JIDA'22

X JORNADAS SOBRE INNOVACIÓN DOCENTE EN ARQUITECTURA

WORKSHOP ON EDUCATIONAL INNOVATION IN ARCHITECTURE JIDA'22

JORNADES SOBRE INNOVACIÓ DOCENT EN ARQUITECTURA JIDA'22

ESCUELA TÉCNICA SUPERIOR DE ARQUITECTURA DE REUS
17 Y 18 DE NOVIEMBRE DE 2022

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

GILDA GRUP PER A LA INNOVACIÓ I LA LOGÍSTICA DOCENT EN ARQUITECTURA

Organiza e impulsa GILDA (Grupo para la Innovación y Logística Docente en la Arquitectura) de la **Universitat Politècnica de Catalunya · BarcelonaTech (UPC)**

Editores
Berta Bardí-Milà, Daniel García-Escudero

Revisión de textos
Alba Arboix Alió, Jordi Franquesa, Joan Moreno Sanz, Judit Taberna Torres

Edita
Iniciativa Digital Politècnica Oficina de Publicacions Acadèmiques Digitals de la UPC

ISBN 978-84-9880-551-2 (IDP-UPC)

eISSN 2462-571X

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JIDA'22. X Jornadas sobre Innovación Docente en Arquitectura
Reus, EAR-URV, 17-18 noviembre, 2022
DOI: 10.5821/jida.2022.11641

Método Sympoiesis con la fabricación robótica: prototipaje colectivo en la experiencia docente

Sympoiesis method for robotic fabrication: collectively prototyping in architecture education

Mayor-Luque, Ricardo
Advanced Architecture Group, Institute for Advanced Architecture of Catalonia, IAAC, Spain.
ricardo.mayor@iaac.net

Abstract

This paper considers how research by design and innovative technologies can join in the development of a collective project in Architectural Education. Based on the book Staying with the Trouble by Donna J. Haraway, this paper establishes a method called Sympoiesis methodology in which a theoretical framework is introduced that consists of collective design, prototype interaction and robotic fabrication. The aim of the paper is to propose a new method in architectural design studio teaching based on collective problem-solving access through making-with prototypes over the implementation of robotic fabrication. Finally, a 6-week seminar studio is presented as a case study, illustrating the proposed framework and helping determine its applicability, impact and limitations, to establish a more profound dialogue between new technologies and digital tools in new participatory learning spaces in the best practices and design in Architectural Education.

Keywords: *collective design, design/build, manufacturing-driven design, material exploration, robotic fabrication.*

Thematic areas: *technology (construction, structures and installations), actives methodologies (MA), digital fabrication.*

Resumen

Este artículo considera cómo la investigación a través del diseño e innovadoras tecnologías pueden unirse en el desarrollo de un proyecto colectivo en la enseñanza de Arquitectura. Basándose en el libro Staying with the Trouble de Donna J. Haraway, se presenta un método llamado metodología Sympoiesis que propone un marco teórico compuesto por: el diseño colectivo, la interacción con prototipos y la fabricación robótica. El objetivo es proponer un nuevo método dentro del estudio de diseño arquitectónico basado en un acceso colectivo a la resolución de problemas a través de la creación de prototipos con la fabricación robótica. Finalmente, se presenta un seminario de 6 semanas que ilustra el marco propuesto y ayuda a determinar su aplicabilidad, impacto y limitaciones, para establecer un diálogo más profundo entre las nuevas tecnologías y las herramientas digitales en nuevos espacios de aprendizaje participativo, mostrando así una nueva forma de abordar el diseño en la escuela de Arquitectura.

Palabras clave: *diseño colectivo, diseño/construcción, diseño conducido por sistemas de producción, exploración material, fabricación robótica.*

Bloques temáticos: *tecnología (construcción, estructuras e instalaciones), metodologías activas (MA), fabricación digital.*

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Introduction

This paper considers how Research by Design and Technologies can join in the development of a collaborative project in Architectural Education. While research is devoted to the production of knowledge, the implementation of innovative technologies, such as robotic fabrication, within design allows it to directly associate with the creation of artefacts[1] as a source of experience and emotion, towards the production of a new form of knowledge.

The use of automation and robotics has demonstrated numerous advantages in many industries including manufacturing[2]. Therefore, it is expected that robotic technology plays a key role in achieving a successful construction project. In this connection, robotic technology has become more present in the Architecture, Engineering, and Construction industry. Nevertheless, beyond emergent industry applications and manufacturing systems, in this paper, we question that if we integrate these tools at an architectural design studio will students understand the robotic fabrication technology? How directly linked it to the design process within a collective process? And consequently, how does it affect their creativity?

Building on this framework, in the book *Staying with the Trouble*, Donna Haraway (2016) offers provocative new ways to reconfigure our relations to the earth and all its inhabitants in a contemporary world that does not forget how much ecological trouble it is in. She refers to our current epoch as what she calls the Chthulucene, as it more aptly and fully describes our epoch as one in which the human and nonhuman are inextricably linked in tentacular practices. The Chthulucene, Haraway explains, requires *sympoiesis* or making-with, rather than auto-poiesis, or self-making.[3]

To address this concept, this paper proposes Simpoiesis methodology, which challenges the notion of a participatory learning space of collective-design-to-fabrication workflows and explore the possibilities of making bottom-up design decisions while building through interaction with robotically manufactured prototypes as a new teaching mechanism within the architectural design studio[4].

1. Context: Collective Processes in the Architectural Design Studio

1.1. Learning in Architecture Design Studio

The architectural design studio is an important process, which aims to shape the skills, knowledge, and sensitivities of students and enhance their creativity as well as their problem-solving skills. Building on this framework, in the midst of the information age and the advent of

[1] In the book A theory of Craft: Functions and Aesthetic Expression, Howard Risatti (2007) refers to the artefact as the prototype itself created by the craftsman. In reference to this, Prototype As Artefact - Design Tool for Open-ended Collaborative Assembly (Atanasova and Gramazio et al, 2021 defined Prototype-as-Artefact fabrication workflows as a process which challenge the notion of a top-down linearity of design-to-fabrication workflows and explore the possibilities of making bottom-up design decisions while building in a human-robot collaborative setting.

[2] In the paper "Industrial robots, employment growth, and labor cost: A simultaneous equation analysis", Junga, J.H. and Limb, D. (2020) notes that recent advances indicate that "the increase in both unit labour costs and hourly compensation levels induce an extensive application of industrial robots".

[3] HARAWAY, D. J. (2016). Staying with the trouble - Making Kin in the Chthulucene. Duke University Press.

[4] This paper belongs to a series of projects co-developed by students and staff around the teaching methodology research inside the context of robotic fabrication in Architecture school, and in continuation of the paper "Craft-based methods for robotic fabrication: a shift in Architectural Education", MAYOR, R, MARENGO, M, DUBOR. A. (2021) presented in the JIDA'2021 call.

new tools based upon information technologies, the spectrum of the architectural field and the role of the designer needs to be reshaped, from theory to construction.

Architectural design covers a wide range of factors beyond the physical and structural aspects of buildings. Diverse subjects other than architectural design are important domains to study during the development of the architecture course. Therefore, architectural education is a multifaceted field due to the complexity of the social and cultural aspects normally associated with it. In this context, Donna Haraway uses the term tentacular thinking to expand on the argument that bounded individualism in science, politics, and philosophy has finally become unavailable to think with, truly no longer thinkable, technically or any other way.

