elahmar,

Paolo Fiamma, Silvia Gargaro, Gianluigi Loffreda, Wolfgang E. Lorenz, Davide Simeone, Gabriel Wurzer and me that were able to review abstracts during the last days to accomplish missing reviews on time.

We thank and congratulate all authors for their hard work and support on using the ProceeDings tool and finalizing their full papers carefully in time. In this last phase of editing full papers we want to thank for his "extra-ordinary" work Gabriel Wurzer, the Master of the ProceeDings and Wolfgang E. Lorenz and Ugo Maria Coraglia, who with high sense of responsibility worked with us and to successfully produce high quality proceedings.
We also continued the practice started in eCAADe 2015 conference in Vienna of having all the session chairs to give prospective comments of the papers and to evoke the discourse at early stage between the author and session chair for the 27 sessions of the conference. All the session chairs also participated the peer review process of the extended abstracts.

We owe great gratitude to the session chairs for their commitment and their long-term contribution to the process until the final paper presentations.
We thank the keynote speakers and their contribution of writing the keynote papers concerning their lecture themes: Gianluca Peluffo, Chair in *Exhibition Design* and *Art & Architecture*, IULM - International University of Language and Media; John Gero, Research Prof. in *Computer Science and Architecture*, University of North Carolina at Charlotte and Krasnow Institute for Advanced Study George Mason University; and Gernot Riether, Director of *School of Architecture*, NJIT – New Jersey Institute of Technology, Editor of *DCA Journal*.
Workshops are part of eCAADe conferences, so we thank all the organizers for their workshop and for their contribution of short papers (non-peer reviewed) about the contents of their own workshop.

We are also grateful to Wolfgang Dokonal and the eCAADe Council for organizing the traditional PhD workshop for young researchers and supporting the grant winners with a subsidy for traveling to Rome.

We recovered an old tradition of previous eCAADe Conferences bringing poster session to life again, so during the conference we had 4 free lectures on interesting themes.

This year for the first time we launch an international competition linked to the Conference, the "eCAADe2017 Logo Contest" that helped in disseminate the spirit and values of eCAADe in new areas. We thank the International Jury that was made up by Antonino Saggio (President, Chair in *Information Technology applied to Architecture and Urban and Architectural design*), Eleonora Fiorani (Vice president, Chair in *Cultural Anthropology and Sociology of Innovation*),

Henri Achten (former eCAADe President, Chair in *Computer Aided Architectural Design*), Maria Argenti (Chair in *Architectural Composition* and Editor in chief of *Rassegna di Architettura e Urbanistica*), and Antonio Fioravanti (Chair in *Architectural Engineering*). Two Winners and three Honourable mentions were awarded (see on website https://www.daadgroup.org/result/).
We would like to express our gratitude for the administrative help in organizing this conference to eCAADe council and especially Nele De Meyere that has provided us valuable input and lessons learned from past conferences.

We have also had support from DaaD*group* for managing the conference services, ranging from the registration process to the actual on-site registration services. A big thank you goes to PhD students Ugo Maria Coraglia and Francesco Rossini for their extra-work in critical situations.

Thanks to the sponsors we were enabled to organize an international conference as eCAADe is. Financial supports, apart Sapienza University of Rome, was generously provided by A-Sapiens, AT Advanced Technologies, Autodesk; 3TI Progetti and Bentley Systems International Ltd. Technical support was provided by Epson Italia, Gangemi Editore, Geores, it solution, Noumena and ProceeDings.

We wish to also thank Gangemi Editore in person of Giuseppe and Fabio Gangemi for their very fast and accurate printing process and the high quality of both volumes.

As a special form of sponsorship, all members of the Organizing Team and students of Architecture-Building Engineering M. Course that donated their time to help prepare and organize this conference. Thank you all !!!

