TECHNE

Journal of Technology for Architecture and Environment

Special Series
Vol. 2 | 2021

FUTURE SCENARIOS

on line ISSN 2239-0243

FIRENZE UNIVERSITY PRESS

SITdA

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Editorial Office
c/o SIT*d*A onlus,
Via Toledo 402, 80134 Napoli
Email: redazionetechne@sitda.net

Publisher
FUP (Firenze University Press)
Phone: (0039) 055 2743051
Email: journals@fupress.com

Journal of SIT*d*A (Società Italiana della Tecnologia dell'Architettura)

RIMOND This special issue has been realized thanks to the support of RIMOND

REFEREES

As concern the Double-Blind Peer Review process done in 2019-2020, we would thanks the following Referees:

2019
Ilaria Agostini, Francesco Alberti, Davide Allegri, Eugenio Arbizzani, Vitangelo Ardito, Paola Ascione, Erminia Attaianese, Adolfo Baratta, Alessandra Battisti, Oscar Eugenio Bellini, Stefano Bellintani, Lorenzo Boccia, Roberto Bolici, Roberto Bologna, Filippo Bricolo, Andrea Campioli, Stefano Capolongo, Francesca Castagneto, Pietro Chierici, Laura Daglio, Valeria D'Ambrosio, Giuseppe De Giovanni, Domenico D'Olimpo, Paola Favaro, Enrico Formato, Rossella Franchino, Matteo Gambaro, Jacopo Gaspari, Valentina Gianfrate, Francesca Giofrè, Roberto Giordano, Ruggero Lenci, Danila Longo, Laura Malighetti, Alessandro Massera, Martino Milardi, Elena Mola, Antonello Monsù Scolaro, Elena Piera Montacchini, Pietro Nunziante, Ingrid Paoletti, Carlo Parrinello, Paola Pleba, Sergio Pone, Raffaella Riva, Antonella Sarlo, Enrico Sicignano, Cesare Sposito, Andrea Tartaglia, Serena Viola, Antonella Violano, Alessandra Zanelli.

2020
Ilaria Agostini, Filippo Angelucci, Eugenio Arbizzani, Vitangelo Ardito, Serena Baiani, Adolfo Baratta, Alessandra Battisti, Chiara Bedon, Stefano Bellintani, Pietro Chierici, Andrea Ciaramella, Luigi Cocchiarella, Valeria D'Ambrosio, Domenico D'Olimpio, Laura Daglio, Sergio Ermolli, Luca Maria Francesco Fabris, Daniele Fanzini, Cristina Forlani, Rossella Franchino, Matteo Gambaro, Maria Luisa Germanà, Valentina Gianfrate, Elisabetta Ginelli, Ruggero Lenci, Danila Longo, Adriano Magliocco, Enrico Sergio Mazzucchelli, Martino Mocchi, Elena Mola, Alessandra Oppio, Ingrid Paoletti, Carlo Parrinello, Gabriella Peretti, Paola Pleba, Sergio Pone, Raffaella Riva, Fabrizio Schiaffonati, Nicoletta Setola, Cinzia Talamo, Andrea Tartaglia, Serena Viola, Antonella Violano.

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Società Italiana della Tecnologia dell'Architettura

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Design Technology Practice

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NOTE

PROLOGUE

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ART PHOTOGRAPHY edited by Marco Introini, Valentina Puglisi

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ESSAYS AND VIEWPOINTS

RESEARCH AND EXPERIMENTATION

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Learning architecture in the digital age. An advanced training experience for tomorrow's architect

RESEARCH AND EXPERIMENTATION

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Abstract. What Mario Carpo defines as "the second digital turn" (Carpo 2017) represents for architecture an irreversible process meant to modify many consolidated rules in the professional practice. Without upgrading his methods and points of view, education in architecture turns out to be inappropriate for future scenarios, both in terms of content and methods.
In this regard, in 2018 the School of Architecture and Design "Eduardo Vittoria" (SAAD) of the University of Camerino launched an experimental educational programme focused on: a) "digital fabrication" as a building strategy; b) the SAAD-Lab#Prototype (the SAAD fab-lab) as fulcrum of an innovative workshop in the field of building construction. The paper presents the result of the 2018/19 workshop concerning a temporary settlement for students made with customised building systems.

