: FOLD >UNFOLD

DEPLOYABLE STRUCTURES # DIGITAL FABRICATION

Ignacio Borrego (ed.)
Collaborative Design Laboratory

TU BERLIN
Universitätsverlag der TU Berlin

CoLab Berlin
VOL 02

CoLab Berlin VOL 02
The scientific series *CoLab Berlin* is edited by: Prof. Dr. Ignacio Borrego

Deployable Structures | WS 2016.17

TU Berlin | Collaborative Design Laboratory
FG Architekturdarstellung und Gestaltung

Universitätsverlag der TU Berlin

The scientific series “CoLab Berlin” is edited by: Prof. Dr. Ignacio Borrego.

Deployable Structures and Digital Fabrication February | March 2017
TU-Berlin in collaboration with ETSAE Cartagena.

Advisory Board:
Prof. Dr. Ignacio Borrego
Dr. Pedro García Martínez
Dr. Martino Peña Fernández-Serrano
Dr. Montserrat Solano Rojo

Authors:
Prof. Dr. Ignacio Borrego
Dr. Pedro García Martínez
Dr. Martino Peña Fernández-Serrano
Dr. Montserrat Solano Rojo

Layout:
Dr. Pedro García Martínez
Dr. Martino Peña Fernández-Serrano
Gabriela Barrera
Pauline Peter
Sebastian Labis
Laura Díaz Vizoso

Cover Image:
Gabriela Barrera

Photo documentation:
Dr. Pedro García Martínez
Dr. Martino Peña Fernández-Serrano
Dr. Montserrat Solano Rojo

Selected Students:
Mirza Vranjakovic | Sebastian Labis | Jacob Bövner | Leonhard Schönfelder
Iris Huneau | Elise Helm
Ángel Armando Arquiero Ramírez | Tomás Roselló Barros | David Masip Vilá | Tan Phong Nguyen
Clara Almanzara Andreu | Miguel Delgado Rodríguez | Laura Díaz Vizoso

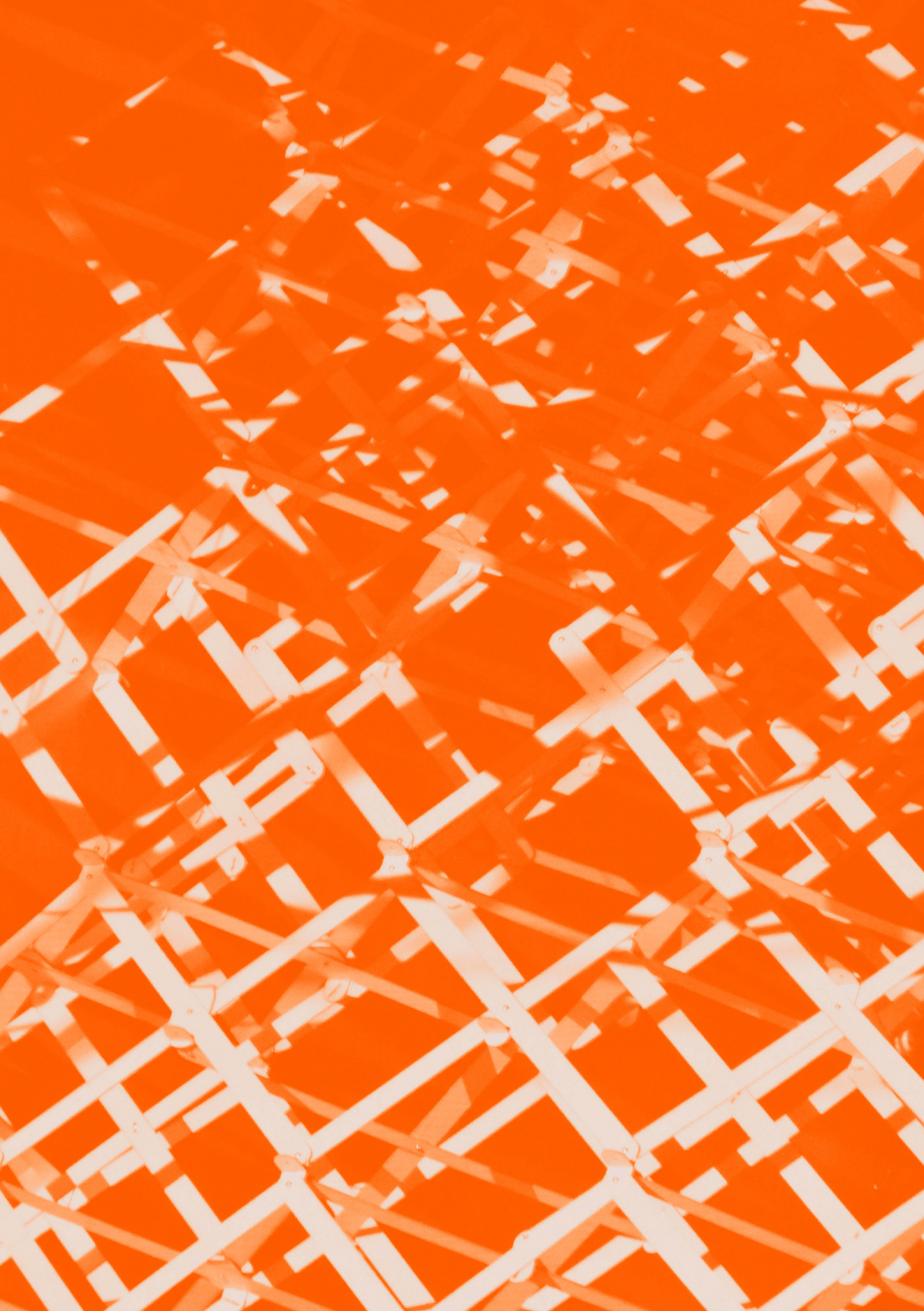
: FOLD >UNFOLD

DEPLOYABLE STRUCTURES AND DIGITAL FABRICATION

CoLab Berlin VOL 02

Edited by Ignacio Borrego

CONTENTS



CoLab is a Collaborative Design Laboratory. Its goal is to investigate those transfers which shall exist between design strategies and new design processes employed in contemporary industry, to apply to the design practice and architectural representation, employing a collaboration model based on collective work.

