Lecture Notes in Civil Engineering

Volume 24

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Digital Wood Design

Innovative Techniques of Representation in Architectural Design

Springer

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Contributions are published under double blind review mode

ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-3-030-03675-1 ISBN 978-3-030-03676-8 (eBook)
https://doi.org/10.1007/978-3-030-03676-8

Library of Congress Control Number: 2018963030

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Introduction

Grandi invero sono le cose che in questo breve trattato io propongo alla visione e alla contemplazione degli studiosi della natura. Grandi, dico, sia per l'eccellenza della materia per se stessa, sia per la novità loro non mai udita in tutti i tempi trascorsi, sia anche per lo strumento, in virtù del quale quelle cose medesime si sono rese manifeste al senso nostro.

In the present small treatise I set forth some matters of great interest for all observers of natural phenomena to look at and consider. They are of great interest, I think, both from their intrinsic excellence, and from their absolute novelty, and also on account of the instrument by the aid of which they have been presented to my apprehension.

Galileo Galilei—*Sidereus Nuncius* (1610)

DWD

Digital Wood Design. Innovative Techniques of Representation in Architectural Design intends to undertake the digital representation strategies that can change the future of wooden architectures, through the combination of tradition and innovation. Calling on anyone who intends to bring innovation and experience in wood construction field, this volume is related to the advanced digital modeling with a particular attention on the solutions associated with generative models and dynamic value, inherent to the relation between knowing how to draw and how to build, a relation that finds its foundation in geometry. Although wood is one of the oldest construction materials, in recent years many innovations have affected the production techniques and the design tools, and they have paved the way for new formal, esthetic, and structural solutions, which can fill the application fields of this material. Lightness and eco-compatibility of features make this material a valuable alternative to materials that have characterized the recent architectural debate, offering the ability to build with sustainable, fully renewable, and high-performance materials in energy and structural aspects, capable of complying with architectural solutions of great freedom. Thanks to the potential of computing, parametric design

and digital manufacturing are decisively contributing to renew a spinneret to look forward in driving the future of construction.

The book is developed in the centrality of representation, starting from the lesson of Marshall McLuhan about the correspondence between medium and message. Representing corresponds to create a model, a condition marked by digital revolution through the application of computational potentialities.

The new role of representation derived by digitalization is connected to the techniques, but it is firstly a cultural question, an expression of the cultural passage from a society of the image to a society of simulation. If maybe digital representation is developed in correspondence of precision and replication necessity, if the communication aspect promoted a valorization of tri-dimensional model, step by step, in the predominance of morphological approach, the possibility to represent the complexity of the reality has defined the role of digital design as fulcrum: On one hand, it is becoming day after day the place where to converge different data, and on the other hand, the medium to replicate the dynamical relation and the processes, extending the question to time dimension. As in the digital era as in the prehistoric, representation is the instrument useful to understand the world, to analyze and break up the phenomena, and to prefigure future scenarios. Representation is a transdisciplinary language, able to integrate specific technical language, by using the abstraction of geometry to transform the analogy of the real in a simpler and understandable discretized interpretation. It is so important to understand how these tools are used to build the model, because in this interpretation it could be hidden a reductive simplification or conceptual misunderstandings.

Wood represents a really contemporary material, rethought and transfigured by design, always carrier of its natural essence, unable to forget the work of man and the traditional lessons. Wood design is returning to have also in Europe a central question, according also to its nature of renewable resource that can respond to the energetic and climatic challenges. Digital studies are transforming wood production and the workflows in the construction process, so that the distance between project and realization is reducing more and more.

Digital wood design integrates different approaches, from the historical research to the material analysis, the architectonical research of freedom. Different points of view, the implicit need of interdisciplinary, support the explication of the hidden relation is the basis of construction issues. But the particular approach of this volume is connected to mark the centrality of the model and the value of digital medium.

Drawing, model, and architecture are inseparable aspects of the same question. Deepening the representative question helps to find the origin, the sense, and the roots of our architectural aims.