Haraway describes tentacular thinking as a counter-term and critique of a visually dominated, anthropomorphic form of thinking. The world, on the other hand, is to be perceived by touching, feeling and trying things out. The tentacles stand for the other, the non-human and implicitly pose the question of how a perception that is not two-armed, two-eyed, two-eared and one-brained, but many-armed and many-brained can generate other forms of knowledge (Mosayebi, 2018)

In addition to the foregoing, within education, and in relation to architecture school, the term pedagogy traditionally refers to strategies of instruction or a style of instruction. Hence, the design studio is the nucleus of the architecture program where the architecture student explores and experiments with various architectural solutions while acquiring the basic skills and knowledge the teacher or the institution has set out to impart. In contrast to this view, and with regard to the Chthulucene epoch explained by Haraway, this paper addresses a participatory method in which students focus on understanding the problem rather than kick-starting solutions as the architecture course offered should be able to produce innovative, creative and holistic architects who are sensitive to the current demands of society, the environment and technology. Therefore, the question now is what these problems are and how we can provide our students with the correct tentacular methods and tools to face the analysis and exploration of them.

1.2. The Role of the Architect

Even though the discipline of architecture is very old, there is no consensus on what an architect actually defines. And the architects have not been helpful as well in their self-positioning. In addition to this fact, it is a well-documented fact that the effects of the information age are felt across the whole spectrum of the architecture field.

During the last two decades, we have observed multiple samples which lead us to question the role of the architect as well as the teaching methodology in the architecture school. As a sign of it, last June 2022, the Twitter account *The Cultural Tutor* went on a rant detailing the problems with modern architecture. From a non-sustainable development or overshot technology to a focus purely on cost-efficiency, they broke down precisely why modern structures leave much to be desired. That led to many occasions where architects have been excluded from projects and meaningful conversations/decision-making, even though they should be the people at the table who understand how things are “wired up” and give good input when defining the right solution.

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Fig. 1. *The Cultural Tutor.* Twitter, Jun 11, 2022

In this connection, today there is a change in the role required: on one hand, the old role description has not worked out, and the current tools and the architecture content have become more complex. Tim Brown from IDEO proposes that designers cannot meet all of these challenges alone[5] The importance of the current environmental challenges together with the new advancements offer us the opportunity to reconsider designing as a vital role of collective intelligence. On the other hand, on a technical level, the increased accessibility and interest in digital fabrication methods, or in other words the creation of design prototypes using numerically controlled tools, gives us - designers - the possibility to implement a new flexible learning system which formerly focussed exclusively on design iteration, to create various manufacturing-driven design processes as one agency.

1.3. Moving from individual to Collaborative design to Collective design

Architects and urban planners were involving communities in design for years prior to the mid-1970s when participatory design first became a research area (Kensing and Blomburg 1998). Since then, participatory design has become a recognised mode of professional design practice, enabling the inclusion of stakeholders, such as employees, partners, customers, citizens, or end users, possessing a wide range of knowledge and skills - who are not necessarily designers.

Building on this context, the concept of collaborative design[6] has recently come under renewed attention in the field of design teaching. However, within education, and in relation to architecture schools, “historically the education of an architect has been a highly individualised pursuit, focused on the development of an individual skill set that seldom includes collaboration beyond that of student and professor” (McPeek, Dockter, 2019). In opposition to this view, this paper proposes a collaborative design approach as a collective response to tackle the current challenges in which a partnership is established between experienced and inexperienced fellows who together, through this process, understand and build information.

In addition to the above is evidence of the current availability of new tools to collaborate and become involved in the process. The topic of collective design has been gaining increasing attention in the design community as a growing number of online platforms support new ways of

[5] https://www.ted.com/talks/tim_brown_designers_think_big?language=en

[6] “In the paper Requirements for Collaborative Design in Architecture, Achten, H.H (2002) notes that Collaborative design looks at how the process of design itself can be improved in such a way that collaboration –working together in a manner to enhance each participant’s contribution to the design– emerges from the process.

addressing complex problems by allowing motivated individuals to contribute. Thence, Collective design can facilitate a more inclusive design process by designers and non-design specialists by motivating the broader community to participate in design thinking. To address this question, this paper considers collective design as a methodology which already includes the collaborative path supported by digital tools to facilitate the development of design environments. It refers to shared or group intelligence that emerges from the collaboration and the collective efforts of individuals.

1.4. Collective processes in Robotic fabrication

In architecture schools and the academia context, we have seen recent projects and reports on the use of robots which have extensively referenced collective construction as a mode of production embodying different materials and techniques. Hence, this can be witnessed in research and projects as an interdisciplinary proposal to investigate whether humans and robots could collaboratively fabricate and assemble a spatial structure by the Institute for Computational Design at the University of Stuttgart (Vasey, Schwinn et al. 2016); the use of robots to overcome material and fabrication imprecision into the project "Fusta Robotica"(2015)[7], continued by "Digital Urban Orchard" (2016)[8] which overcome the challenge of imprecision by implementing new advanced tools such as 3D scanning, in which both projects were co-developed by students, staff and industry as part of the OTF program 2015/2016 at the Institute for Advanced Architecture of Catalonia - IAAC-; and, recently, the use of robots to introduce an open-ended fabrication workflows that examine the possibilities of designing and creative choices while building in a human-robot collaborative setting to develop a spatial timber assembly by Gramazio Kohler Research, ETH Zurich (Atanasova, Gramazio et al, 2020)

Though active research is being done to introduce robots and other fabrication equipment directly onto the construction site (Helm et al. 2012, 2014), the use of robotic fabrication in a collective process in large-scale projects often necessitates a workflow in which components are processed offsite and then assembled onsite. This type of workflow provides little recourse if unexpected tolerances or deviations are encountered during the assembly and construction process. Accordingly, a robot's precision system can be augmented by the cognitive abilities of the human together with the monitoring of the process and feedback enabled through user interfaces allowing a coherent balance of tasks between human and machine.

Over these considerations, collective research through architecture education on the construction practices with digital mechanisms and just-in-time production by involving humans directly within the robotic fabrication process can contribute and offer several benefits to existing protocols as well as develop new ways of design teaching in the architecture school.

1.5. From Craftsmanship to Collective Robotically Manufactured Prototyping

The term prototype is commonly used in architecture schools to indicate different architectural qualities, creating multiple approaches that structure design methodologies around prototyping in some form or another. Hence, it is possible to argue that in the vast majority of cases, the process described is not actually prototyping in the sense of construction, but rather as a form of representation. In opposition to this view, the method here analysed was developed through hands-on experience with robotic systems from a small to a larger scale, allowing students to approach the tools and technologies currently available in the construction industry as well as

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[7] https://iaac.net/project/fusta-robotica-otf-2015/

[8] https://iaac.net/project/digital-urban-orchard-otf-201516/

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construction parameters, and consequently integrate them into the design method in Architectural Education.

In this connection, of interest is to examine some relevant construction methods that have occurred during the whole building history. For instance, the big demand for construction during the II World War and after this became one of the main reasons why the work of designers like Jean Prouvé established a culture based on experimentation to develop designs for buildings. From his first experience as a blacksmith, the use of models was compelling in his work highlighting an investigatory approach that in turn explained a new way to produce and understand architecture (Ramos-Carranza, Bueno-Pozo, 2019).