Rome, 1st September 2017

Antonio Fioravanti

Conference Chair

Angelo L.C. Ciribini, Gabriele Novembri and Armando Trento

Conference Vice-chairs

List of Reviewers

Sherif Abdelmohsen - American University in Cairo, Egypt
Henri Achten - Czech Technical University in Prague, Czech Republic
Asterios Agkathidis - University of Liverpool, United Kingdom
Hasim Altan - University of Sharjah, United Arab Emirates
Aleksander Asanowicz - Bialystok University of Technology, Poland
Gideon Aschwanden - The University of Melbourne, Australia
Phil Ayres - Centre for Information Technology and Architecture (CITA), Denmark
Guenter Barczik - Erfurt School of Architecture / HMGB Architects, Germany
Joo H Pbilip Bay - Curtin University, Australia
José Beirão - University of Lisbon, Portugal
Anand Bhatt - Architexturez Imprints, India
Henriette Bier - TU Delft, Netherlands
Nimish Biloria - University of Technology Sydney (UTS), Australia
Stefan Boeykens - KU Leuven - University of Leuven, Belgium
Johannes Braumann - Association for Robots in Architecture & University for Arts and Design Linz, Austria
Peter Buš - Faculty of Architecture, Czech Technical University in Prague, Czech Republic
Gulen Cagdas - Istanbul Technical University, Faculty of Architecture, Turkey
Erik Champion - Curtin University, Australia
Teng-Wen Chang - National Yunlin University of Science and Technology, Taiwan
Sheng-Fen Chien - National Cheng Kung University, Taiwan
Benny Chow - AEDAS Architects, Hong Kong
Mark Clayton - Texas A&M University, United States
Birgul Colakoglu - İstanbul Technical University, Turkey
Stefano Cursi - Sapienza University of Rome, Italy
Bauke de Vries - Eindhoven University of Technology, Netherlands
Marcella Del signore - Tulane University, United States
Wolfgang Dokonal - University of Technology Graz, Austria
Dirk Donath - Bauhaus University, Germany
Theodoros Dounas - Xian Jiaotong Liverpool University, China
Jose Duarte - Faculty of Architecture, University of Lisbon, Portugal
Athanassios Economou - Georgia Insitute of Technology, United States
Salma El Ahmar - Sapienza University of Rome, Italy
Ahmed El Antably - Arab Academy for Science, Technology and Maritime Transport, Egypt
Sara Eloy - Instituto Universitario de Lisboa, Portugal
Halil Erhan - Simon Fraser University - Canada
Alessio Erioli - Alma Mater Studiorum - Università di Bologna, Italy
Paolo Fiamma - University of Pisa, Italy
Antonio Fioravanti - Sapienza University of Rome, Italy
Pia Fricker - Aalto University, Finland / ETH Zurich, Switzerland
Tomohiro Fukuda - Osaka University, Japan
Silvia Gargaro - Sapienza University of Rome, Italy
Harald Gatermann - Hochschule Bochum University, Germany
David Gerber - University of Southern California, United States
John Gero - UNC Charlotte, United States
Ipek Gursel Dino - Middle East Technical University (METU), Turkey
Jeremy Ham - RMIT University, Australia
Malgorzata Hanzl - Lodz University of Technology, Poland
Jie He - School of Architecture, Tianjin University, China

Pablo C. Herrera - Universidad Peruana de Ciencias Aplicadas, Peru
Urs Hirschberg - TU Graz, Austria
Jia Hu - Independent Researcher
Tim Ireland - Kent School of Architecture, United Kingdom
Patrick Janssen - National University of Singapore, Singapore
Iestyn Jowers - The Open University, United Kingdom
Anja Jutraz - University of Ljubljana, Slovenia
Matevz Juvancic - University of Ljubljana, Slovenia
Anetta Kepczynska-Walczak - Lodz University of Technology, Poland
Sora Key - Independent Researcher
Joachim Kieferle - Hochschule RheinMain, Germany
Arto Kiviniemi - University of Liverpool, United Kingdom
Erik Kjems - Aalborg University, Denmark
Robert Klinc - University of Ljubljana, Slovenia
Michael Knight - University of Liverpool, United Kingdom
Tuba Kocaturk - University of Liverpool, United Kingdom
Volker Koch - Karlsruhe Institute of Technology, Germany
Reinhard Koenig - Bauhaus-University Weimar, Germany / Austrian Institute of Technology, Austria
Odysseas Kontovourkis - University of Cyprus, Cyprus
Jose Kos - Federal University of Santa Catarina, Brazil
Toni Kotnik - Aalto University, Finland
Sylvain Kubicki - Luxembourg Institute of Science and Technology, Luxembourg
Matthias Kulcke - Hamburg University of Technology, Germany / HafenCity University Hamburg, Germany
Hyunsoo Lee - Yonsei University, Korea
Ji-Hyun Lee - Graduate School of Culture Technology (GSCT), Korea / Korea Advanced Institute of Science and Technology (KAIST), Korea
Jos van Leeuwen - The Hague University of Applied Sciences, Netherlands
Andrew Li - Kyoto Institute of Technology, Japan
Biao Li - Southeast University, China
Katherine Liapi - University of Patras, Greece
Gianluigi Loffreda - Sapienza University of Rome, Italy
Thorsten Lomker - Zayed University, United Arab Emirates
Werner Lonsing - Independent Researcher
Wolfgang Lorenz - TU Wien, Austria
Russell Loveridge - NCCR Digital Fabrication / ETH Zürich, Switzerland
Mark Luther - Deakin Uviversity, Australia
Carlos L. Marcos - Universidad de Alicante, Portugal
Earl Mark - University of Virginia, United States
Bob Martens - TU Wien, Austria
Tom Maver - Glasgow School of Art, United Kingdom
Benachir Medjdoub - Nottingham Trent University, United Kingdom
AnnaLisa Meyboom - The University of British Columbia, Canada
Jules Moloney - Deakin University, Australia
Volker Mueller - Bentley Systems, United States
Michael Mullins - Aalborg University, Denmark
Walaiporn Nakapan - Rangsit University, Thailand
Taro Narahara - New Jersey Institute of Technology, United States
Katerina Nováková - Czech Technical University in Prague, Czech Republic
Yeonjoo Oh - Hyundai Construction and Engineering, South Korea
Konstantinos-Alketas Oungrinis - Technical University of Crete, Greece
Rivka Oxman - Technion University, Israel
Burak Pak - KU Leuven, Belgium
Hyoung-June Park - University of Hawaii, United States
Sule Tasli Pektas - Bilkent University, Turkey
Giuseppe Pellitteri - Università degli Studi di Palermo, Italy
Chengzhi Peng - University of Sheffield, United Kingdom
Frank Petzold - TU Munich, Germany