Drawing as Model

Galileo Galilei is titled by Albert Einstein as the father of the modern science, according to his introduction of the synthesis of model to the study of phenomena. But Galileo found in the instrument, in his innovative tool, the fundamental help to support his genius and his methodology. Medium is the message, as Marshall McLuhan teaches us. This condition is really strong in our contemporary era, characterized by a digital soul.

Digital wood design, a theme centered on innovation and digital tools, which cannot forget the lesson of the history. The performance of instruments reduces timing, which is dedicated to the reflections about essential questions and the aims of architecture. We editors have the courage to promote this approach to digital wood design not in virtue of the value of our innovative research, but because of the role of Italian school in drawing studies, but also because the medium is useful to all. We want to involve the tradition to help a critical vision of the future development.

The master of the past shows us contemporary lessons about the value of drawing as model. In particular, Leon Battista Alberti, in 1485, starts his treatment *De re aedificatoria* introducing the centrality of this field of research. It is necessary to analyze the original Latin version because in some English texts it is often not presented in a correct translation:

> *Tota res ædificatoria lineamentis et structura constituta est.*
>
> *Lineamentorum tota vis et ratio consumitur, ut recta absolutaque habeatur via coaptandi iungendique lineas et angulos, quibus ædificii facies comprehendatur atque concludatur.*
>
> *Atqui est quidem, lineamenti munus et officium praecribere aedeficiis et partibus aedificiorum aptum locum et certum numerum dignumque modum et gratum ordinem, utiam* tota aedificii forma et figura ipsis in lineamentis *conquiescat.*
>
> *Neque habet lineamentum in se, ut materiam sequatur, sed est eiusmodi, ut eadem plurimis in ædificiis esse lineamenta sentiamus, ubi una atque eadem in illis spectetur forma. Et licebit integras formas præscribere animo et mente seclusa omni materia; quam rem assequemur adnotando et præfiniendo angulos et lineas certa directione et connexione. Hæc cum ita sint: erit ergo lineamentum certa constansque præscriptio concepta animo facta lineis et angulis prectaque animo & ingenio erudito*
>
> Architecture is constituted by drawing and construction. The impact and the ratio of the drawing lie in finding the correct and unique way of joining and fitting together those lines and angles through which the building images are defined and understood. The function and duty of the drawing consist then to assign to the buildings and to the parts that compose them an appropriate place, an exact proportion, a convenient order, and a harmonious arrangement, so that the whole form and figure of the building subsides in the drawing itself. So, the drawing doesn't have inside itself anything derived by matter; and that is why we experience the same drawing in more buildings, where the visible form is just one. And it will be possible to represent the integrated designs in our thought and imagination entirely separate from matter, a condition that we understand by recording and presetting angles and lines to defined directions and connections. This being so, the drawing will be a defined and constant design, conceived in the mind, made by lines and angles, and carried out by a person endowed with intelligence and culture.

The philological analysis of one of the most important architectonic treatises can show us the full comprehension and anticipatory forecast that helps us to deeply understand the sense of our research, especially in the digital age.

Lineamenta, drawing, modeling. The first reflection can be addressed to the translation of the word "lineamenta": Some English authors use the word "design" or "lineaments," but *lineamanta* is clearly connected to a system of lines, so as in the first Italian translation the word used is "disegno," now we can use the word "drawing." But inside this word, there is a deepening sense of these tools: Line, in fact, is the first algorithm for primitive man; it defines the birth of culture, a magic medium that transforms the void in form. Drawing is the system of lines, the conscious use of this medium to understand the real. In this conception is forecast our contemporary idea of generative modeling, composed by a link of simple algorithm to define a digital path. Drawing is the modeling.

Architecture, drawing, modeling. Alberti shows us a series of considerations about the value of drawing: "The architecture is constituted by the drawing and the construction." Drawing, as our digital models, is the constitution, the essence, and the statute of architecture, which find its form in the construction, in the real concretization. Alberti marks how architecture is an integrated process from the virtual space of the idea to the defined form of the construction, these are two structures composed together. But in Alberti's theory, drawing and design are the work of the architect, and construction is just a transcription of the idea. The model is the space of generation, the place where it is possible to connect together the elements. The main point of this sentence is the interpretation of a hybrid definition, which is predominated by the virtual that defines the construction process.