In order to further analyse these themes, this paper explores the potential of an experience-based learning methodology in connection to the material culture derived from craftsmanship.

2. Simpoiesis Methodology

Bearing on this context, this study presents a six-week seminar as a case study in which implemented the simpoiesis methodology through hands-on experience on robotic systems in the architecture design studio. Based on the concepts explained by Haraway along the sympoiesis notions, the following sections describe the various building blocks and implemented methods necessary for realizing this research project:

2.1. Method

The simpoiesis research method proposes both qualitative and quantitative approaches consecutively through documentation, analysis and study over digital and physical explorations. Thus, a prototypical fabrication system utilizing robotic wood *pick and place* technologies was developed based on the following criteria:

(1) Component-based Design/Funicular geometries: First, the seminar invites students to explore component-based design system for funicular structures as a process built by dividing solutions into a collection of manageable (and most importantly, reusable) parts that then are used to create/interact with an end result (architecture structure).

(2) Hand-work exploration: A series of manual explorations would be iteratively conducted. This enables students to understand the difficulties and limitations of the craftsmanship process. Lately, hand-exploration would be translated to digital and subsequently the robotic path.

(3) Design by Making-with Components: Design would be developed through the robotically-built component interaction. An easy prototypical robotic fabrication process would allow the production of unique components which would be afterwards, assembled in spatial systems.

(4) Rapid Robotic fabrication iteration: The total time required for a single component fabrication was limited to 10-15 minutes. It could not be overly simple, nor so difficult that someone unfamiliar with the task could complete it.

(5) Analysis and Simulation: Digital tools are provided during the seminar to explore and analyse the experimental data to improve robotic fabrication.

(6) Community-based learning: New digital tools, such as online digital platforms, for exchanging ideas and taking important decisions, as well as teacher-student communication would enable the collective design workflow.

(7) Collectively building: A final structure at a 1:1 scale would be built on through the assembly of several robotically-built components.

2.2. Operational methodology: Tentacular thinking and Simpoietic arrangements

In reference to Jean Prouve and Haraway's "tentacular thinking", this method proposes a design-tool interaction by understanding through the hands-on work with robotically-built components, and ultimately aiming at replacing top-down hylomorphic thinking with bottom-up material processes of formation(Ingold 2010) Then, it is as if each test had to have an error to make an advance, strengthening that commitment which would justify the numerous designs, prototypes and variants in the same workflow that Prouvé realised.

Secondly, by understanding the act of making, Haraway defines sympoietic arrangements to refer to the critters (individual organisms) fundamental practices through symbiotic assemblages in which it established dynamic complex interactions that can only be conceived as competitive or cooperative. To address this notion, the method here presented proposes to tackle weekly exercise as problem-solving that should always establish a link with the previous and subsequent exercise, and in turn, establish relationships between all the research lines opened in the whole studio. In consequence, the class workflow generates a constant discussion which is continually providing collective feedback and then, feeding the research symbiotically.

2.3. Stage 1: Structuring the Collective design studio

The collective workflow consists of alternating robotic fabrication and user actions of component-assembling in which students develop weekly exercises. The aim and objective of the research were to explore and analyse the potential and limitations of the wood-component development through the robotic pick and place technologies towards a final assembly of a large-scale compression-only funicular structure collectively designed.

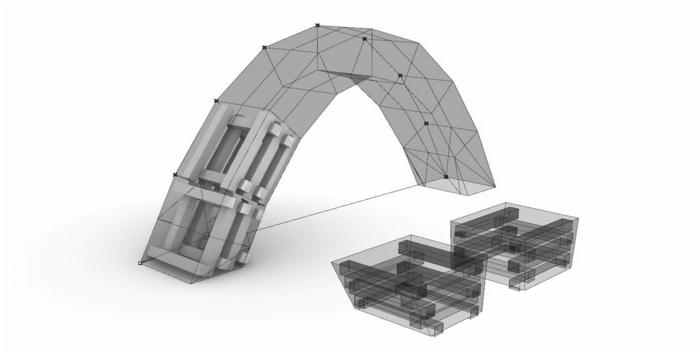

Fig. 2 Compression-only funicular structure developed through robotically-built components

The seminar was structured in five parts as follows: an introductory manual exploration (1:10 scale), robotic fabrication implementation and component exploration (1:5), funicular structure parts (1:5 scale), and large-scale funicular structure (1:1 scale) Hence, three initial states more focused on exploration and research, and a final one fully engaged on production with particular consideration on architecture and construction.

2.4. Material system

Following the information explained above, a set of workflows and technologies to facilitate a collective workflow for robotic-component-shaping tasks was developed. In this connection, the objective of the proposed fabrication workflow was to establish a method based on basic rules for quick component-assembly iterations, through robotic pick and place technologies, with the goal

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to streamline and speed up the process towards a further deeper exploration on the spatial geometrical ones which will be developed through hand-work assembly rules (Fig.3)

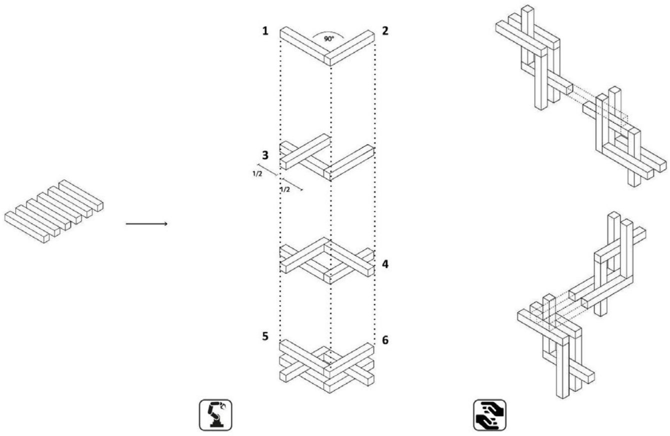

Fig. 3 (a)Material system: one module consists of same-sized timber elements robotically connected with glue (b)Component-Interlocking assembly steps distributed collectively according to a set of design rules and options

Built on this context, different exercises at different scales were proposed as follows. First, to realize the manual explorations at 1:10 scale students worked with same-sized timber elements with dimensions 10x10x65mm which were attached by different possibilities such as glue, screws or rubber rings (Fig.4)

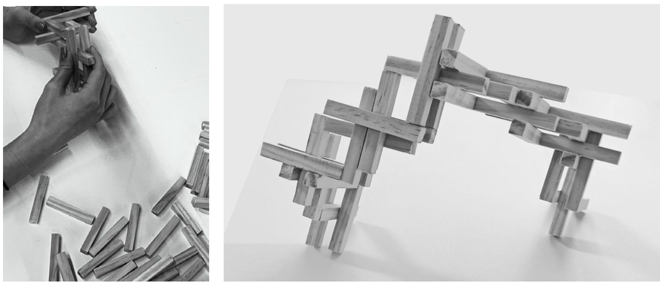

Fig. 4 Inital hand-work exploration. Source*: Charicleia Iordanou, Victor Engelhard Suarez, Mara Müller-de Ahna and Diego Vazquez de Santos*

Secondly, at the robotic fabrication stage at 1:5 scale the students started working with same-sized timber elements with dimensions 20x20x150/200mm which were attached by manual glue ejection exploring and building different parts of the subsequent structure.