Keywords: Digital Fabrication; Technology; Education; Architect; Future

Digital in architecture: «nothing is more powerful than an idea whose time has come» [1]

Digitisation of design processes has come a long way since the pioneers of Computer-Aided Design (CAD) «replaced their pencils with mouse and keyboard in the 1980s» (Kuhnhenrich and Rose, 2019). Since then, a new generation of digital tools has become widespread as a natural part of the architect's profession. Particularly in the last decade, the development of ICT technologies has made available new families of interconnected tools. The latter have turned out to be so powerful as to stimulate, in a short time, the emergence of new design cultures and, with them, the rise of new rules and roles in architectural practice. Parametric and Computational Design are just two of the most evident and not fully explored outcomes of the "revolution" underway.
Extending the observation field to the whole building sector, to date, digital innovation has had different types of impact on the three phases of the process (design, production, and construction). In many contexts, construction (in particular) and industrial production for building are, with some exceptions, mainly analogic processes. If digital technologies for manufacturing (from CNC to robotics and other "enabling technologies", according to Industry 4.0 vocabulary) have already largely spread in many branches of industrial production, their application in building construction is still not common. Even if this inhomogeneity constitutes a critical issue, the digital renewal of the building sector is an irreversible process destined to change, in the short and mid-term, many rules, methods, and roles, even in architectural practice.
This is why the architect's role, like that of many construction professionals, is bound to evolve in a time that promises to be short. Without upgrading his expertise, the architect risks marginalisation to the benefit of new figures and new specialised skills brought by digital culture. This does not mean that the architect of the digital age will have to turn into informatics and give up to the humanistic profile (that is a prerogative of his cultural heritage). As Italian writer Alessandro Baricco argues, «the game» - the way Baricco defines our life in the digital age - «more than anything else [...] needs humanism» (Baricco, 2018).
To create the ethical and scientific basis to allow the architect to play a leading role in a future that is announced as increasingly "digital", a radical re-thinking of the educational paths in architecture is necessary, as well as the testing of innovative methods and models based on the prefiguration of future (medium and long-term) scenarios.

A digital training experience

"Digital fabrication" is one of the possible applications of "digital" in the construction sector[2]. Digital fabrication is a process that combines 3D modelling or computer-aided design with additive and subtractive manufacturing for the production of building components. In this context, design and manufacturing constitute a single workflow where digital data directly drive manufacturing equipment[3]. Among the main and crucial consequences of digital fabrication, two, in particular, are strategic for the definition of new design paradigms: a) the opportunity to design and produce "customised" and non-standard elements (structural, façade, internal or otherwise); b) the return to a closer relationship between design and construction.
In 2018, SAAD launched an experimental course focused on digital fabrication as a building strategy for temporary architecture. This work is part of a larger activity promoted by the University of Camerino aimed at developing innovative educational paths[4]. The course is based on the workshop formula and is devoted to the students of the bachelor's degree in Architecture Science[5]. Introducing digital fabrication in the early years of a student's career has been a strategic choice. Indeed, the course aims at introducing digital fabrication not as a specialised topic based on the management of sophisticated tools, but as an innovative approach to architecture potentially destined to change the way we conceive, design and build the space we live in.
The workshop is centred on the SAAD-Lab#Prototype, i.e., the University of Camerino's fabrication laboratory (fab lab). It is equipped with devices for both additive and subtractive digital manufacturing. The basic equipment adopted during the workshop mainly refers to: laser cutting machines with a 600x400 mm working plane, laser cutting machines with a 1500x500 mm working plane, Roland CNC milling machine with a 270x270x145 mm working plane, and a 3-axis CNC milling machine with a 3,000x2,500x 500 mm working plane, Makerboat Replicator 3D printer with a print volume of 280x150x150 mm, and Wasp 3D printer with a print volume of D 600 x H 1000 mm (Fig. 1).
Unlike other educational experiences focused on digital fabrication and carried out in the most advanced fab labs of European universities[6], the SAAD experience is not focused on experimenting with extreme structures and complex geometries as a result of a computational approach. Instead, its main goal is designing and prototyping an innovative artefact based on the hybridisation of conventional components and building systems, coming from the current indus-