Contents

CAAD EDUCATION - HISTORY

New digital trends in current architecture

A comprehensive critical examination

Giuseppe Pellitteri[1], Alessia Riccobono[2]
[1]Dipartimento di Architettura, Università degli Studi di Palermo [2]Köln International School of Design, TH Köln
[1]giuseppe.pellitteri@unipa.it [2]alericco@kisd.de

The research presented is about digital revolution in architecture, which has contributed to the birth of new figurative trends. The work was conducted through the definition of a framework to identify and classify architectural design elements that should be attributed to the methods and techniques of design computing, then applied to sixty prominent recent architectures which are acknowledged products of digital means. The early results suggest that a new era is coming, where the conceptual starting point of designers is often born in the digital space, taking advantage of the augmented representation skills to control and manipulate form. We will also do an overview of these new architectural trends, discussing both causes and cultural roots and identifying eventual criticisms and further developments.

Keywords: *digital design thinking, contemporary architecture, design process, digital trends*

INTRODUCTION

At the beginning of digital revolution, the computer was only an exclusive toy for an academic and technological elite of researchers and developers jealously guarding an expensive technology and its applications, and restricting it to their internal preoccupations. However, since the commercialization of the first CAAD (Computer Architectural Aided Design) programs in the '80s, initially born to *aid* the production of *drawings*, software has progressively begun part of designer's tools. Despite at first an undoubted advantage was the extensive exploration of the architectural space and the direct control of its transformations in all phases of the project, after some years of experimentation it was clear that software aided the expression of designer's creativity too.

Through current modelling software, you can get even more complex forms of representation: they add up to traditional graphics media and an additional system of information is directly available. It becomes a stimulus to our conceptual skills, using new media to govern the complexity and to give free rash to design creativity. Definitely, this has led the architect to a radical change of its relationship with the design. The classical conceptualizations, previous to the final form configuring and expressing architecture, go now almost in parallel with the repre-

sentation of the form itself. Nowadays everyone agrees that digital tools are currently used in architectural professions and that the effect of their use is rather evident on the formal and aesthetic configuration of some buildings. On the other hand, it is actually unclear how much CAAD software influenced this new figurative dimension.

Therefore, the first goal of the research is identifying the extent and scope of digital influences on real architectural expressions. It is unclear what these influences entail and what evidence we have for their existence and significance. It seems that we all generally agree to the existence but are not able to recognize their influences and effects. After a closer inspection, it becomes evident that the main reason for recognizing digital elements is what the designers themselves or some critics said. Indeed, after the objective identification of digital influences in a new architecture, we should be able to identify their origin, too: do they derive from a research or are they products of general computer literacy? In this scenario, what is the role of composition and why is architectural expressivity changing? This question is central to the role of design computing in architectural education but also points out research goals and directions that may be absent in current research (Riccobono et al. 2013).

To achieve this goal, we need first of all a coherent and comprehensive overview of elements derived from design computing, so that we can unambiguously identify them in some recent architectures. Then we have to apply it to real cases in order to verify its adequacy and, when this is done, to examine how these elements appear and are used in practice and what is the linkage with geometry and spatial composition. Finally we must consider how digital influences contribute to a new way to intend architectural design and its formal expressions, to understand what is the state of architecture nowadays: which are the most common trends? Which are the positive and negative aspects of the digital revolution? Which could it be the future of our work?