CoLab Berlin is part of a wider network which includes also a team in Madrid, where it emerged in 2009. CoLab Berlin is located in the department of Architectural Representation and Design at the Technical University of Berlin.

I am very pleased to present and to include in our CoLab Berlin series the research results of the academic module “Digital Fabrication & Deployable Structures” that has taken place in our Institute for Architecture at the Technical University of Berlin between February and March of 2017.

In this occasion the “Architecture representation and Design Department” of the TU Berlin has received three visiting lecturers from the Architecture and Building Technology Department of the University of Cartagena in Spain: Martino Peña Fernández Serrano, Pedro García Martínez and Montserrat Solano Rojo, whose invaluable support made the experience possible.

I would like to emphasize the great impact of this docent exchange, that enriches not only the students, but also both the visiting docent team and the local one. The transfer of knowledge includes content and teaching methodologies. In my opinion very important aspects of contemporary teaching methodology has been tested from design to construction, through a collaborative process, as well as the practical use of new fabrication technologies.

The proposed tasks are developed by master students, and guided by the assistant professors during four intense days. The results of the experience have been analyzed during the last eight months, to be crystallized in this publication.

I wish this experience will be the first in a long series of international workshops to bridge distant academic institutions.

Prof. Dr. Ignacio Borrego

Prof. Dr. Ignacio Borrego

Architecture Teaching Methodologies in the Digital Age

New digital tools within our reach have implied a revolution not only in our approach to representation in Architecture, but also in the emergent methods of teaching and in the training of future architects. New software allows us to have a more accurate representation of reality, and the digital fabrication tools allow us to control at the same time both the design and the fabrication.

Before the founding of the École des Beaux-Arts in Paris in 1671, the communication between the teacher and the apprentice took place through direct experience in building on site, and theoretical knowledge consolidated on a narrow contact with reality. After the institutionalization of architecture teaching and, as a consequence of the Industrial Revolution that required a massive amount of trained professionals, the traditional relationship between praxis and theory was reversed. Since then, the conventional academic education produces an evident separation between theory and practice. Teaching at university reaches usually only a theoretical level even for design and technical subjects. This lack of direct contact with reality forces the new graduated architect to clash with an unknown and very important aspect of their future activity.

The process of materialization has a strong influence in the result, and this is something we can confirm only through our practicing experience. Architecture cannot avoid an interesting tension between formal intentions and fabrication possibilities, between what we want to achieve and how we produce it. This influence is very diverse. The process can lead the final form or the other way around, but reality is headstrong and imposes its rules.

Digital fabrication technology (3D printers, Laser cutters, CNC Milling machines, Robots...) avoids us from mastering handmade building technics and allows us to produce objects with a simple click on a computer. This capacity helps us to focus on the requirements of the fabrication process, and not consuming the time in the fabrication itself or in acquiring the skills to be able to build the objects with our hands. The future building

technics used by architects will not be necessarily digital fabrication processes, but these tools used as an academic exercise have the advantage of combining easily at the same time designing and building. Digital fabrication has somehow managed to bridge the gap between conception and construction, and can be the key to link education with direct experience once again.
Architects are used to represent reality with drawings and models reproducing some of its qualities such as geometry and some material properties, but there are many properties that cannot be easily reproduced, and do not stay invariable through a change of scale, for instance, mechanical resistance. Here is a crucial difference between models and prototypes. Models represent reality, they reproduce only some properties of it, and prototypes are final objects, they are reality themselves. This difference is sometimes not so exact in all the cases, as the amount of reproduced properties can vary a lot. The level of accuracy of a representation defines if we are considering it a model or a prototype.

A new educational approach whose outcome are not just scale representations (drawings and models) but final prototypes themselves (objects that we can use) involve the introduction of parameters that are often rejected in many academic environments such as construction time, material consumption, weight, strength, cost, leftover material, and so on. When we try to achieve any structure, system or form, we have to consider what material and what machine we are going to use, because it will have an influence on the result.
Being at the same time designers and builders (represent and fabricate) gives us a complete overview that allows the designer to consider other important parameters of the process besides the final result.

In this course our students were confronted with a simple question that became a profound architectonical task as it had to be built. They had to design and build a portable structure to host a temporary desired function. This starting point had implicit the necessity of being able to fold the structure to be able to reduce its size to transport it and storage it. The second big restriction was the fabricating system that was cutting with an available laser cutter (SABKO GmbH SH-G1290, 1200mm x 900mm, 110W), and the third one was the material, that should be light, cheap (out of own interest) and suitable to be cut by laser.

Function, Fabricating method and Material, those are the main restrictions of our task, as in any other real architectural challenge. Only physical context is missing in this equation, but avoiding it was implicit in the condition of transportability. The only consideration was to expect a flat surface to land on.

Collaboration has been as well an interesting issue in those intense days. The sharing of the same working space allowed all the participants to profit very fast from the technical discoveries from other teams, and this will turn into a knowledge pool, that together with the theoretical inputs prepared by the teaching staff, will provide the next year students a richer kick off.

Another factor that fabrication introduces in teaching is error. A new aspect that does not exist in a theoretical environment, but necessary when operating with reality. Any deviation is inversely proportional to the precision of the applied materialization processes. However, deviations are always present when a design's programmed routine is to be tested in terms of viability. The need to obtain a built product implies dealing with issues such as compatibility, try and error or tolerance.