ISSN online: 2239-0243 | © 2021 Firenze University Press | http://www.fupress.com/techne
DOI: 10.13128/techne-10698

01 | SAAD-Lab#Prototype 3-axis CNC milling machine, Author's pic

02 | The OpenStructure grid adopted as modular basis of the temporary settlement, Author's pic

trial production, with customised components and systems resulting from the application of digital techniques of fabrication. This scenario is not new. There are also not very recent advanced design experiences - that of Renzo Piano, for example – focused on the combination of standard building components and of customised components [7]. If Piano's works were complex hi-tech experiments, the progressive digitisation of industrial production could make these processes less extraordinary, as demonstrated by some experiences of "offsite" construction in northern Europe[8].

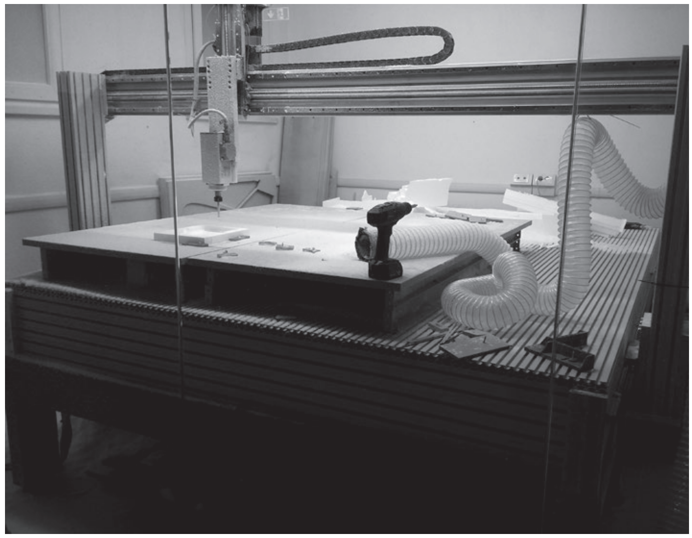
Three workshops have been held since 2018, all focused on temporary and small-scale architecture, according to the research interests and tradition of studies of the SAAD teaching group. In particular, the 2019 edition was centred on the general topic of new urban nomads (refugees, tourists, guest workers, expats, and students, a category of traditionally nomadic city users). The exercise consisted in designing and prototyping a little temporary settlement for students.

One of the peculiar aspects of this experience (in relation to the traditional methods of teaching architectural design and building processes) is the methodology adopted. Each student was given a wooden tablet (Fig. 02) that corresponded, on a scale of 1:10, to a square-shaped lot (with a side equal to 9.6 square metres). A grid was engraved with a laser cutter on each tablet as a shared "guide" for all projects. Students could use just part of this lot, i.e., 40 square metres and a volume of 280 cubic metres to produce their little temporary house. The tablet constituted the basis of the final prototypes (also in a scale of 1:10), but also a tool to check the design phase. The final assembly of the artefacts positioned on the lots - that is the prototypes positioned on the engraved tablet - was the final act of the workshop, the collective product: a modular settlement for temporary users; a theoretically replicable and incremental atypical "village" built with partially customised building systems.