RESEARCH METHODOLOGY: A BOTTOM-UP APPROACH

Everybody can state that digital influences in a building are often easy to perceive in the overall shape [Fig. 1], as well as in some critical parts such as the architectural envelope, but it is rather difficult to understand when and how extensively the designers actually used the digital media in the design process (Pellitteri 2010). They might use digital means to solve specific problems, e.g. to represent complex geometries, or for design actions constrained by the use of digital tools (frequent use of particular geometric primitives or operations, for example). In many cases, the computer is used to facilitate representational and design actions, e.g. model complex surfaces that tend to be hard to specify by hand and may require more information than what is available in conventional orthographic projections. But in many others the digital media software were used for specific and technical aspects, like the optimization of performance features or for the facilitation of construction phases.

The identification of digital influences in a single project is quite useful for the refinement of the framework, i.e. the definition of the repertories and the clarification of the specific forms their members may assume. This problem could be approached in two opposite ways: with a top-down or a bottom-up approach. The first means the production of an extensive, possibly exhaustive series of examples for each digital element and use the results, properly

Figure 1
NOX Lars Spuybroek, Son-O-House, Son-en-Breugel, The Netherlands 2000-2004, © NOX.

classified and clustered, as templates for identification. Such a series can be produced by observing designs, collecting relevant occurrences and probably augmenting the results with plausible, possible and probable variations. Instead, we have opted for the bottom-up approach: identifying instances of digital elements directly on the existing projects, without attempting to complete the spectrum with additional instances. This agrees with the critique moved by Dorst (2008), who have denounced a certain absence of consistency and logic in researches on digital design, a lack of scientific methodology, and at the same time he has suggested to apply the scheme observation-description-explanation also to our field of knowledge.

For a real bottom-up analysis, in order to clarify how much CAAD software have contributed on the emergence of Digital Design with precision and overview, we have avoided opinions (either from academia or from practice) and focused instead on the actual products, analysing sixty recent buildings clearly related to digital methods or techniques.

The analyses were conducted in a uniform objective manner and collected in a database, which allows a wide variety of queries on the identified features and where the collection of data, the classification of projects on the basis of predefined objective parameters and, above all, the interrelations between two or more parameters. They permit us to understand the role of digital means in contemporary architecture with clarity and consistency, so that we can not only describe but also explain the state of the art.

Inclusion criteria

The case-studies were chosen from the high end of contemporary architecture. They are:

- architectures where the influences of digital tools and culture are strongly evident;
- high-quality buildings, testified by the publication on international journals. We have chosen not to include projects that exist only on paper, because this does not permit analysis and evaluation of many aspects, e.g. the real relationship with the environment or tectonic issues;
- buildings from all over the world, since the effects of digitization on current architecture have been not dependent on local culture;
- projects realized in the last twenty years;no specific typology. As in the case of global scale, digital influences on current architecture are not dependent on the specific functions accommodated in the building.

Database Structure

To make easier our analysis, it was chosen to collect all the information related to these buildings in a database so as to ensure consistency: each building is analysed in the same manner and the results are described in the same terms, thanks to some predefined parameters [Fig. 2]. The use of a database has several positive aspects: firstly it gives us the possibility to apply a combinatorial approach, which allows us to figure out relationships among several elements in a building's description, to visualize them and to interpret the results; secondly, 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 first part of data collection concerns the description of each building through fields 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 photographs, drawings and dimensional data. After this first descriptive part, we deal with the real analysis and close examination of the cases.

To develop the analytical framework, in order to search for digital influences in a building, we have based our investigation on formal and representational repertories offered by digital means, grouped under two main categories, *general features*, that do not refer strictly to the use of computer, but put attention on other important points, and *local features.*

Figure 2
The main interface of the database.

General features regard the taxonomical analysis of each project, through the recognition of its *Geometry* and *Morphology*. *Local features* have a wider purpose, especially as new digital methods and techniques continuously add to them. They comprise three complementary groups, the first of which contains the *geometric primitives* and *models* used in a project: cones, cubes, cylinders, freeform solids, *NURBS* surfaces etc. In this group, the dual role of digital means becomes quite evident: at least some of these primitives are not bounded by computational environments; it is simply their definition and manipulation that becomes significantly easier and more reliable with digital means. Other geometrical models are inconceivable outside computational environments either because they emerged in relation to computation or because they are mathematically or geometrically hard to implement and control.