Each team started working with different deployable systems, using the laser cutter at the same time. The process was developed more in a workshop atmosphere than in a theoretical studio. Students had to react immediately to real physical problems besides their dreams for spatial structures. The activities of imagining and building were happening continuously one after another in a productive process or trial and error. The concerns of the students as designers where not only functional and spatial aspects, but technical and practical issues: to calculate and reduce the amount of material to buy, to limit the cutting time in order to let the other groups use the only available laser cutter, to manage the time required to assemble all the pieces to be on time for the final presentation in only four days, etc. Those parameters that could and should be optimized, have been calculated and represented in specific diagrams to manifest the importance of not only the result, but also the process of fabrication. This efficiency diagrams have been already used by CoLab Madrid since 2009[1]. This is a lesson that, in my opinion, any architect should translate to every professional phase, even if the designer is not involved in the construction.

Designing and representing should not be foreign to the knowledge of the production details. Contemporary industry provides us with almost any possible formalization. It seems especially appropriate to consider and analyse these means, to introduce the necessary design improvements to optimize the manufacturing process. Architecture is the confrontation between figuration desires vs configuration restrictions. This clash, far from being a problem should be an inspirational source of solutions and beauty. Considering it from the design phase will provide a logic that will have a positive impact on the result. Beyond what we create and what we represent, we must ask ourselves how we want to build it.

1 Almudena Ribot, Ignacio Borrego, Javier G.-Germán y Diego G.-Setién. CoLaboratorioetsam 2009. Ed. Mairea Libros + DPA ETSAM + CoLaboratorio, Madrid 2010

Dr. Pedro García Martínez

Deployable Structures:

Designing and Researching in Space of Indetermination

Threedimensional structures or space frames underwent an important evolution throughout the last century. The main boost came from the military field, which advanced quickly because of the World War conflicts. Researchers behind this development had the key objective to lighten combat aircraft fuselages and warship hulls while still gaining rigidity.

To this end, structures composed mainly of linear elements were devised. These elements (usually prefabricated metal rods) work solely under tensile or compressive forces. Bending stresses are avoided thanks to articulated mechanical joints. These joints allow for loads to be distributed three-dimensionally throughout the structure.

Subsequently, as in many other cases, these inventions, which arose for warlike purposes, slowly moved into other areas of daily life. The American architect and inventor Buckminster Fuller (1895–1983) applied these advances to civil architecture and urbanism early on.

The Spanish architect Emilio Pérez Piñero (1935–1972), not as well known as Fuller, devised a particular type of space frame structures that surprised even the American architect.[1] From his childhood on, Piñero lived and worked in the so-called Región de Murcia, the same Spanish province in which ETSAE (UPCT) is located. It is where, Martino Peña, Montserrat Serrano and myself usually teach and research. The structures invented by Piñero, which had the characteristic feature of being deployable, were patented in 1961 in Spain and in 1965 in the United States.[2]

Goining more into detail, the implementation of those space frames can be divided into three phases. Firstly, elements that make up the structure

1 Empresa Pública Regional de Murcia. Las estructuras vivas de Pérez Piñero. <https://vimeo.com/684393> [25/11/1017]. EPR. Murcia. 1992.

2 Emilio Pérez Piñero. Estructura Reticular Esterea Plegable. Patente nº 266.801 de Abril de 1961. Ministerio de Industria y Energía. Registro de la Propiedad Intelectual. Madrid. 1961. Emilio Pérez Piñero. Three dimensional reticular structure. Patent nº 23. 185.164, May 1965. U.S Patent Office. 1965.

Fig. 1: Perez Piñero and Salvador Dalí in front of *Vidriera Hipercúbica Desplegable* model

(rods and joints) act as one mechanism; this allows the set to be deployed. Then, in the second phase, elements are fixed and the structure acquires a stable configuration that enables it to support certain loads. Finally the structure can be re-folded taking up a much smaller space, which gives them important advantages when transported or stored for later use.
That is the way it was demonstrated in the 'Transportable Pavilion for Exhibitions', one of Piñero's most important projects, designed in 1964.

Another relevant project is the Dome above the Dalí Theater-Museum in Figueras, Spain. Some years before the design of the aforementioned pavilion, Salvador Dalí asked Fuller to design the geodesic dome that would crown his museum (fig. 1). It was then when Fuller said that there was a young architect in Spain who did things that he himself had not been able to achieve, Fuller was referring to Piñero.[3]

3 Empresa Pública Regional de Murcia. Op. cit.

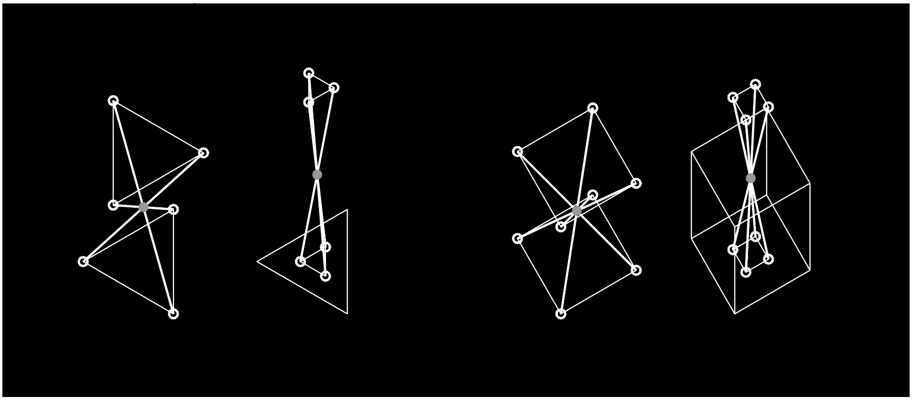


Fig. 2: Diagram of Piñero's basic modules (unfolded and folded)
by Pedro García Martínez

Dalí contacted Piñero and he soon designed the project that the painter demanded. The works began in 1969, once it obtained the necessary founding, but wasn't completed until 1973. Unfortunately the Spanish Architect could not see his work completed. He died in a car accident in 1972, while going back to Murcia after having visited a project on a site in Figueras.

Another Spanish architect, Félix Escrig (1950–2013), is considered an important successor to Piñero's investigations. In 1984 he registered a patent as well, in which he collects Piñero's researches and, to an extent, generalizes them.[4]

In his patents, Piñero defines the deployable structures by means of basic modules, of which every single one could be considered the structure's main unit. We could therefore say that Piñero conceived them as some kind of foldable bricks, that only when put together will compose a whole set.