This method represents an innovative application of the "OpenStructure" theory, an open-source modular construction model based on a shared geometrical grid[9]. Conceived by Belgian designer Thomas Lommée, the OpenStructures method explores the possibility of design in a modular environment where "everyone designs for everyone" being able to share with the community the file of their components ready to be fabricated (in the OpenStructure method the file of each component can be made available for public download). In the SAAD experience, students generated their components to share them with their colleagues through an analogue process.

Those "pieces" were designed through the use of cad-cam software technologies (RhinoCAM in particular) and produced with CNC milling and 3D printing techniques[10]. The range of parts manufactured under the digital fabrication regime constitutes a heterogeneous catalogue of construction systems and components: structural joints in thermoplastic material, entire wooden construction sys-

| 01



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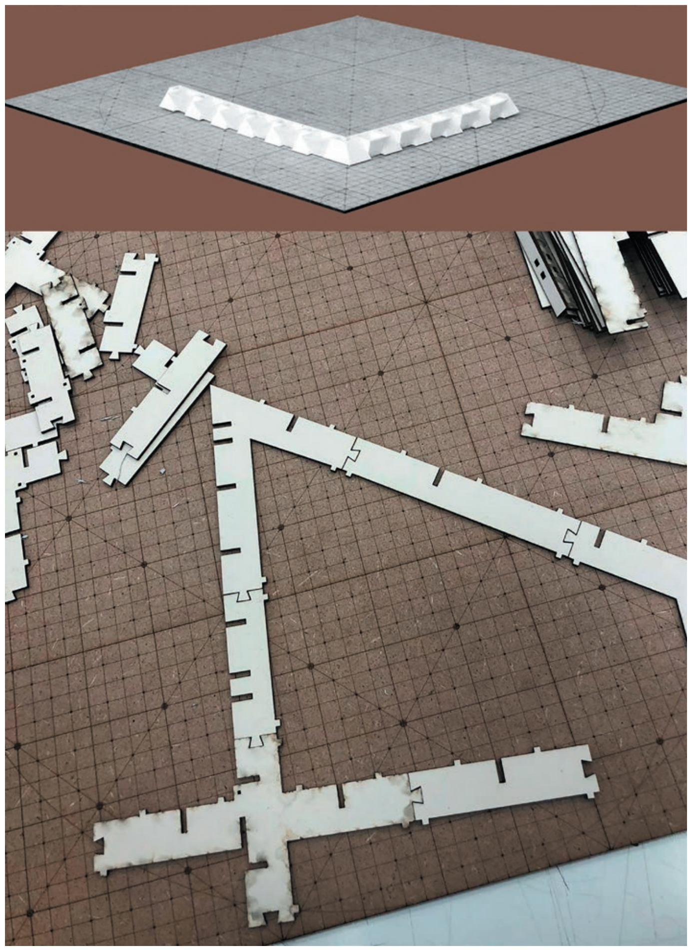
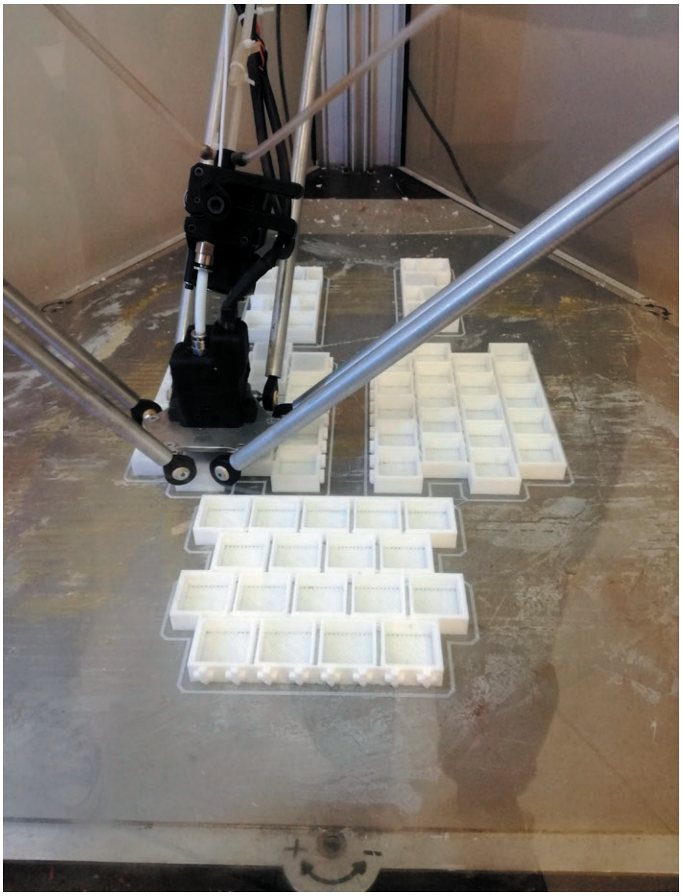