Finally, taking all the knowledge from previous explorations the collectively designed large scale structure at 1:1 scale was developed through same-sized timber elements with dimensions 20x20x150-350mm which were attached by automatized glue deposition forming robotically manufactured components which will be later assembled together.

2.5. Fabrication Setup and System

The Atelier Lab at the Institute for Advanced Architecture of Catalonia - IAAC- in Barcelona includes two 6-axis ABB IRB 140 robotic arms (6kg payload, 810 mm reach, IRC5 Controller) utilized for the research project.

A 3d-printed custom end effector which incorporates a Venturi's vacuum generator connected to two pipes provided with suction cups was developed that could precisely control the pick and place operations of the timber same-sized elements (Fig. 5)

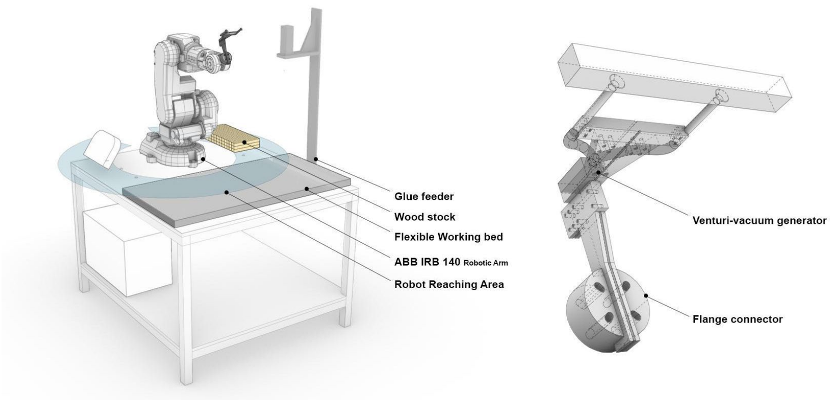

Fig. 5 Robot set up and Venturi vacuum generator+suction-cups End effector. This tool was previously designed together with Kunaljit Chadha for the workshop "Design for Remote-controlled robots" developed during the Global Summer School - GSS 2019 - done at IAAC

To this end, a series of robotic experiments have been iteratively conducted. The geometries of prototypes and robotic path have been modelled in Rhinoceros® via Grasshopper's Robots® plug-in. The aim of the research was to teach students how to deal with a six-axis machine with offline programming and thus, probe the potential of design and create new collective work processes between humans and machines.

For fastening the elements, with regard to the initial manual glue deposition explorations, an automatized glue dispenser, synchronized with the component fabrication path, was used on the final production as shown in Fig. 6.

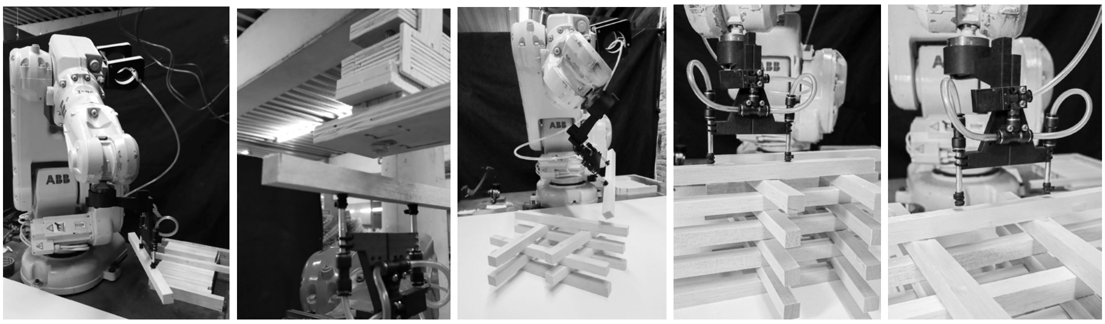

Fig. 6 Snapshots from the time-lapse of the robotic component fabrication process

Finally, the choice for the simple non-glue connection type between components was influenced entirely by the requirement of enabling variable placement of components as well as the mounting-dismounting facilities of the structures.

2.6. Stage 2: Defining the goals and objectives of the project

The objective of this stage was to first initiate among the students, an exploration and comprehension of the notion of funicular structures and their development through robotically-built components. Therefore, a set of research lines, linked by simpoietic arrangements, were opened with regards to different parts of the system application: catenary arch, component-assembly system, joints, stability and geometrical configurations.

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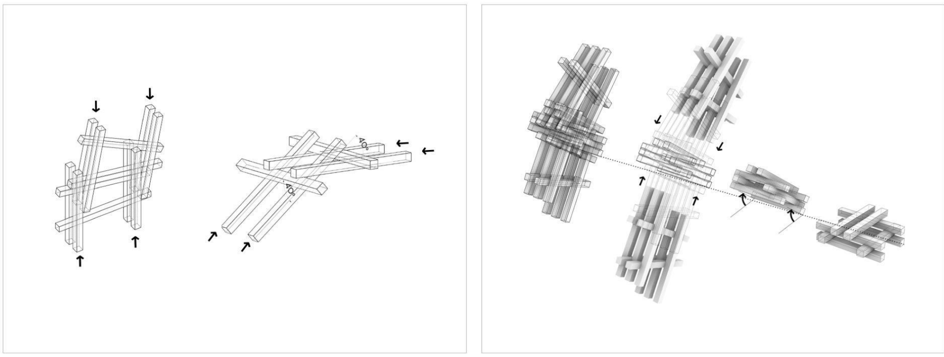

Fig. 7 (a)Linear-component assembly: systems in which the base plane of the robotic component fabrication establishes a repetitive relationship with the funicular structure geometry; (b)Spatial-component assembly: systems in which the base plane of the robotic component fabrication establishes different relationships with its neighbours, and these are independent of the base plane of the robotic fabrication, establishing different rules with regard to the spatial assembly strategies [9]

First, for the robotic fabrication of each component, short-length structural members have been chosen. These short members are well suited to articulated structures, which, by employing an inverted funicular geometry, only incur axial stresses and can employ simple (non-moment resisting) timber connections (Baber and Burry et al, 2020) Thence, the best results of stability, rigidity and precision are showcased through the following explorations.

To introduce differentiation in the component-assembly exploration, over all the different iterations, two types of assembly systems were stand out: linear-assembly and spatial-assembly (Fig. 7).

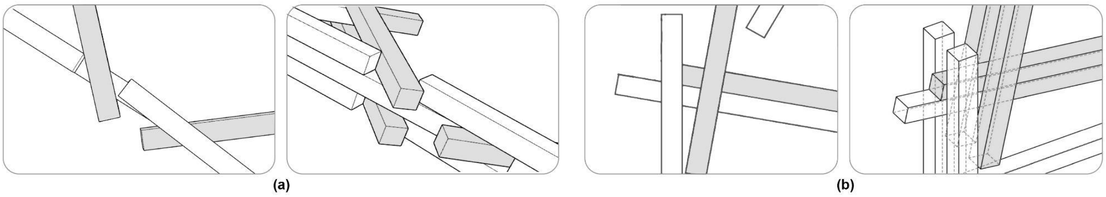

Fig. 8 Joint system exploration: (a)open joints; (b)face-to-face joints

Secondly, regarding the joints exploration, and based on the stability and rigidity of the structure, it is concluded here that the union in which the same-sized timber elements were continuously connected face-to-face demonstrates the best result, stability and rigidity of the final funicular structure (Fig. 8)

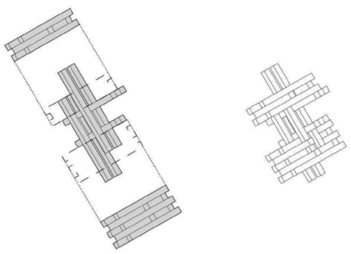

Fig. 9 Staple-Component interlocking assembly system

[9]In addition to these systems, a few explorations were developed based on slicing or stacking methods of repetitive frames. The exploration within the studio concludes that this strategy entails the use of many components and therefore, a lot of material, as well as not ensuring a successful result in terms of stability and rigidity. Similarly, the structures developed do not allow much design space freedom and very interesting or innovative design opportunities have not been developed through these explorations.