4 Félix Escrig Pallarés. Sistema modular para la construcción de estructuras espaciales desplegables de barras. Patente nº 532.117 de mayo de 1984. Ministerio de Industria y Energía. Registro de la Propiedad Industrial. Madrid. 1984.

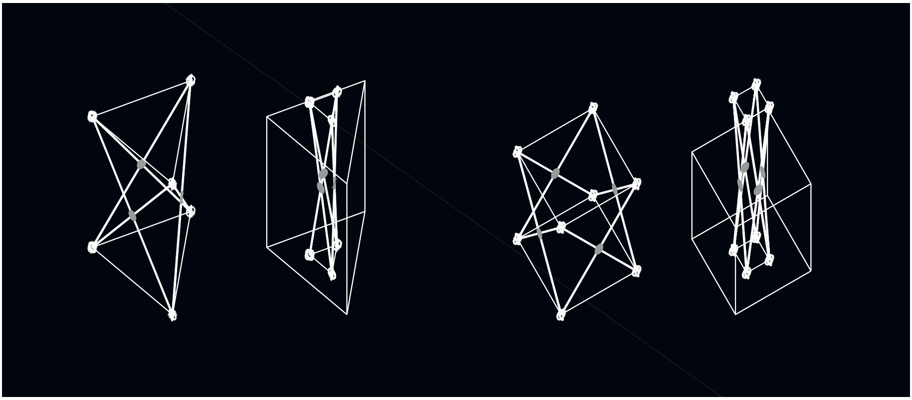


Fig. 3: Diagram of Escrig's basic modules (unfolded and folded)
by Pedro García Martínez

Three or four bars make up the most characteristic modules of Piñero's structures. In every case they are articulated in a central joint that connects all of them, giving rise to a triangular base antiprism or a rectangular prism respectively (fig. 2).

However, from Escrig's texts it can be deduced that, for him, the basic unit of the deployable structures is not the module, but something more elementary: a so-called scissor or cross, two rods joined together by means of a joint to generate it. This scissors can be arranged following different geometries, giving rise to several types of modules and, consequently, to structures of different shapes. This also implies that the systems depicted by Piñero can be considered as a particular case of the structures patented by Escrig, or put another way, that the patent of the latter is a generalization of Piñero's inventions (fig. 3).

Traditionally scale models have been the most used instruments to study, project and develop deployable structures. Piñero, for example, developed his projects using practically nothing but models. The difficulty of representing the trajectories of the different pieces of the structure through drawings relegated the graphic tools to a secondary role.

Currently, computer-aided design software constitutes a valuable tool to approach the study of this type of structures from a new perspective. Such tools not only allow us to generate three-dimensional designs of an object before constructing it, but also to define algorithms to simulate the movements of knots and bars.

At the same time, the means of digital fabrication put at our disposal possess an important range of tools that enable us to build objects designed using the aforementioned software on a real scale. These instruments also allow us to achieve a degree of accuracy much greater than the ones obtained with traditional manually operated manufacturing means.

On the other hand, it is also possible to observe that until now deployable structures, like space frames, have been used mainly as a roof for large areas. However their use in closer or more reduced scales is something that is no so usual, but also an area of great interest.

The combination of all these factors allows us to speak about an indetermination field around deployable structures; in it, activities of investigating and projecting architecture clearly converge.

In this book, we intend to collect a series of exercises in which our students have tried to explore this space of indetermination. They have researched by projecting (or projected researching) how deployable structures can be designed using some of the digital tools available today, how deployable structures can be used on a smaller scale (intermediate between architecture and furniture) to generate spaces to carry out several activities and how deployable structures can be built with unusual materials as cardboard.

To this end we designed an exercise in which students, working in groups of three or four people, had to design and build a prototype in which to carry out activities that they themselves would define (based on the previously explained patents, suggested means of digital manufacturing and available materials). The resulting prototypes had to be inscribed in a cube of two and a half meters on each side. They were built and optimized while being designed. At the same time, the projects were analyzed, observing their response and comparing it to a series of parameters. This allowed us to characterize each project diagrammatically.[5]

The project-research is based, in methodological terms, on what Sou Fujimoto evokes when he talks about the duality between cave and nest.[6] The cave is an element of nature; its form is a pre-existence, something found, for its inhabitant. On the contrary, the nest is a functional place, its form has been modeled by its inhabitant so that it fits his needs.

However, we could say that the boundary between those two concepts is not something clear; it is rather a blurred area that participates in the aforementioned indetermination. The human being accidentally inhabits the cave, gradually converts it into a nest, he or she recognizes in it a certain spatial potential to perform certain activities and not others. At the same time this inhabitant, when he inhabits the cave, discovers new activities to be carried out in it, he thereby discovers himself.

These are some of the approaches shared with the students who participated in this course. A course, whose results should therefore be understood as exploratory steps in this space of indetermination, momentarily interrupted by the temporal limits of the activity, but collected with the hope that they can be resumed at any time.

5 The parameters that are analyzed in such diagrams are detailed on p. 40-99.

6 Sou Fujimoto. Primitive Future. El Croquis 151, p.198-213. Madrid. 2010.

Dr. Montserrat Solano Rojo

Colonized Spaces:
Habitats and Displacements

The term Colonization is derived from the latin word 'colere', which means 'to inhabit', 'to occupy a space'; but it also refers strictly to migration, to move into 'new territories'. Both definitions can be directly related to architecture and to two important concepts: the notion of inhabiting and the notion of displacement.
It is precisely this double character of the concept 'colonize' that I would like to observe, specially from the perspective of the architectural project. This duality between habitat and displacement could be researched further by designing prototypes, using digital fabrication and collaborative work. Therefore, two main objectives were proposed and studied in CoLab Berlin: to design a prototype of an 'inhabitable cell' and to build it with a deployable structure.