About *primitives*, we have also distinguished two different levels. In the *first* level, it is possible to choose among the several parameters with a forced selection, so that the primitive detected is one and unequivocal; you cannot pick both parallelepiped and sphere, because always one is prevalent on the other. For this reason, we have admitted a *second* level where to identify the other elements which participate to composition, with the possibility to choose more parameters [Tab. 1].

Following this taxonomic exploration, the analysis continues with the other two groups of local features, regarding the role of composition in the design process. Firstly, we focus on the recognition of the *formal concepts*, which cover local, general, bilateral and multilateral relationships such as *alignment, axiality, horizontality, symmetry, verticality* etc. These underlie the conceptual arrangement of primitives but

Category	**Parameters** (underlined words indicate the parameters related to the digital domain)
Geometry	Rectilinear, Curvilinear, Hybrid
Morphology	Anthropomorphic, Biomorphic, Geometrical, Zoomorphic
Geometrical primitives and models (1st and 2nd order)	Cone, Cube, Cylinder, Ellipsoid, Free-form solid, Helix, NURBS Surfaces, Parallelepiped, Prism, Pyramid, Solid of extrusion, Solid of revolution, Sphere, Tetrahedra, Torus, Wedge, None

Table 1
The classification of case-studies, with respect to geometrical features. (Riccobono, Koutamanis, and Pellitteri 2013).

are not limited by themselves: they are discernible as patterns and coordinating devices that may be quite indifferent as to the elements they apply to (Arredi 2006). In digital representations, such formal concepts are often expressed as constraints.

Then we focus on the *compositional operations* (Di Mari and Yoo 2012), which serve two related purposes: the implementation of formal concepts, e.g. as in the use of reflections and translations to create symmetric forms, and the transformation of primitives to produce generally more complex forms. The effects of these operations arguably determine most of the cues that allow us to recognize digital influences in a design, e.g. a Boolean combination or the adaptation of a mesh [Tab. 2]. Even in this case, it was previously defined which operations were born in the computational domain and which not.

While these repertories were initially compiled in a bottom-up manner by observing the several cases and correlating their features to the capabilities of digital design environments, there is also substantial support from literature, especially in some studies about the theoretical conception in architectural design, conducted through the observation and analysis of morphological features related to digital tools (Evans 1995, Liu and Lim 2006, Oxman 2008, Wong 2010). The choice of the parameters used in each category was based on the Getty Art & Architecture Thesaurus [1], in an attempt to add lexical consistency to the description of digital designs.

The analysis concerning these repertories can be done in two complementary ways, *syntagmatically* and *paradigmatically* (Van Sommers 1984). *Syntagmatic* analysis refers to the sequence of actions by which different primitives, concepts and operations entering in the design. *Syntagmatic* aspects can be of great value in computational and algorithmic studies (e.g. in shape grammars) but they are also difficult to detect in the final design and in many cases only loosely related to design thinking, as there can be various sequences of actions by which we arrive at the same results. Consequently, *syntagmatic* analyses tend to reveal more about contextual factors, including a designer's understanding of digital means.

Paradigmatic analysis focuses on the elements of the design, in our case primitives, concepts and operations, their existence and interrelationships without reference to temporal precedence or such mental hierarchy. This allows us to identify traces and effects of digital means in design representations, with the obvious exception of prescriptive algorithmic techniques like shape grammars. The economy and effectiveness of *paradigmatic* aspects made this analysis a safe starting point for this research.

QUERIES, RESULTS AND INTERPRETATION

After collecting all data and settling all parameters for each case study, we have used the database to obtain results through its combinatorial possibilities. The main operation was setting out of several queries and questioning the software to visualize quickly the results and combinations in form of graphs, tables, reports, etc.

We have queried the database to show the related prevalence per each category. Referring to *Geometry*, we noted the high prevalence of the curvilinear one (67%), which confirms our first impression and cases selection. In turn, the strong tendency to-

Table 2
The classification of case-studies, with respect to compositional issues. (Riccobono, Koutamanis, and Pellitteri 2013).