As a final step, a spatial-assembly configuration based on an iterative setup named staple-component system (Fig.9) has been the most successful exploration proposing a system that responds with great results to stability tests, creates clean and rigid joints, as well as develops a wide variability and adaptability to innovative open-ended geometrical configurations, with particular consideration of building construction. Finally, this development proposes an easy and efficient system for component assembly and disassembly with regard to the time and robotic production of each component.

Based on these explorations, a set of catenary-arch models were developed with the goal of illustrating the proposed principles and evaluating their applicability.

2.7. Stage 3: Interaction with participants and Digital tools

The objective of this stage was to provide students with a set of tools which enable collective and shared workflow. Thus, it also investigates the limitations and effectiveness of the community-based learning platforms to analyse and determine several actions throughout the whole research such as exchanging ideas or taking important decisions collectively.

The community-based learning platform named Miro® was suggested to students with the purpose of connecting, interacting with the teachers, exchanging ideas, and learning together. Miro® has been a fundamental tool for exchanging updates on each part of the research, as well as communication and review of the required exercises.

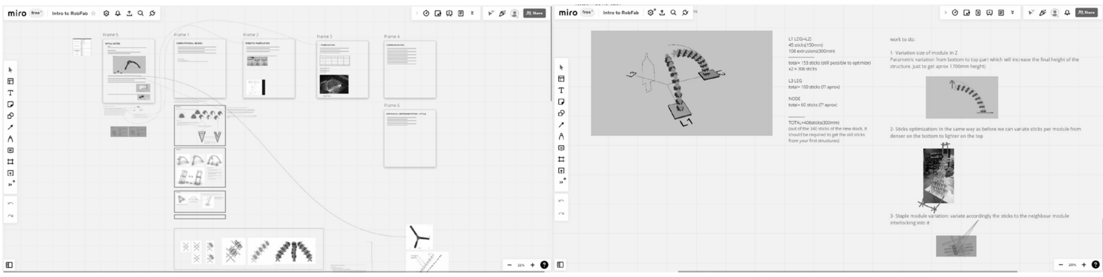

Fig. 10 Sketches, screenshots, drawings, written ideas, brief etc., on the shared Miro® platform

During the seminar, in parallel with robotic fabrication, the research has been enriched with several digital tools for testing and analysing experimental data. Accordingly, through the use of the Grasshopper's Physx® plugin, students could evaluate the fabrication hypothesis before running the robotic path. The validation of these studies and then the potential for the final solutions was requested from the students through the collective design reviews every week.

In addition, several rules over the tolerances, movements and accurate assembly of each timber element through fabrication and digital physics studies were implemented to improve the final robotic fabrication operations.

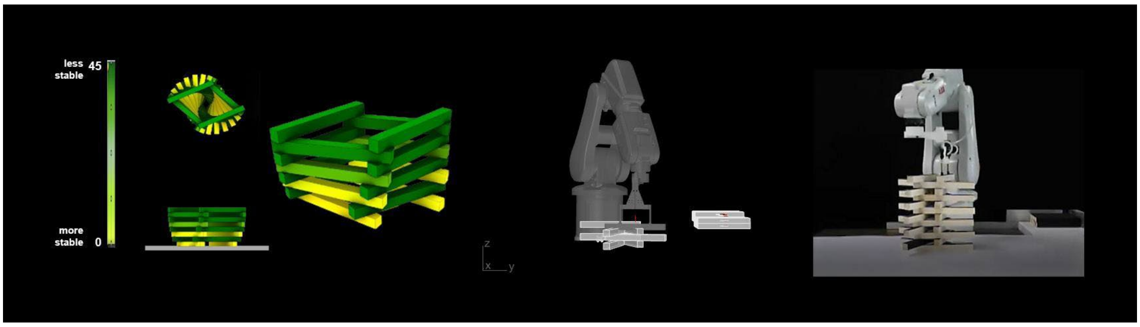

Fig. 11 Physics analysis + Robotic simulation + Robotic fabrication

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Finally, through the robotic simulation, students could evaluate the robotic movements and motion range to improve an efficient and productive robotic path, as well as avoid collisions along the whole fabrication process.

2.8. Stage 4: Collectively building a large-scale project

At this stage, the participatory studio method enabled students to first establish a common research basis grounded on the previous explorations with the aim to define the goals and objectives of a full-scale prototype structure construction. In reference to the simpoietic arrangements, a workflow based on the development of a collective design solution by linking each step inside the exploration has been planned across the following units in which students were distributed respectively: Computational design, Robotic fabrication, Assembly and Management/Documentation.

First, the main driver of the global structure's design was to describe an only-compression funicular structure composed of three catenary arches connected in a single node. The Initial design exploration carried out by the Computational unit, focused on form-finding funicular structure iterations with the live physics engine grasshopper's plugin named Kangaroo® (Fig.12a)

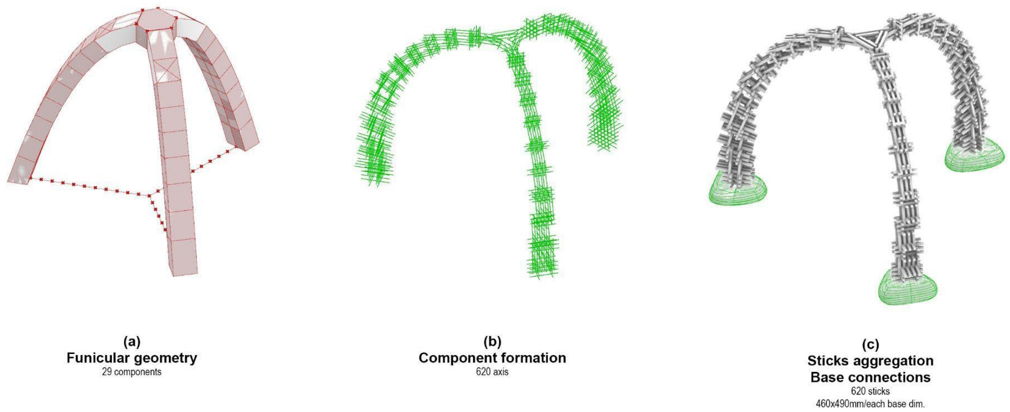

Fig. 12 (a)Interactive funicular modelling: Given the design area of 4x3x2meter, a planar network of generating lines in the ground plan was composed and used as the geometry input for the initial hanging chain simulation. As a result of several iterations, a final solution was defined from the digital simulation of different loads and anchor points; (b)Component-discretization through robotic pick and place strategies; (c)Component-based funicular modelling + Base connections

The generated design conforms to a 1900mm-high funicular model (Fig. 12a) which was consciously designed according to the criteria described in *2.1. Method* section, and the following rules explored during the *Stage.2*: component-formation size, number of sticks, robotic fabrication time and height. Therefore, each component was composed of 10-14 timber elements and approximately estimated of 15 minutes time of robotic fabrication.