1950–1970: Experimental Projects

The aftermath of the Second World War was the beginning of a key period of experimentation and in that context, looking back, we can recognize many strategies related with the idea of colonization. From the mid-1950s to the 1970s mobility was one of the decisive issues faced by architecture: young architects came up with ideas for several types of mobility, involving objects, architectural structures or even urbanism, and they were interested in the relation between users and built environment.
However, the notion of mobility applied to the field of housing quickly became one of the central topics to investigate. The questions about the minimum space needed to live and about flexibility of the domestic spaces were critical interests in that interesting resurgence of architecture.
Numerous prototypes of housing units and furniture that were therefore generated and built during that time, can nowadays be magnificent references. It could be interesting to review, to interpret or to improve many of these design strategies, in which mobility was taken as the center of the architectural experiments. Different significant projects about cells and furniture can be taken as a starting point; a brainstorming about mobile and flexible architecture before jumping into experimentation with digital fabrication and contemporary habitat prototypes.

Cells: Mobile Architecture

The minimum housing unit: this was one of the main ideas for the new generation of architects after the 50s. However, the units were not thought as rooms with reduced dimensions; the units were designed as a unique space, as a minimum home. They experimented with architectural projects related with the idea of ‘cells’.

Domestic architecture, therefore, linked to individual space or shelter. Habitat associated with the notion of inhabiting a shell, as it was described by Gaston Bachelard: “a shell seems to have been a truth of well solidified animal geometry, and therefore, ‘clear and distinct’. (...) and it is the formation, not the form, that remains mysterious. (...) The mollusk’s motto would be: one must live to build one’s house, and not build one’s house to live in. (...) Snails build a little house which they carry about with them, so, they are always at home in whatever country they travel. (...) A snail’s shell, this house that grows with its inmate, is one of the marvels of the universe”.[1]

The industrial context and the technological advances also influenced the proposals.“New production methods and materials brought about fundamental changes to traditional ways of building and opened up new possibilities: they were easy to use, lightweight and reproducible. This meant that the living environment could be built quickly and its morphology could be adapted to changes in configuration and sometimes even moved”.[2]

To design a minimum inhabitable cell, with the capacity of displacement –without a fixed position–was the main objective of a lot of prototypes. Several strategies were investigated and we can select some architectural projects as references:

<u>Geometric Cells</u>: systems to be set freely, anywhere, combining geometric parts. Charles & Ray Eames designed The Toy (1952), a self-assembly

1 Gaston Bachelard. The Poetics of Space. Bacon Press. Boston. 1969.

2 Marie Pierre Vandeputte. Archigram, de l´utopie à la folle fiction. Azimuts nº 34, p.54-65. Saint-Etienne. 2010.

project with colored plastic-coated panels. Four squares and four triangles came packed in a hexagonal tube, which could be used to produce multiple structures, not only by children.

Inflatable Cells: bubble architecture conceived as something able to be erected anywhere through pneumatic inflation. Hans Hollein developed the inflatable Mobile Office (1969) and provided take-along-workspace to blow up. Mike Webb–Archigram–conceived Suitaloon (1967) as a space close to the body's skin and possible to connect to other individual cells. Haus-Rucker-Co built Yellow Heart (1968), a weekend house for two people, designed as a spherical space that was made up of soft, air-filled cushions.

Modular Cells: industrialized plastic system designed as "multipurpose cells" which could be very easily moved, installed and assembled; multiple combinations of modules to define different types of houses. Three prototypes developed by a generation of French architects can be named as significant references: Maisonbulle (1965), built by Jean Maneval, composed of six polyester shells, identical in shape and dimensions, connected to one another by a lower hexagonal steel frame; Domobiles (1972), designed by Pascal Häusermann and Hexacube (1972), designed by Georges Candilis, in which the cell was above all a simple hexagonal bubble made out of two fiberglass reinforced polyester shells, and everyone was then free to choose the dimensions of his house by adding cells.

Houses: Flexible Architecture
Achieving flexible space was also another important goal. During 20th Century housing units were not built to comply with flexibility criteria; on the contrary, the housing units were designed with a kind of typology that strictly adjusted to the typical family of that time. Therefore, the young architects researched about open systems and furniture prototypes that, thanks to their capacity of transformation and movement, could adapt to the interior spaces and to the life of its users.

To increase flexibility in the domestic space, through the incorporation of mobile furniture, was another objective. The partition of housing units, with fixed walls, could be replaced with moveable or foldable elements. Numerous experimental designs promoted users participation in architectural designs.
From this perspective, Joe Colombo described some interesting ideas during the 70s: “we will have to make the home live for us, for our needs, for a new way of living (...) All the objects needed in a house should be integrated with the usable spaces; hence, they no longer have to be called furnishings but ‘equipment’. (...) Furnishings will disappear... the habitat will be everywhere... Now, if the elements necessary to human existence could be planned with the sole requirements of maneuverability and flexibility... then we would create an inhabitable system that could be adapted to any situation in space and time”.[3]
Therefore, cells and furniture could be designed as organization and flexibilization tools. “Inhabitant is who makes the house, with its presence and with the objects that are extended over this territory...through a systematic colonization (that we exercise with the furniture) (...) It could be possible to think about furniture from another point of view (...) to test the capacity of transformation of the house itself, to know better the different limits, to check how the house is adaptable to other conditions”.[4]

Minimum cells and furniture units were designed and placed in the interior of houses to improve the flexible space. These were some of the studied strategies:

<u>Domestic Cells</u>: Adaptable furniture, with specific forms, allowing the structure to host a multiplicity of activities. Verner Panton built an extensive range of furniture designs: The Living Tower (1969) with its organic forms, and over two metres high, could be used on four different levels and to interact with others; Multi-level lounge (1963) and Multi-level living (1966), steel frame structures with upholstery for sitting and lying.

3 Joe Colombo. Total Furnishing Unit. MOMA. New York. 1971.

4 Pere Fuertes. Mudanza Interior. Inhabiting, UPC. Barcelona. 2010.

Foldable Equipments: furniture without fixed positions which allowed to move the different parts of the unit and to adapt them to the space. Virgilio Forchiassin designed Spazio Vivo (Snaiderocucine) (1968), an innovative solution: the kitchen components could be alternatively displayed avoiding the usual alignment along the wall. This simple movement could revolutionize the way of living the space and the family relationships.