Drawing code. About drawing, Alberti shows us as "*tota vis et ratio*," its vitality, its impact, its force, and its reason, but also the methods, "his way," is not the role of a simple tool or the results of a path, but it is an identification of relations and instruction for architecture realization. In the words of the great theorist, drawing as model is a net, defined by the connections of the designed forms multi-aspects. Drawing is a system for the form-finding, aimed to have, after a path, after a hard work in mind, the definition of elements and connections, a system that in virtuality cannot be clearly verified. Drawing, in fact, is a scientific code, "correct and unique," absolute way of joining and fitting together lines and angles. Model and drawing are both founded in the discretization of the elements: The digital logic is the expression of man's needs, but its goal is to return to the organicism of the architecture. These relations are hidden in the form that expresses the complexity of architecture. Lines and angles are the elements that configure the form of the building. In our digital logic, it could be related respectively to the vector element and to the links between them. Through these elements and these relations, through the construction of the generative modeling, it is possible to obtain two different results: One is a defined architecture, because the drawing is a scientific construction, and it is a two-way function between the domain of the reality and the codomain of the ideas; the other, marked by Alberti, shows a support process to understand, literally it takes together, it transforms the multiplicity of perceptions and elements in a whole, the building

images, not the form, but the results, the impact, the esthetic value, so that the value of the drawing is found in the simulation function.

Drawing as language. Drawing is founded in a scientific language but, at the same time, model is a cultural path. Alberti is a son of his time, and his words are full of humanistic culture. His architectural theory finds a central reference in Vitruvius, who, in *De Architectura*, writes that "proportion is a correspondence among measures of the members of an entire work, and of the whole to a certain part selected as standard." Drawing derives from measurement operations, in Latin *mensura*, from *metiri*, which means to "distribute," "divide." Dividing up a space it involves applying a rule, defining a relation; this is making architecture. From this, it results the principles of symmetry. Without symmetry and proportion, there can be no principles in design of any time; that is, if there is no precise relation between its members, as in the case of those of a "well-shaped man" (Vitruvius, *De Architectura*, III, 1, 1). He proposes "*Six Principles of Design*" as order (*ordinatio*), arrangement (*dispositio*), proportion (*eurythmia*), symmetry (*symmetria*), propriety (*decor*), and economy (*distributio*) (Vitruvius, *De Architectura*, I, 2, 1): Order consists in adapting the right measure to single elements of the work; arrangement is their appropriate collocation; eurythmy is the harmonic vision of the proportion between parts; symmetry is the correspondence between each single part in the whole set; propriety is the formal improvement; economy is the equilibrated administration of resources and space (Vitruvius, *De Architectura*, II). Modeling as cultural language, as an expression of a study of these relations, is not just a set of commands, it is not just a procedure, but it is a path aimed to create architecture and its deeper esthetic value.

The virtuality of the drawing. Figuration recalls the concept of imaginary, the interpretive action that gives a sense to the perceived form. This conceptualization, that defines the real essence of modeling, is one of the central questions made by Alberti, who marks in a different way, underlining the absence of materiality in this differentiation between figure and form. Here is a reference in the value of vision, so important in the construction of the model. Drawing is anyway an abstract process, and in this, as a condition that defines the value itself of architecture, in its connection with culture. Drawing defines itself in the virtual space of imagination, in "*animo et mente*," through the experience and feeling. There is a centrality of virtual memory, so close to our digital approach, in the process of elaboration of stimuli, in a centrality of the visual impact for the architectonic finalities.