Category	Parameters (underlined words indicate the parameters related to the digital domain)
Form and compositional concepts	Alignment, Articulation, Asymmetry, Axiality, Balance, Complexity, Contrast, Disproportion, Frontality, Gesture, Harmony, Horizontality, Linearity, Monumentality, Obliquity, Plasticity, Proportion, Rythm, Scale, Simmetry, Simplicity, Unity, Verticality
Compositional Operations	Align, Boolean, Break, Bulging, Copy, Divide, Extrusion, Folding, Interrupt, Loft, Mesh, Move, Offset, Overturning, Repeat, Retract, Revolution, Rotation, Scale, Slicing, Sliding, Smooth, Stretch, Sweep, Taper, Tilt, Translation

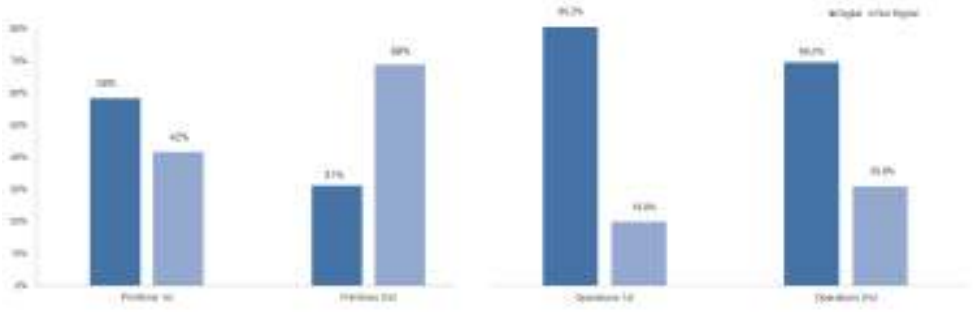

Figure 3
Prevalent primitives and operations in both levels and digital attitude (Riccobono 2014).

wards designs with curvilinear configurations is accompanied by a rigid geometrical control, testified by the high percentage (70%) of geometrical parameter in the category *Morphology*.

At level of *Primitives*, where we have identified two orders the most represented is *NURBS* Surfaces (25%); it is also significant that, filtering our results through the variable Digital-not Digital, there is an high prevalence of digital primitives (60%) in the first level, but not in the second level (only 24%). This suggests that the conceptual phase begins in the computational space with a primitive, rather than with e. g. a sketch (Dorta et al, 2008), but subsequent primitives used in the composition are conventional and not digital [Fig. 3].

If we look at *compositional* level, it is evident that a high percentage of designs used operations totally digital (81%), where *folding* (33,8%) dominates both as an expression of the ability to reliably control complex surfaces by computer and of certain tendency to abandon straight and regular geometries [Fig. 3]. Preferring curved lines, sloping planes and organic spatial configurations is one of the fundamental evidence of Digital Expressionism.

This attitude is arguably also confirmed by the relevant presence of operations like *loft* and *bulging*. As regards formal concepts, most of them cannot be called strictly *digital*. However, the popularity of concepts like *plasticity* (12%), *complexity* (10,1%) and *unity* (9,7%) confirms the feeling that architectural products of this trend are often intended as artistic expressions.

Figure 4
Zaha Hadid Architects, Heydar Alyev Centre in Baku, 2007-2012. © Zaha Hadid Architects, Iwan Baan.

Looking at the Figures 3 and 4, we can assert that the digital attitude is pretty evident in both morphology and composition. Design thinking and conception are becoming more and more identified by a pervasive use of digital technology and by geometrical and mathematical operations offered by commercial software. Proliferation of curvilinear geometries and plastic spatial configurations appears related to the main change allowed by digitization of architecture that is linked to representation, but not just to it.

Table 3
The main features of Digital Expressionism (Riccobono and Pellitteri, 2014) .

Geometry	Operations	Concepts	Design Strategies
Curvilinear	Digital Domain	Plasticity, Complexity, Unity	Artistic Fact, Blob, Flows, Fluidity, Folded Surfaces

EMERGING TRENDS IN THE DIGITAL AGE

The last part of analysis is devoted to map the conceptual criteria based on each case. 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 identifying, 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 we have considered that some buildings might have more than one classification. Among the categories identified, we find *blob*, term coined by Greg Lynn (1998), 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 computationally deformed becomes instrument for designing forms and spaces unpredictable and changeable. Other used identifying terms, 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).

Comparing those results with what already obtained by the analysis of digital operations and primitives, it is possible to identify some transverse movements in which we could subdivide the digital-influenced architectures.

Digital Expressionism

This trend gathers architectures with a strong morphological approach, where building envelope, often with curvilinear configuration, is treated as an art work, refining, folding and shaping surfaces [Tab. 3]. This appears linked to the main change caused by digitization of architecture, 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 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 this 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 and other relevant factors.