Colonizing Units: autonomous cells or furniture, independent of their architectural container, that can be coordinated and programmed to adapt in any spatial situation. Total Furnishing Unit (1971), designed by Joe Colombo, as an example: self-contained plastic units providing all the services of a room, a set of functions–kitchen, bed, bathroom, etc–carried out within a modular system. Ettore Sottsass designed Mobile and Flexible Environment Module (1972), a networked system of grey plastic containers, equipped with sliding wheels and plastic cables for reciprocal linking.

Prototypes: Inhabitable Cells

Diverse important aspects for the spatial configuration of the cells in the "inhabitable and mobile prototype", especially after the experiments of modern architecture, can be considered according to our two general leading concepts :

Habitat

Space: cells or furniture designed to shelter one or two users.
Bodies: prototypes associated with body movements and specific dimensions of body gestures.
Program: activities that could be developed inside the cells or around the furniture.
Proportion: relation between body, structure and the total space.
Flexibility: be able to use or colonize the minimum space in different ways.
Adaptability: be able to place the prototypes in different circumstances and environments.

Displacement
Mobility: cells or furniture designed as mobile architecture.
Deployable structure: selection of the best deployable mechanism for each specific cell.
Geometry: patterns designed to define optimally the particular spaces of the cells.
Systems: geometrical mechanisms able to combine and extend the project of the cell.
Instability: cells or furniture built with double character, as permanent and ephemeral architecture. Materiality: be able to design the cells considering at the same time their lightness and strength.

The prototypes made during this workshop together with CoLab Berlin, were meant to fill a maximum volume of: 2,40 m x 2,40 m x 2,40 m. Each team of students, was able to imagine any deployable structural system to define the space efficiently, and had to take advantage of the possibilities of digital fabrication as an interesting process to build and try rapidly the parts of the prototypes.
These 'inhabitable cells' should be able to increase the virtues of the minimum space and to allow different ways of displacements and colonization. These experimental projects should be able to narrate interesting possibilities to inhabit temporarily the interior of the cells; and we should be able to imagine and remember a solidified geometrical shell.

Dr. Martino Peña Fernández-Serrano

Utopic Megastructures:
Changing the Scale

Although the main goal was to design an 'inhabitable cell' using a deployable structural system, it was proposed to change scales. Usually, architects are used to jump between the small-scale (furniture, cells, dwelling) to the large ones (city, regional planning, country developments). It was suggested changing from the real scale to the utopian one. Megastructures are often defined as utopian proposals; nevertheless some of them were built during the sixties. The big scale prototype was used to accommodate the small scale one–the inhabitable cell–and despite the fact that those structures' designs were based on stability, permanence and hardware, in the middle of the decade Ron Herron imagined the 'Walking city' as "an enclosed environment of colossal size that is mobile enough to traverse the world".[1]

Definitions

It could be said that Megastructures are a utopia, this term derives from the greek syllable 'u' and 'topos'. The first one could mean either 'no' or 'well-being', the second one as it is already known means 'place'. Therefore, utopia could be a not existing place, or maybe a place for the well being, or a wonderful place, a nonexisting place.[2] Usually utopia describes something that it not real, and with the definition of somewhere in the World and sometime in the Future we have the groundwork for Science-Fiction. At the same time when the term Megastructure appeared at the second half of the twenty century, the colonization of the moon and planets was a reality.

Taking a look at the word Megastructure, it contains two terms; the greek one mega, which means 'big' and structure. This second one has different meanings and, according to the Oxford Dictionary, one of them is: 'the arrangement of and relations between the parts or elements of something complex' or in other words the manner in which the elements or parts of something are organized. With these two definitions a Megastructure could be a big structure, but as Reyner Banham said "Not every big building is a

1 Archigram. Archigram 5: Metropolis. London. 1964.

2 Cristoph Düesberg. Megastrukturen: Architektureutopien zwischen 1955 und 1975. DOM Publishers. Berlin. 2013.

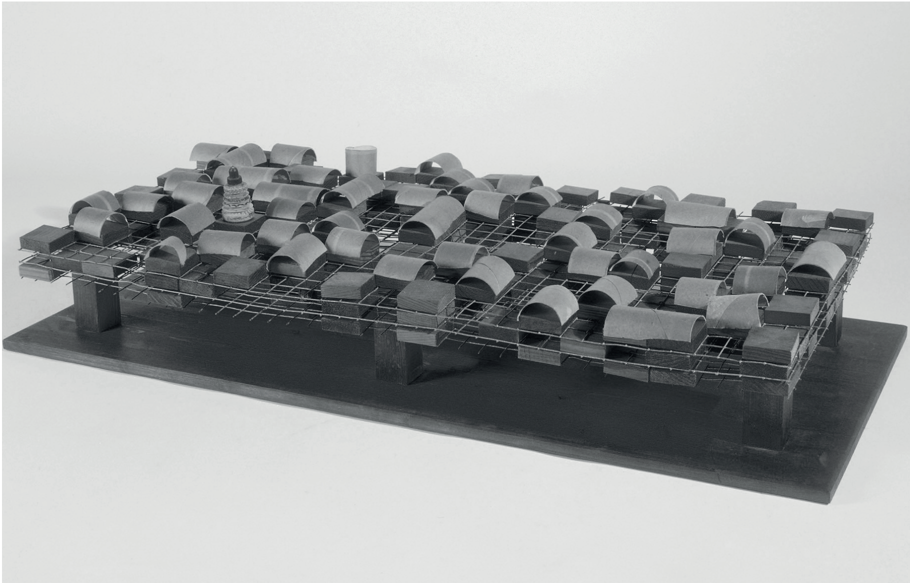


Fig 1. *Ville Spatiale*. Yona Friemdan.
© Collection FRAC centre, Orléans

Megastructure", they have to comply with other requirements to be one.[3] In this way big bridges or huge containers, as shopping malls, cannot become Megastructures because they do not function as one.