Figure and form. Another central aspect introduced by Alberti is the distinction between figure and form: The term "figure" derives from *fingo*, which means "to give form," with a mainly plastic connotation, so much that *figolus* is the potter. It is distinguished from "form," making clear etymologically the sense of "hold," as it testifies the correlation with the word "stop," with which the linguistic root is in common. If then "form" has a static sense of stabilizing and concretizing, "figure" is tighter to dynamic, because form is defined as the arrest of a process. Figure is also heuristic, abstracting from the visible matter through perception and through reasoning form models, expression of the necessity of the eidetic-constructive research for the comprehension of what is observed: It is in this context that is more comprehensible because in geometry the figure is a set of points or lines or surfaces,

which present a whole construction. Both find their reason and their address "*in lineamentis conquiescat*," to stop itself, to find a quiet and a rest of mind process, always dynamic and in exploration. In drawing, it is necessary to have choices, to define logic, and to determinate univocal relations. Drawing is not an idea but the concretization and the place of comprehension of the ideas, because, as written by another great theorist of architecture, Giorgio Vasari, "il disegno è apparente espressione e dichiarazione del concetto che si ha nell'animo, e di quello che altrui si è nella mente immaginato e fabbricato nell'idea" (drawing is an apparent expression and declaration of the concept that a person has in the soul, and of what others have imagined in mind and built in the idea) (Vasari, *Le vite*, 1568, 11).

Drawing as generative modeling. Drawing is the set of rules and relations; once it is frozen in the form, as a geometrical conceptualization, a triangle can generate infinite forms, each one different from the others in terms of measure, proportion, relations, etc. For this reason, "we experience the same drawing in more buildings, where it is possible to define one and the same form": Generative drawing, the relation that defines modeling, is a reality with its own life. This conceptualization is really close to our approach to digital design, in the mass customization logic, in the replication of the design field of application. Centrality of variation is another theme of the classicism, as Alberti remembers, in the same book, when he writes: "Variety is always a most pleasing space, where distant objects agree and conform with one another; but when it causes discord and difference between them, it is extremely disagreeable" (Alberti, 1485, I, IX). Ante litteram, Alberti shows how parametric principles are the basis of architectural theory, founded in the composition of this relations, showing how also in this field difference is not diversity, in the unity of the model.

Integrated design. In the Latin text, Alberti defines the possibility of "*integras formas præscribere*" that can be translated as "representing integrated designs." This interpretation is defined by the etymological sense of the word "*prae-scribere,*" literally "writing before," the signs made in a previous time, connected to logic of "project," throw forward, in the same sense of "re-present." "*Integras formas*" could be translated also as "defined solutions," uniform and complete forms, but the sense of this word is connected to the possibility of making complex results. "*Integras*" is whole, full, derived by "integer," in the sense of making something complete. Integrated design is very close to our digital approach where the distance between projects and construction is ever more reduced, also if the project is separated from the material, and it finds his field of existence in the virtuality of representation. In this context, for example, the actual condition of wood design shows the breaking of the conditioning of material in form and structure because wood itself is engineered. The real issue is the relation between form, structure, and matter, which is understood in this text when the authors connect the understanding process to the record and the presetting of geometrical elements, interpreted as our concept of vectors and links. The integrated design is a sort of second step; it is a complexification of the results when the model is stressed.

Hybridization as synthesis. To conclude his digression, Alberti proposes a synthesis to describe all the aspects of drawing process: It is defined and constant design, in this dialect between form and figure, between virtuality and reality, marked also by the word constant, something that standing firm, invariable, and uniform. Drawing is conceived in the mind, made by lines and angles, through geometrical elements but also through their relations. In this sense, the model is something hybrid, as asserted in the first sentence, connected to the construction, to the interpretation of the complexity hidden in the architectural shapes, and to the esthetic value of architecture. For this reason, drawing is reconnected to man, to his author. In this humanism, the value of the drawing is not reduced to the tool, it is not a simple machine, but it is "carried out by a person endowed with intelligence and culture," "*animo & ingenio erudito,*" a man with heart and mind, because drawing, also in our digital world, always maintains its evocative purpose, using high-tech solutions, in the deepen coordinates of architecture, which Alberti descript as "*ad vitam bene beateque agendam faciant,*" building to have a better and happier life.

Starting from the origin and originality of the first architectural treatises, digital wood design can find and redefine new models to innovate architecture.

The Structure of the Volume

The volume is composed of 61 chapters, written by 153 authors from 5 continents, 24 countries, and 69 centers of research (57 universities). These numbers witness the international approach of the question, inedited integration of different schools in the world.