Second, the Robotic fabrication unit started exploring the defined volumetric component through a set of fabrication iterations in continuous discussion with the Computational and the Assembly units. As a result of this exchange, the Assembly unit detected some limitations in the previous explorations by developing a set of components based on the spatial-assembly component and joint systems featured in the *Stage 2* section. In response to this, an integrated-flexibility system that allows variability in the growth development of the components along the Z-axis, through the implementation of basic geometric rules in the positioning angle of the timber elements was proposed (Fig. 13)

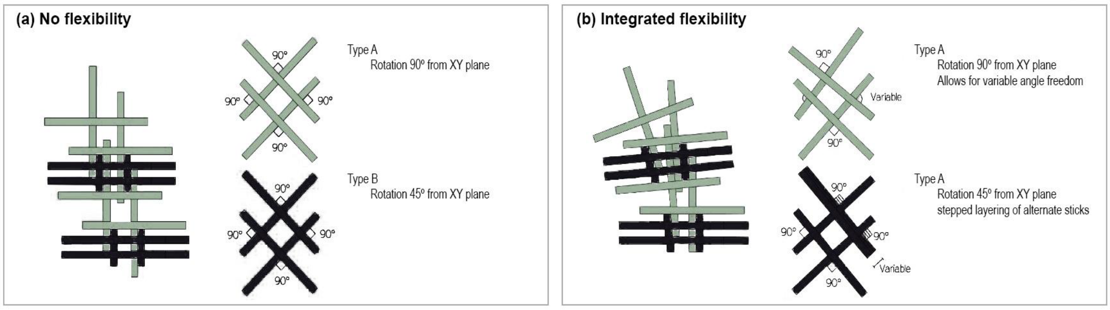

Fig. 13 (a) No flexibility system: one of the first problems is the fact that the initial staple-component assembly system did not allow the development of the component with a flexible variability along the curvature of the catenary arch (funicular chain); (b)Integrated-flexibility system: Interlocking system which allows for flexible angle-component rotation along the z-axis (funicular chain)

Third, a set of robotically-built components were developed by the Robotic fabrication unit, as well as analysed through digital physics simulation with the goal to evaluate its applicability (Fig. 14). The relatively high speed of a heuristic approach enables rapid designer feedback as to the amount of material used and the quality of the assignment.

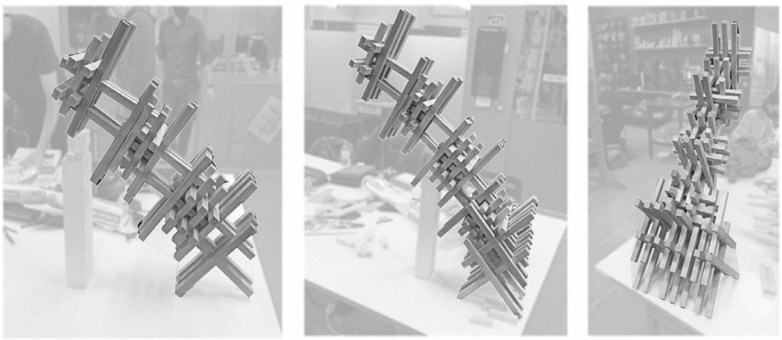

Fig. 14 Part assignment heuristic: Analysis and evaluation through prototyping of the rules established on the Integrated-flexibility system (Fig.13)

In brief, a funicular model (Fig. 15) was developed based on the following parameters:

- Staple-component assembly system: Each component previously defined in the form-finding physical studies has been adapted to the component-staple assembly system (Fig.9) integrating the new flexible interlocking system (Fig. 13b) to improve the assemblage, stability and rigidity of the structure.

- Parametric component variation along the z-axis, based on the curvature of the catenary arch and the number of timber elements of each neighbouring component.

- Timber elements optimization along the Z-axis based on the structural behaviour of the entire funicular structure.

- Base connections: Each catenary arch has been finally connected to a rounded wooden base made of different layers which have been milled previously, and finally assembled and sanded together.

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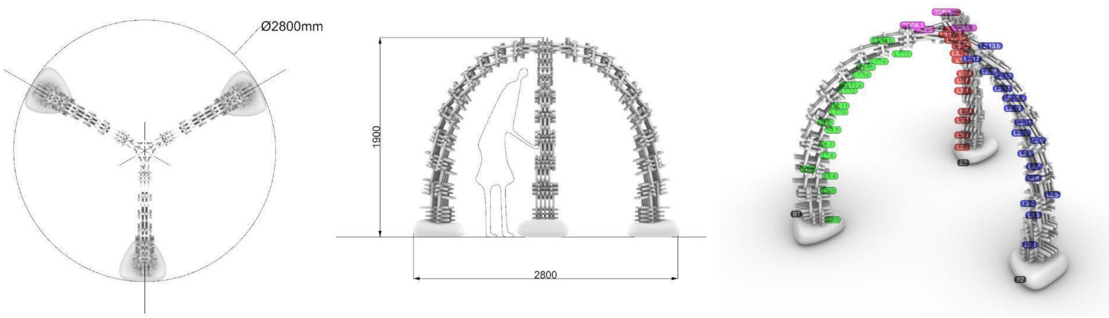

Fig. 15 Component-based funicular structure plans and axonometry: The implemented bottom-up design strategies were applied to building elements that different parametrically vary in size and shape along the z-axis with the aim of improving the structural behaviour of the whole structure

Finally, with the aim of collectively building the final geometry and led by the management/Documentation unit, it was established a comprehensive shared guide for all the participants composed of a production schedule and assembly steps. In addition, this guide was also composed of technical drawings, diagrams and a common axonometry design which included the assembly order of each component in relation to the whole funicular model (Fig.16)

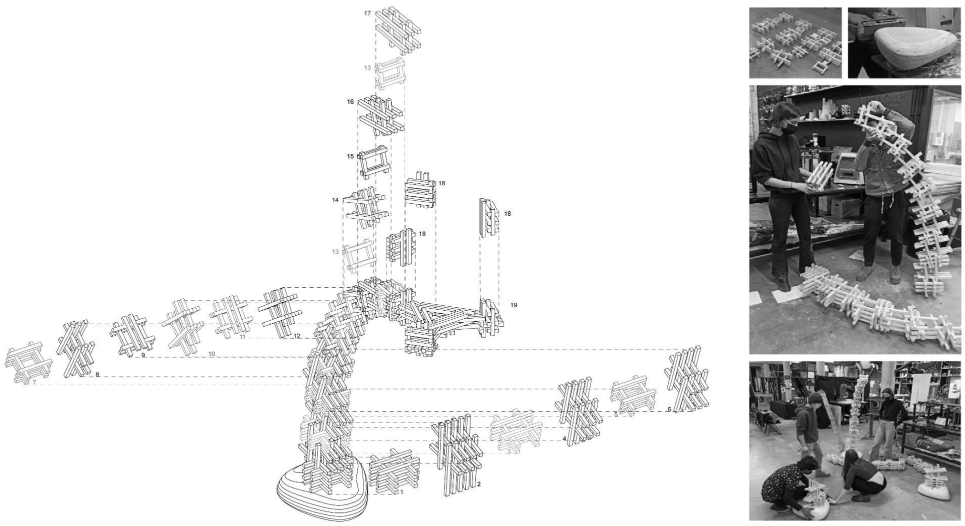

Fig. 16 (a)Assembly steps: Components division of the catenary-arch of the funicular structure; (b)Pictures during the collective assembly process. All the components were placed, correctly labelled according to the guide drawings, once manufactured, on the building floor and then began the assembly process only once the robotic fabrication was finished

Finally, the whole robotic fabrication was developed over 10 hours of fabrication and the collective assembly was realized on a building floor circumference-area of 2800mm diameter which was close to the robots used during the whole fabrication process. as shown in Fig.16b.