Hi-Tech Evolution

This category includes buildings in which the generation of the shape is digitally derived by optimizing one or several parameters, e.g. environmental, procedural, structural, and so on [Tab. 4]. When digital media appeared in the 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

Geometry	Operations	Concepts	Design Strategies
Curvilinear	Digital Domain	Complexity, Articulation, Plasticity	Performance optimization, Mathematical Derivation

Table 4
The main features of Hi-Tech Evolution (Riccobono and Pellitteri 2014).

increase building *performances*, the new software allows the creation of autonomous architectural forms, arising directly from the optimization of different parameters. Another approach to build performance is to obtain the final shape through the modification of a primitive (e.g. from a sphere, a cube, a parallelepiped), which will further deformed by following approximations, until it reaches the best possible configuration. This trend was called by some critics *Performative Architecture* (Kolarevic and Malkawi 2005), even if it not properly a new attitude. In fact, looking at the protagonists of this kind of methodology, we find Norman Foster [Fig. 5], Nicholas Grimshaw, Renzo Piano, who are the same protagonist of the so-called *Hi-tech* trend in the '80s. 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.

Figure 5
Foster & Partners, The Sage Gateshead, Gateshead, UK 1997 – 2004. © Foster & Partners.

Diagram Architecture

This trend was not born with digital technologies, but with their huge diffusion the sense and use of architectural diagrams was modified [Tab. 5]. 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.

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 [Fig. 6] and Rem Koolhaas, 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 Deconstructivism.

CONCLUSIONS

The first thing evident in our multi-case analysis is that there is no easily discernible the digital approach concerning methods and techniques used. In con-

Geometry	Operations	Concepts	Design Strategies
Curvilinear (50%) Rectilinear (50%)	Digital Domain	Complexity, Articulation,	Diagram, Grid

Table 5
The main features of Diagram Architecture (Riccobono and Pellitteri, 2014).

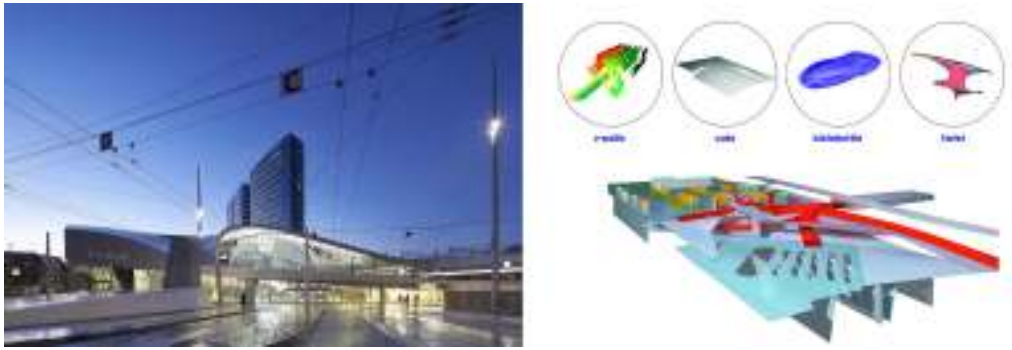

Figure 6
UNStudio, Masterplan of Arnhem Central Station, Arnhem, The Netherlands, 1996-2015 . © UNStudio.

trast to the assumptions underlying design computing research and teaching, there is no predefined process or even clear strategies for each particular problem. The application of digital means seems opportunistic and generally dictated by contextual or cultural reasons - as many decisions are in architectural design (Till, 2009). Such reasons may result in-to effective, innovative solutions that serve well goals relating to function, performance and, more often, visual impact. Computational media produces the novel forms of *Digital Architecture* that attract the attention of a wide public and presents opportunities for combining different aspects and elements in ways that interest the architectural public. From our sample, it is evident that digital means are used for differentiation: just like modernists avoided decoration, digitally influenced designs seem to prefer *curvilinear* forms, even if tactics and concepts may have very different foundations. This seems to be done to indicate their opposition to earlier architecture and show clearly that the design is (partly) motivated by design computing ideas as expression of the future.

Prominent designs shows these digital influences in critical, high-risk situations where designers tend to pay more attention to project success, client requirements and overall appeal than to any computational principles and approaches. Our sample verifies the claim that digital means have become a ubiquitous part of architectural design tools and have irremediably changed the architects' way-to-design. Despite the existence of many algorithms and programs currently used, their architecture is not able to leave the visual approach out of consideration. Indeed, the main advantage given by the computer is the possibility to work visually in real time on 3D-shapes, by seeing what effects are produced by their actions. On one hand this fact has speeded up the design operations, but on the other hand the risk to "run into a loop", endlessly modifying the geometrical configuration, appears quite real (Riccobono, 2015). Increasing the number of 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), it is unavoidable that digital influences at the morphological level will keep increasing. From our research it is still unclear whether this will be accompanied by increased compositional awareness and more intensive use of digital methods in synthesis (as opposed to representation).