In the value of integration and interdisciplinary, the richness of these variations in the theme is organized in five parts that connect digital wood design to the integrated approach and generative design, to the model synthesis and morphological comprehension, to nature lessons and material explorations, to constructive wisdoms and realization challenges, and to parametric transfigurations and morphological optimizations.

The first section concerns the integrated approach and the generative design developed with different approaches by groups of research from all over the world. The volume starts from our chapter (Bianconi, Filippucci) about the evolution of digital representation in timber architecture, describing the activity of our group of research in the balance between AI and NI and showing the researches applicative developed founded in computational design. The section continues in the international cooperation between Canada and Germany in the architectural language through wooden prototype, in a critical approach to recent technical developments in design, fabrication and material innovation and supported by a re-appropriation of interdisciplinary teaching methods (Correa, Krieg, Meyboom). The theme of the Danish Centre for IT and Architecture is new workflows for digital timber, which explore how computation and a challenging of traditional material practice can impact the use of timber in architectural design and fabrication (Svilans, Tamke,

Ramsgaard Thomsen, Runberger, Strehlke, Antemann). IAAC and at the Bartlett School of Architecture show their collaboration in a series of project, case studies of tolerance management in robotized fabrication with different kind of wood (Dubor, Figliola, Brugnaro). The timber design across a variety of scales, from furniture to structures, is the theme of the research activity developed by the Australian Advanced Timber Concepts Research Centre (Beale, Morgan). The Californian group of research describes Geodesic Lattice Shell Methodologies, hybrid approach in modeling of these surfaces those combine an elegance of forms with the efficiency of structure driven by the material constraints of straight lath members that can be bent into shape (Cabrinha, Korman, Testolini). The NTNU Norwegian group analyzes the mass customized architecture obtained through the application of designing site-specific, customer-inclusive, and bespoke timber structures (Haddal Mork, Luczkowski, Manum, Rønnquist). The gridshell.it research group linked to Naples University describes reciprocal implications between design and construction process of timber gridshell, showing the development of a new information technology design tool (Pone, Rando, Lancia). This part ends with the digital wood researches of the Chinese Tongji University's DDRC, centered in the relation between traditional culture and innovation, a condition that involves also timber architecture, in a digital design process based on the reinterpretation of traditional wood structures that ends with fabrication technologies (Yuan, Chai).

The second part of the volume is based on the centrality of representation as a synthesis model and morphological comprehension, deepening in lessons always proposed by the cultural heritage and the value of drawing as knowledge instruments. The section begins with an overview about the role of wood models from the Renaissance to the architectural avant-garde as an alternative method to virtual representations (Taboada). In connection here are reported three central case study of the Wooden models of Vatican Basilica (Bianchini, Ippolito, Senatore), the Coliseum (Valenti, Romor, Conti), and Bologna's theater (Amoruso), paradigmatical also if miniature architectures surveyed, represented, analyzed, and understood by the support of the advanced digital tools. This part continues analyzing the use of models and prototype in design practice (Chernicoff), the application of advanced techniques as parametric kerf bending for double curvature surfaces for wooden furniture design (Capone, Lanzara), and the integration of technique in digital joinery for hybrid carpentry (Magrisso, Zoran). The connection between design and wood is analyzed also in the study of cultural heritage, as in the case study of geometric patterns in the traditional Turkish woodworking (Hattap). This part continues reporting the research in architectural representation of wooden cultural heritage, reporting at the beginning the Italian heritage documentation in the application of HBIM in the Church of Eremitani at Padua (Giordano, Borin, Panarotto), in *Venetian* complex wooden structures (Gottardi, Balletti, Guerra, Florian), in South Tyrolean farm (Brusaporci, Luigini, Vattano, Maiezza, Tata), and in the study of traditional fishing machines (D'Uva). The same Italian school is not limited to local landscape, but it exports also to study Finnish and Russian heritage (Bertocci, Porzilli), techos de armaduras in Cuban colonial (Morganti, Bartolomei, Predari), and the Caribbean Bahareque in Colombia (Leserri, Guzman Bejarano).