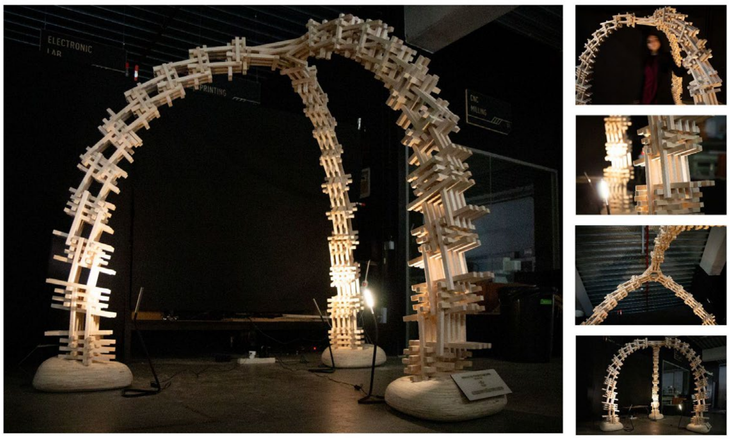

Fig. 17 Assembled timber only-compression funicular structure, by authors

In conclusion, coherent task divisions with continuous feedback between all the studio units, the correct use and implementation of shared digital tools, and exchange between students and teachers were fundamental to completing all the steps and achieving the final built structure inside the collective architectural design studio. The complete timber structure is shown in Fig.17.

3. Results and Outlook

On the basis of the core concept of participatory architecture design studio, collective construction and open-ended digital design-to-fabrication workflows, this project demonstrated that students could successfully collaborate to build a large structure collectively designed through the interaction with robotically manufactured components.

Based on the scale and construction of the prototypes, the realization of this concept was facilitated by a heuristic method in which participants are concurrently and inextricably designers and users during the whole process. Therefore, a coherent understanding of the demands of the design project from the user perspective is reflected in a significant increase in the confidence in the series of design decisions by the students, which in turn echoed in articulate and efficient design reviews.

Despite the project’s successes, many directions for future work have been identified. First, due to the number of built components compared to the scale, the built prototype’s structural behaviour could be intuitively anticipated by the users and thus affect their design decisions during the building process. However, the user’s intuitive decision-making will require additional methods for evaluating the structure’s stability.

Second, one of the most significant limitations of the project was the tolerances studies which affect the final assembly and joints between components. During the process, accurate results were improved through calibration and repetition studies. Accuracy could have been improved by implementing new advanced digital tools such as external sensors or 3d scanning. Similarly,

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though the whole research was developed through new shared digital tools and platforms, a cloud-based operating system with direct access to models could be used.

Finally, the process could be scaled up to enable the fabrication of larger structures together with further material research, to validate the stated concepts for fabrication at a full architectural scale.

4. Conclusion

The realization of the project manifests a process that can transform utility-grade timber into a high-value timber product. The structure also has inherent value when considering lifecycle costs, due to its facilities for mounting and dismounting the whole system.

The simpoietic method here presented proved that students could successfully work with a community and build confidence in their own abilities when placed in a real setting, which enabled interactions face-to-face and at a distance to solve a challenge and achieve a common goal. Consequently, the idea of 'distance/blended learning' becomes ever more present in the pedagogical methodology.

Furthermore, this method generates a heuristic approach in which students interacted with their peers and faculty by working alongside industry systems and technologies on parameters such as design requirements, materials, and time constraints. Therefore, new avenues are established to connect architects with the field of design and contemporary industry, in this case through collectively-prototyping in the sense of construction.

Over these considerations, we can observe an emergent shift in education, breaking free from the individual architectural design method towards a collective and heuristic flexible approach in which we adopt these technologies to foster a new way of thinking in participatory learning spaces in Architectural Education - design and practice.

Finally, learning from these experiences and methodology explorations, IAAC has explored and produced a large series of successful experiments and prototypes, applying robotic fabrication within its educational programs, and consolidating an emerging paradigm within the current production system.

5. Acknowledgements

Many thanks to Mathilde Marengo for her comments and contribution to earlier drafts for this article as well as his advice on Haraway's work. This paper and the research were supported by Areti Markopoulou and Alexandre Dubor, as well as all the Advanced Architecture Group team at IAAC. Thanks to Kunaljit Chadha and Ashkan Foroughi for their support and knowledge.

The research in "Introduction to Robotic fabrication: Exploring possible applications of robotic wood pick & place fabrication for Architecture" is a project of IaaC, Institute for Advanced Architecture of Catalonia developed at Master in Advanced Architecture first-year (MAA01) in 2022 by:

Faculty. Ricardo Mayor Luque

Student Assistant. Liang Mayuqi Lana Awad

Students: Aishwarya Arun, Furio Magaraggia, Perniyal Waseem, Preetam Prabhakar, María Fernanda Rodríguez Orviz, José Manuel Asensio Torres, Meagan Sinead Enright, Aswin Kumar Ganesan, Weihao Yin, Aaron Jude Pereira, Emily Bishop, Miran Calmanovici, Cansu Kilinc,

Sarjak Rakholiya, Alessandra Weiss, Brian Woodtli, Charicleia Iordanou, Diego Vazquez de Santos, Mara Luisa Müller-de Ahna, Victor Iñaki Engelhard Suarez.

6. Bibliography

ACHTEN, H.H. (2002). Requirements for Collaborative Design in Architecture. Timmermans, Harry (Ed.), Sixth Design and Decision Support Systems in Architecture and Urban Planning - Part one: Architecture Proceedings Avegoor, the Netherlands.

ACHTEN, H. (2001). Futures scenario for a collaborative design session and feature list, Stellingwerff, M. and J. Verbeke (eds.), Accolade – Architecture. Collaboration. Design. Delft University Press, Delft, p. 163-167.

ATANASOVA, L.; MITTERBERGER, D.; MITTERBERGER, D.; SANDY, T. & DÖRFLER, K. (2021). Prototype As Artefact - Design Tool for Open-ended Collaborative Assembly Processes. ACADIA 2020: Distributed Proximities / Volume I: Technical Papers [Proceedings of the 40th Annual Conference of the Association of Computer Aided Design in Architecture (ACADIA) ISBN 978-0-578-95213-0]. Online and Global. 24-30 October 2020. edited by B. Slocum, V. Ago, S. Doyle, A. Marcus, M. Yablonina, and M. del Campo. 350-359.

AKIPEK, O.F. & KOZIKOGLU, N. (2007). Prototypes in architectural education: as instruments of integration in the digital era. METU JFA 2007/2, p.169-178.