03 | Customised thermoplastic components prototyped with a 3D printing, Author's pic

04 | Customised wooden building systems prototyped with a laser cutter, Author's pic

05 | Customised concrete components prototyped with a 3D printing, Author's pic

03 |

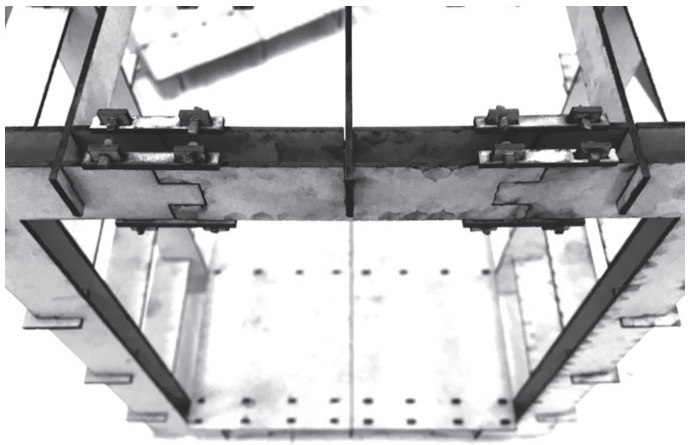


Being able to directly experiment with tools, machines and materials, students were able to take inspiration from "something they find while manufacturing something": doing and thinking become a simultaneous operation again, which has an influence on our thinking as architects. In this design dimension, the laboratory became the place of imagination, training, and production of a "total" experience (Pugh, 1991).

Education in the future tense

Placing the student at the centre of the construction process, where goals and tools of architecture coexist seamlessly, has been a very stimulating experience, even if more powerful instruments would have allowed the design experimentation to go further. For example, it would have also been interesting to prototype some components on a real scale. The SAAD-Lab # Prototype offers a good level of equipment, which can certainly be improved. An upgrade of the devices contained therein is currently planned and, in particular, the addition of a 3D printer

| 04



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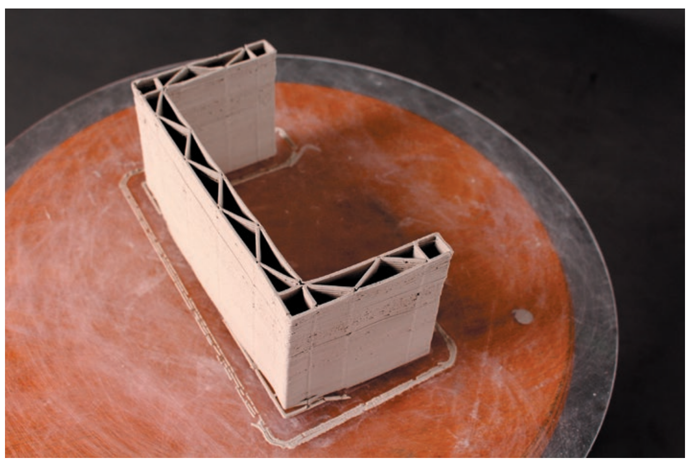


tems made with an innovative "interlocked" building system (as an innovative interpretation of the traditional Japanese Veneer House system), metal solar shading panels, wooden bricks, and disposable plastic formwork, and even load-bearing walls in concrete are some of the recurring construction elements experimented with in the small temporary village (Figs. 3-4-5).