The third part describes the relation between nature lessons and material explorations, in the value of digital design that involves also materiality. This part analyzes the mathematical interpretation inside the computational mechanical modeling of wood, starting from microstructural characteristics over wood-based products to advanced timber structures (Füssl, Lukacevic, Pillwein, Pottmann). The section continues reporting research connected to the valorization of natural characteristic of wood, as in the case of hygroscapes, understood as an Innovative Shape Shifting Facades developed in an international cooperation between American University in Cairo; Arab Academy for Science, Technology and Maritime Transport; Princeton University; and the University of Roma Tre (Abdelmohsen, Adriaenssens, Gabriele, Olivieri, El-Dabaa). In the same logic, the design of a Wood Composite with shape-memory behavior is also connected to a responsive wooden architecture developed in Texas (Mansoori, Kalantar, Creasy, Rybkowski). A similar approach is developed in the exploitation of the physical response of wood, as in the innovation proposed in a construction system to create scalable adaptive stiffness structures (Baseta) and in the study of the conceptual joining linked to branch formations, (Allner, Kroehnert), both the researches developed firstly in the University of Applied Arts of Vienna. The study of the material increases in a detailed scale in the studies promoted in the evaluation of mechanical properties of existing timber structures (Koca). Solid wood and based wood composites and their potential of a short procurement chain of wood represent the investigation of a national cooperation between Italian center of research (Romagnoli, Scarascia Mugnozza, Fragiacomo, Follesa, Brunori). The empirical research arrives to transfigure natural material, as reported in Bamboo's Bio-inspired Material Design Through Additive Manufacturing Technologies developed in Florence University (Buonamici, Volpe, Furferi, Carfagni, Signorini, Goli, Governi, Fioravanti). Also, on the other part of the world, in Australia, wood is transformed into a 3D printed, gradient timber panel composed of forestry waste and by-products (Löschke, Mai, Proust, Brambilla).

The fourth part concerns the constructive wisdom and realization challenges, by analyzing the conceptualizations but also the paths to transform the research in building. This section is opened by a shape grammar lessons derived from a tree saw as a prerequisite to timber architecture (Muslimin). The second chapter presents a new perspective for designers to work with timber in the twenty-first century, in the Nervi's request of "Constructing Correctly" in the values of the person places on material understanding and constructional methods within specific context, analyzing also the series of applications (Tang, Chilton). This part continues with an examination about the emergent theme in digital wood design, exploring the ways in which researchers have been exploring the use of technology to expand the use of wood while minimizing the energetic impact of the construction (Beorkrem). Housing prototypes, timber tectonic culture, and digital age are the theme of the following chapter, which raises a series of discussion points centered on the role of timber-based products, in a digitally enabled domestic construction industry (Colabella, Gardiner). Another two overviews concern the main research paths in Europe, marking the research in performance-based design, material culture and fabrication process (Figliola, Battisti), and the wooden skyscrapers, connected to the design experience

(Buffi, Angelini). This section continues analyzing the knowledge-based engineering in timber construction, applied in industrialized building and data management by the Australian group of research managing the complex and multidisciplinary nature of design, fabrication, and installation (Day, Gasparri, Aitchison). The earthquake-proof is one of the reasons for the application of this technology in territories afflicted by earthquakes. The use of wood timber, designed in BIM environment, is descript in the case study of Amatrice's prefabricated bus station (Cianci, Calisi, Di Benedetto, Molinari). The application of generative path is applied by the group of University of Perugia (Seccaroni, Pelliccia) in the customizable social wooden pavilions, design based on a workflow for the energy, emergy, and perception optimization in Perugia's parks. From Japan, an innovative methodology became the "Veneer House" project, an empathic design founded in an agile technology applied in different solutions (Kobayashi, O'Keefe). From New Zealand, it derived the proposal of an innovative non-orthogonal assembly optimized light timber frame construction design, realized by using digital manufacturing technologies (Finch, Marriage). From Germany, another really important international case study regards the use of timber plate Shell Structures, a historical technique of construction that becomes the inspiration for new assembly methods according to the efficient realization that can now be achieved through algorithmic geometry processing (Robeller). From USA, the proposal of a computationally derived cross-laminated timber reinforcement and construction is developed, a solution derived from the recent advances in computational analysis and simulation (Ellinger, Beorkrem, Dodson). The application of the innovative technologies is applied also to the construction, as in the application of Beech wood for architectural design, rewritten by a series of geometric and topological variations on the theme of the wood-frame roof (Fallacara, Pantaleo, Scaltrito). Another really interesting case study is developed in Papua Guinea, the Brise-Soleil House, a system for seamlessly integrating design, fabrication, and assembly of a geometrically complex timber veil (Nelson, Knapp, Spence, Hutchines). The successive case study concerns the Italian Ecodomus project, a proposal that sees the mass customized wooden housing in the Mediterranean area, a prototype created by an irregular geometry made up of CLT panels and using digital fabrication technologies (Colella, Fallacara). This section is concluded with the description of the HOUSE 1 as scaffolding and protostructure, experimentation of Wood Collaborative Design and Construction in First Year Studio Teaching at EPFL (Dietz, Negueruela del Castillo, Mignon, Lafontaine Carboni).