This new style of *digital-influenced architecture* is formally based on free expressions, without a *canon* or a *style*. We think that this recognized digital trends, driven by international firms, introduces new degrees of complexity in the profession. Indeed, during the development of a project, it could happen that some architects will tend to keep merely the style or the formal configuration of some fashion designs, forgetting and not considering other aspects, such as cultural references and contextual choices (Pellitteri 2010). In many projects as those reported in this

research, where the taxonomic values are strong we can see that designers tend to develop their own style, conducting to a simple reproduction of *beautiful forms*. Up to now, just by giving a superficial look at architectural websites like Archdaily.com [2], where anyone can upload their own projects, we can note strong similarities in some professional projects with international firms' ones.

Academic research and teaching may be rich in compositional studies and approaches, but if digital means enter practice primarily as design representations, it is inevitable that emphasis will be on *what* can be done with software rather than on *how* and *why*. In the war between conceptualization and morphology, actually the second seems to have the best. Consequently, each design project serves as a testbed firstly for morphological development (which tends to produce similar results to other designs) and secondly for experimentation with primitives, concepts and operations.

At the end of the game, despite of a general *expressionist* tendency, we cannot anymore talk in terms of language, style or aesthetic values. What the digital revolution has effectively produced is a free way to intend the project, with endless geometries, materials, building systems present at the same time and in the same places, without any consideration about a shared Architecture's Identity.

REFERENCES

Arredi, M P 2006, *Analitica dell'immaginazione per l'architettura*, Marsilio, Venezia

Bijlsma, L, Deen, W and Garritzmann, U 1998, 'Diagrams', *OASE*, 48, pp. 0-92

Dorst, K 2008, 'Design research: a revolution-waiting-to-happen', *Design Studies*, 29(1), pp. 4-11

Dorta„ T, Pérez, E and Lesage, A 2008, 'The ideation gap: hybrid tools, design flow and practice', *Design Studies*, 29(2), pp. 121-141

Evans, R 1995, *The projective cast: architecture and its three geometries*, MIT Press, Cambridge, Mass.

Kolarevic, B and Malkawi, A 2005, *Performative architecture beyond instrumentality*, Taylor & Francis, London

Liu, Y T and Lim, C K 2006, 'New tectonics: a preliminary framework involving classic and digital thinking', *Design Studies*, 27(3), pp. 267-307

Lynn, G 1998, *Folds, Bodies & Blobs: Collected Essays*, La lettre volée, Brussels

Di Mari, A and Nora, Y 2012, *Operative Design: A Catalogue of Spatial Verbs*, BIS Publishers, Amsterdam

Oxman, R 2008, 'Digital architecture as a challenge for design pedagogy: theory, knowledge, models and medium', *Design Studies*, 29(2), pp. 99-120

Pellitteri, G (eds) 2010, *L'involucro architettonico. Declinazioni digitali e nuovi linguaggi*, Fotograf, Palermo

Pellitteri, G and Riccobono, A 2012 'Towards which expressive horizons?', *Proceedings of SIGraDi 2012*, Fortaleza, pp. 84-88

Riccobono, A 2014, *Architectural design in the Digital Era. Identifying computer influences and new expressive trends in current architecture*, Ph.D. Thesis, Università degli Studi di Palermo

Riccobono, A 2015 'New methodologies and approaches to architectural design in the Digital Age: conversations with designers explaining their way-to-work', *Proceedings of ARCHDESIGN '15 / II. Architectural Design Conference Proceedings*, Istanbul, pp. 385-395

Riccobono, A, Koutamanis, A and Pellitteri, G 2013 'Digital Expressionism: the architecture of complex shapes. Multi-case analysis, classification and interpretation', *Cutting Edge: 47th International Conference of the Architectural Science Association*, Hong Kong, pp. 663-672

Riccobono, A and Pellitteri, G 2014 'The Digital change. Reasons and meanings of a new architectural expressivity', *Proceedings of the ARCC/EAAE 2014 International Conference on Architectural Research*, Honolulu, Hawaii, US, pp. 408-417

Van Sommers, P 1984, *Drawing and cognition: descriptive and experimental studies of graphic production processes*, Cambridge University Press, Cambridge Cambridgeshire

Till, J 2009, *Architecture depends*, MIT Press, Cambridge, Mass.

Wong, J F 2010, 'The text of free-form architecture: qualitative study of the discourse of four architects', *Design Studies*, 31(3), pp. 237-267

[1] http://www.getty.edu/research/tools/vocabularies/aat/

[2] http://www.archdaily.com/