According to Banham, the definition of Megastructure has to be understood as the distinction between Macro and Micro; the Macro-structure and the Unit. The macrostructure is the hard part, the permanent one and the rigidity of the system; the hardware. On the other hand the Unit is the soft part, the transitory; the software. At the same time it could be said that the macro is the long term, a structural frame where the short term, the Unit, could be placed, plugged in or hung up, while remaining over time. In contrast the units are temporary, flexible and mobile.

3 Reyner Banham. Megastructure. Urban Futures of the Recent Past. Thames and Hudson. London. 1976.

The Macro
During the second half of the 20th century there was a long tradition of big frames, based on the work of the German architect Konrad Wachsmann, who had developed a mobile aircraft hangar for the Atlas Aircraft Corporation. He would later design aircraft hangars for the U.S. Air Force in the 1960s, which became the paradigm of a big container frame. The German architect has developed knowledge around huge structures that he had disseminated all around the world through seminars that he had conducted. One of these was the Wachsmann's seminar in Tokyo, where some of the members of the Metabolist group were taking part of. Later, these young architects would surprise the world with their artefacts at the World Exposition in Osaka in 1970. Other architects and engineers were dealing with the same archetype, like Richard B. Fuller, who disseminated the reticular dome all over the globe. The American engineer started this process after the second Word War. In his work he was studying the constructions of nature, mainly the ones with the lowest energy consumption, being convinced of the material optimization that nature had undergone. The most important and influential project by Fuller was realized with the American Pavilion at Montreal in 1967 among other utopian projects, as well as the dome over Manhattan, who both could be considered Megastructures.

Around 1964 Fumihiko Maki published Investigations in Collective Forms in which he described Megastructures as "big span structures that actually are occupying a city or a part of it and that it is possible due to the new technology".[4] In the same year Banham was talking about the 'Megayear' according to the large numbers of such types. The magazine 'Archigram 5' displayed different projects from Frei Otto, Paul Maymont, Paolo Soleri, Arata Isozaki, Leopold Gerstel, Eckhard Schulze-Fielitz and Constant Nieuwenhuys. That is why Banham said that it was an illusion of a Megastructure International movement. Nevertheless, for the English group Archigram the macrostructures could solve part of the city's problems: "A major problem of the organization (and the imagery-

4 Fumihiko Maki. Nurturing dreams. Collected essays on Architecture and the City. The MIT Press. Cambridge, Massachusetts. 2008.

control) of large areas of city is the achievement of a consistency running through parts with widely differing functions and sizes. Add to the problem of absorbing growth and avoiding the placement one-offness of block-to-block relationship, the answer is obviously found in a large-scale structural idea, which is anyhow a necessity of a consistent building”.[5]
Archigram believed that ‘within the big structure, almost anything can happen’ what could be related to the Plug-in city as a massive framework in which dwellings could be slotted.
In the same line of research the group GEAM (Groupe d’étude d’architecture mobile) was working. Yona Friedman and other members were thinking about principles of architecture which were capable of reacting to the constant changes that characterize the social mobility. Those would be based on macro structures which could provide housing. In the same way Shulze-Fielitz asked himself: Why can’t we use the free space between the bars and elements in big span structures to provide living units?

The Unit
As well as the group GEAM, Archigram was dealing with the habitat. In 1964 Warren Chalk used the term ‘capsule’ to refer to a prefab living unit which could be plugged into a macro structure, which served the unit with all its requirements. “Conceptually, the ‘capsule’ serves to describe an approach to housing by presenting a series of very sophisticated and highly designed elements locked together within a ‘box’ which is itself highly tailored. It is an industrial design approach. It implies a deliberate – even a preferred – lifestyle”.[6] Also this unit has to provide only the most important requirements of human life and has to serve the contemporary nomads. Archigram tried to improve this kind of life quality. The nomads understood that the mobility is a right of modern society, a right that accompanies with democracy. The next question that came up was, how much one can be able to carry and move to finally turn it into an environment. Therefore several proposals as the Cushicle appeared. The term was an invention between

5 Archigram. Op. cit.

6 Peter Cook and Warren Chalk, Dennis Crompton, David Greene, Ron Herron, Mike Webb. Archigram. Princeton Architectural Press. New York. 1999.