Through tutorials and practical illustrations, students were put in the condition to programme their digital workflow that was based on a reversal of the traditional design phases, where the construction and procedural aspects follow those of architectural concepts and space-functional layout.

In this process, prototyping is the key action of the learning process. If the "model" is the traditional tool for studying and representing architecture, in digital fabrication processes it is replaced by the prototype, which simulates the architectural artefact in all its aspects, including construction and production. This procedure implies an alignment between the creative process and the control of the production phases and requires, in the project construction chain, an anticipation of the concrete aspects of building at the heuristic phases of the project.

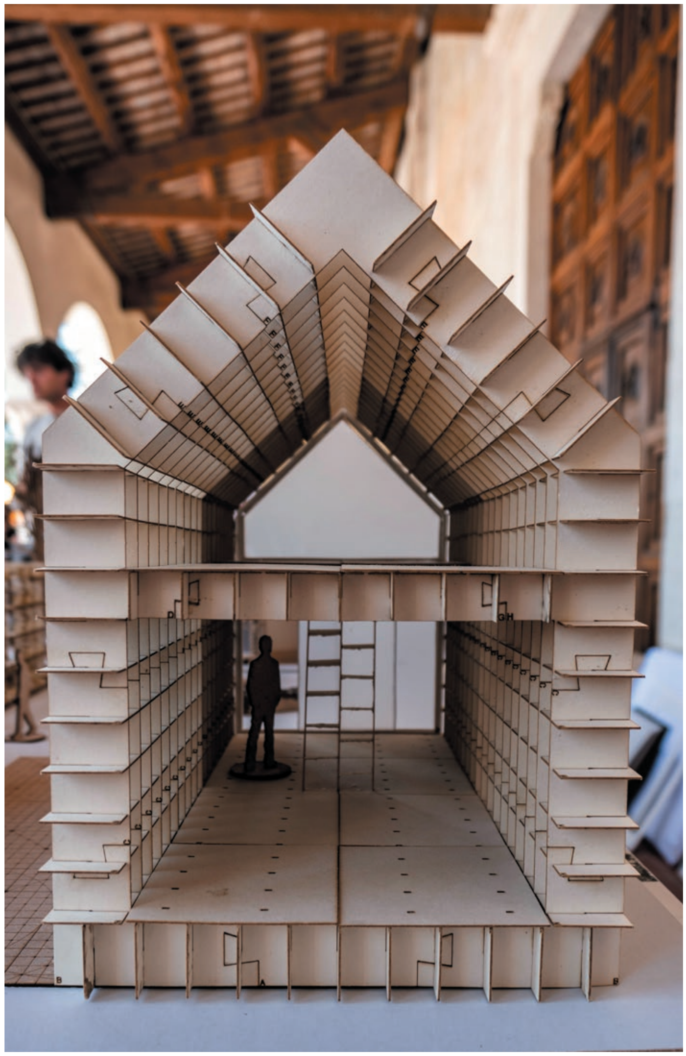
06 |

06 | Temporary house, "mature" approach, Author's pic

08 |

08 | Temporary house, "extreme" approach, Author's pic

| 07



07 | Temporary house, "positivist" approach, Author's pic

(with a high print volume) and of collaborative robots that today represent significant potential in the field of digital manufacturing.
The quality of this kind of educational experience (in this and other schools) will always be a function of how much the universities want and can invest to integrate digital technologies within educational curricula. Creating fabrication laboratories, making available the use of advanced tools, such as parametric/generative software and prototyping/fabrication machines, would become a priority for Architecture Departments to train the future architect. This is a key challenge for architecture schools to guarantee what Alvin Toffler defined an *«education in the future tense»* (Toffler, 1971). This challenge also requires the organisation of specific courses, both theoretical and practical, focused on digital innovation. Some digital design tools – such as parametric, computational or cad-cam software – bring with them innovative approaches in terms of effectiveness, control, and creativity of the design process.
In this last regard, the models produced in the workshop represent different interpretations of the impact that an educational environment based on the use of advanced technologies can have on student's creativity. At least three creative approaches emerge from the projects of young "architects in training" (as the students are):