BABER, K.R; BURRY, J.R.; CHEN, C.; GATTAS, J.M. & BUKAUSKAS, A. (2020). Inventory constrained design of a timber funicular structure. Proceedings of the IASS Annual Symposium 2019 – Structural Membranes 2019 Form and Force 7 – 10 October 2019, Barcelona, Spain C. Lázaro, K.-U. Bletzinger, E. Oñate (eds.).

BOZA, L.E. (2006). (Un) Intended Discoveries Crafting the Design Process. Synthetic Landscapes [Proceedings of the 25th Annual Conference of the Association for Computer-Aided Design in Architecture] p. 150-157.

BRELL-COKCAN, S. & BRAUMANN, J. (2013). Industrial robots for design education: robots as open interfaces beyond fabrication. International Conference on Computer-Aided Architectural Design Futures, Ed. Springer.

CARPO, M. (2017). The second digital turn: design beyond intelligence. Cambridge, MA: The MIT Press.

CHINCHILLA, I. (2020). La ciudad de los cuidados, Madrid. Colección Arquitecturas, La catarata (Asociacion los libros de la catarata).

DENIZ, B. & AÇALYA, A. (2017). Simulating Craftwork in Contemporary Architecture, The Journal of Modern Craft, 10:1, p. 37-57, DOI: 10.1080/17496772.2017.1294324.

GARCÍA VILLALUENGA, Y. "Se acabó la fiesta" La Arquitectura Española de los últimos 20 años" rtve <https://www.rtve.es/play/videos/archivos-tema/archivos-tema-se-acabo-fiesta/1269406/> [Consulta: 20 de Septiembre de 2021]

GRAMAZIO, F. & KOHLER, M. (2008). Digital Materiality in Architecture. Baden: Lars Müller Publishers.

GRAMAZIO, K. & KOHLER, M. (2015). The Robotic Touch: How Robots Change Architecture. Ed. Park Books. 2015.

HERTZOG, T. (2004). Timber Construction Manual. Ed. American Institute of Timber Construction (AITC).

JUNGA, J.H. & LIM, D.G. (2020). Industrial robots, employment growth, and labor cost: A simultaneous equation analysis. Technological Forecasting and Social Change, Volume 159, October 2020, p. 120202.

JUTRAZ, A. & ZUPANCIC, T. (2014). The Role of Architect in Interdisciplinary Collaborative Design Studios. DOI 10.15292/IU-CG.2014.02.034-042 | UDK 378.1:72 | SUBMITTED: 06/2014 | REVISED: 07/2014 | PUBLISHED: 10/2014. Author's affiliation: the 1 University of Ljubljana, Faculty of Architecture, Slovenia.

LEACH, N.; TURNBULL, D. & WILLIAMS, C. (2004). Digital tectonics. Chichester: Wiley-Academy.

LOPEZ-PEREZ, D. (2021). R. Buckminster Fuller - Pattern-Thinking. Integral Lars Müller. Zurich, Switzerland.

LATOUR, B. (1983). "Give Me a Laboratory and I will Raise the World", K. Knorr-Cetina y M. Mulkay (eds.), Science. Londres: Sage, p. 141-170.

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LAUREN, V.; NGUYEN, L.; GROSSMAN, T.; KERRICK, H.; NAGY, D..; ATHERTON, E; THOMASSON, D.; COTE, N.; BENJAMIN, D.; FITZMAURICE, G. & MENGES, A. (2016). Collaborative Construction: Human and Robotic Collaboration Enabling the Fabrication and Assembly of a Filament-Wound Structure. ACADIA // 2016: POSTHUMAN FRONTIERS: Data, Designers, and Cognitive Machines [Proceedings of the 36th Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA) ISBN 978-0-692-77095-5] Ann Arbor 27-29 October 2016, p. 184-195.

LATOUR, B. (1993). We have never been modern, Harvard, Cambridge. Harvard University Press.

LUKMAN BIN NIK IBRAHIM, N. & UTABERTA, N. (2012). Learning in Architecture Design Studio. Procedia - Social and Behavioral Sciences, vol. 60, 17 October 2012, p. 30-35.

MAHER, M.L.; PAULINI, M. & MURTY, P. (2011). Scaling Up: From Individual Design to Collaborative Design to Collective Design. Conference paper. Design Computing and Cognition ’10, p. 581-599.

MCCULLOUGH, M. (1996). Abstracting Craft: The practiced Digital Hand. Cambridge Massachusetts. London, England. The MIT Press.

MENGES, A.; SCHWINN, T. & KRIEG, O.D. (2016). Advancing Wood Architecture, A computational approach. ISBN 9781138932999. Published August 22, 2016, by Routledge.

MENGES, A. & WILEY, A. (2012). Material Computation: Higher Integration in Morphogenetic Design. Edited by Achim Menges. ISBN: 978-0-470-97330-1 April 2012, p. 136.

MORITSCH, S. (2017). Craft-Based Design: On Practical Knowledge and Manual Creativity.

MUTLU DANACI, H. (2015). Creativity and Knowledge in Architectural Education.

NANDERA, S.S. (2014-15). The ever-changing role of craft in architecture. University of Sheffield School of Architecture. The thesis was supervised by Carolyn Butterworth. <https://issuu.com/sirdeep/docs/the_ever_changing_role_of_craft_in_> [Consulta: 20 de Septiembre 2021]

NIEDDERER, K. & TOWNSEND, K. (2010). Craft Research: Joining Emotion and Knowledge. The Design Journal, 17:4, 624-647, DOI: 10.2752/175630614X14056185480221

PAULINI, M. & MURTY, MAHER, M.L.P. (2011). Understanding collective design communication in open innovation. The University of Sydney, Sydney, Australia.

PAPAMANOLIS, A. (2018). Prototyping and Architectural Education: An examination of the role of prototypes in the design process.

PINSKI, J.; FAITH KANE, F. & EVANS, M. (20218). Craft-based design for innovation: Potential in novelty, quality and sustainability through hands-on interaction. Artifact: Journal of Design Practice, Volume 5, Number 2, 1 December 2018, p. 3.1-3.20(1).

PRIYA, R.S.; SHABITHA, P. & RADHAKRISHNAN, S. (2020). Collaborative and participatory design approach in architectural design studios. Social Sciences & Humanities Open. Vol. 2, Issue 1, p. 100033.

PYE, D. (1968). The nature and art of workmanship. London: Cambridge, at the University Press.

RETSIN, G.; JIMENEZ, M.; CLAYPOOL, M. & SOLER, V. (2019). Robotic Building: Architecture in the Age of Automation. Ed. Detail.

RISATTI, H. (2007). A theory of craft: function and aesthetic expression. Chapel Hill: University of North Carolina Press.

SENNETT, R. (2008). The Craftsman. New Haven: Yale University Press.

TANERI, B. & DOGAN, F. (2021). How to learn to be creative in design: Architecture students’ perceptions of design, design process, design learning, and their transformations throughout their education. Thinking Skills and Creativity, vol. 39, p. 100781.

WEINAND, Y. (2016). Advanced Timber Structures. Ed. Birkhäuser.

ZHENG, C. & NITSCHE, M. (2017) Combining Practices in Craft and Design. n, in Storni, C., Leahy, K., McMahon, M., Lloyd, P. and Bohemia, E. (eds.), Design as a catalyst for change - DRS International. Conference 2018, 25-28 June, Limerick, Ireland. <https://doi.org/10.21606/drs.2018.537>