The last part regards the parametric transfigurations and morphological optimizations, reporting firstly the case study of pavilions and installations from all over the world, the spaces where it is possible to freely express and exalt digital wood design. The section starts from the installation of KODOMA ideated by Kengo Kuma in a context of international cooperation that sees the direction of Marco Imperadori, installed in the Italian land art park Arte Sella, a polyhedron made only by one wood section and connected without nails or screws (Kuma, Imperadori, Hirano, Clozza, Vanossi, Brunone). In collaboration with the same Italian group, Atsushi Kitagawara shares his installation *Byobu,* a reinterpretation of the really famous EXPO Milano 2015 Japanese Pavilion, a naked structure defined by only

one element, conceived with studs, connected without any screws or nails, thanks to the "compressive-tension" effect, whose concept interprets old Japanese wooden-based techniques of constructions and even handcrafts of complex wooden toys (Kitagawara, Imperadori, Kuwabara, Brunone, Matsukawa). The other chapter reports at the same time wooden temporary architecture and constructions realized in Japan, Italy, and France, developed through digital fabrication and controlled by generative design, as an expression of the translation of the research into a real high-quality architecture (Liotta). In the integration of idea-driven and science-driven design process, a series of full expressive wooden pavilions witness the combination between digital architectural design processes and digital design fabrication technology, and it combines digital learning chain (Gheorghe). From Japan, in a reinterpretation of metabolism in front of digital contamination, here is reported the research experiences in digital wood design, showing its impact on modularity, adaptability, compatibility, and transformability of architectural elements, in the paradigm shift of architectural design and technology between mass production and smart production (Ikeda). Two experiences from Turkey show a wooden folding structure, the A-Chord, a design family of non-standard wooden structures, light-weight, portable (Yazar), and re-usable, and the common action garden, expression of the integration between digital design and fabrication technologies with sustainable landscape issues (Akipek). From the Estonian Academy of Arts, starting from local wooden house manufacturers, the architectonic research shows in the installations the results of a young and vibrant digital design integrated into a smart fabrication process, a way to return to a craftsmanship affordable for a wider public (Tuksam, Pihlak). "FracShell" is a computational morphogenesis project, based on the transformation of fractal geometry (Takagi–Landsberg's fractal surface) into a lattice shell structure, a demonstration of the easy manual construction of a complex digital design taking the advantage of the rule-based shape but also of the versatility of wood in transforming the complex digital design into its real-scale physical structure (Rian). Within the broad context of teaching and research, Bio-Dune Pavilion is the results of a project that involves a pavilion based on developable wooden surfaces, parametric design, and digital fabrication, which are presented in collaboration between Ibero-American universities; the project is addressed to applications of wood to architecture through the CNC cutting of plates, thanks to the properties of developable surface (Martín-Pastor, García-Alvarado). The volume ends with the presentation of several shelters recently designed by the Politecnico di Milano through high-level international cooperation, characterized all by the smallness, a digital codesign that demonstrates the centrality of parametric modeling and of the materiality, in the great potential of wood as a construction material, according to the Vitruvian terms of structures, functions, and esthetics (Imperadori, Salvalai, Vanossi, Brunone).