a. mature;
b. positivist;
c. extreme.

In the first case, the *Kunstwollen*[11], literally "will of art", prevailed over the technological device. In the project that pursued this path, digital innovation was "incorporated" in the architectural artefact and metabolised by it (Fig. 6). In the second one, the enthusiasm for innovation pushed towards a "constructive sincerity" aimed at making digital construction a term of architectural language (Fig. 7). In the third case, digitisation was not limited to the design and construction process but "entered" the rules of use of the living space, suggesting an interactive architecture in which conception, production and use come from the same culture, which is deeply digital (Fig. 8).
These three positions represent as many ways of interpreting the architectural project starting from full awareness of the tools and techniques necessary for its realisation. That is why the second digital twist represents a great opportunity to propose an educational model, for architecture, based on the reconnection of theory and practice, creativity and ability, humanistic and scientific approach.

NOTES

[1] «Il n'est rien au monde d'aussi puissant qu'une idée dont l'heure est venue». Quote attributed to Victor Hugo. Source: http://webscience.com.

[2] In current architectural practice, digital fabrication found its way in some advanced forms of building processes as "off-site construction" that is, currently, the most advanced prefabrication strategy. But digital fabrication can be also considered a best practice in self-construction and participatory building processes, often aimed at social innovation goals and related to small scale projects.

[3] The techniques of digital fabrication generally fit into four main categories: cutting, subtraction, addition, and formation. Data most often comes from CAD (computer-aided design) and is transferred to CAM (computer-aided manufacturing) software. The output of CAM software is data that directs a specific machine, like a 3D printer or CNC milling machine.

[4] In June 2019, the University of Camerino's Educational Innovation Group was established to share and spread innovative educational approaches. The programme is coordinated by Professor Luciano Barboni, the University of Camerino's Pro-Rector for teaching.

[5] The degree course in Architecture Sciences ends, at SAAD, with four intensive two-week workshops. They are held by different teachers and focused on different disciplines. Students can choose which workshop to participate in. The subject of this paper is the "Architecture Construction Workshop" directed by the author of this paper.

[6] In Europe, the ETH of Zurich, the Institute for Advanced Architecture of Catalonia (IAAC), and the Schools of Architecture of the Royal Danish Academy of Fine Arts of Copenaghen, to mention a few, are among the universities with the most advanced teaching programmes in the field of digital fabrication.

[7] The "leaves" of the skylight of The Menil Collection museum in Houston or the "gerberettes"" of the Center Pompidou in Paris, designed by Renzo Piano with the support of Peter Rice, represent two examples of customisation of construction elements.

[8] The UK, in particular, is an outpost of offsite construction, i.e., a tailor-made prefabrication concept based on the combination of CNC and BIM technologies. See on this point: NLA Research Report, (2018), *Factory-made housing. A solution for London*, National London Architecture, London. [Online] Available at https://www.newlondonarchitecture.org/whats-on/publications/all-nla-publications/factory-made-housing-a-solution-for-london.

[9] See: https://openstructures.net/home-page.

[10] Cad-Cam technology is a computerised technology that allows you to obtain a three-dimensional object starting from a vector drawing performed on the computer.

[11] The term *Kunstwollen* was popularised by the Austrian art historian Alois Riegl, and denotes the characteristics and boundaries of an epoch's aesthetics, as well as the intrinsic creative drive peculiar to it.

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