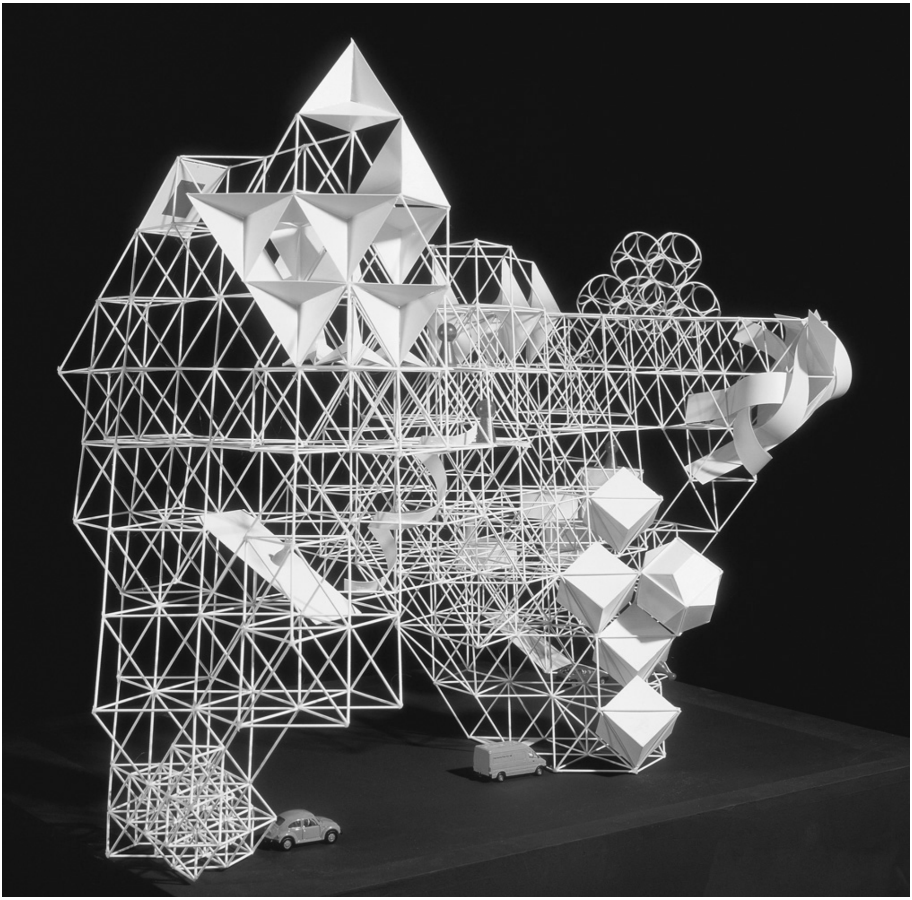


Fig 2. *Raumstruktur*. Schulze-Fielitz. © Colection FRAC centre, Orléans.

the term 'cushion' and 'vehicle' and "enables a man to carry a complete environment on his back. It inflates out when needed. It is a complete nomadic unit – and it is fully serviced".[7] The unit became autonomous and the macro was not needed anymore.

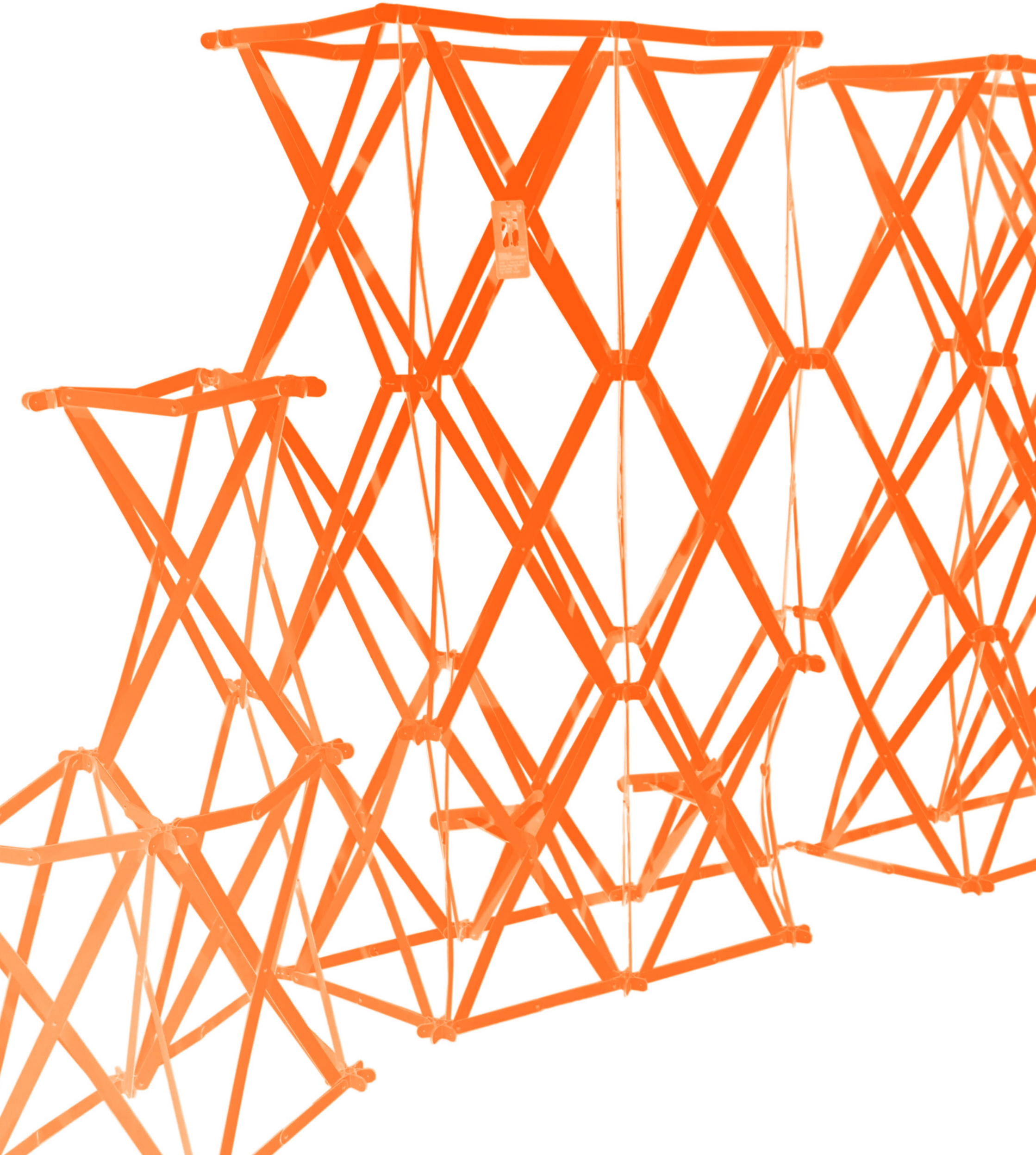
7 Op. cit.

Moreover the Japanese group Metabolist was using the term ‘cell’ to define the same concept. According to their manifesto and the idea of architecture as an organic biological entity, the living cell “encompasses notions of growth, division, exchange, transformation, autonomy of parts, deconstruction, recycling, rings and dynamic stability”.[8] This concept was adapted and applied for the tetra structure of the Expo 70 Toshiba IHI Pavillion and for the Helix Tower at the Osaka International Exposition. At the same Expo the building known as the Big Roof unified the Macro and the Unit. It was about developing an aerial city in which cells or capsules were inserted into a big steel frame of free spaces. In order to manage the aerial city, international architects–such as Safdie, Gudunov and Archigram–and national architects–such as Kisho Kurokawa, Fumihiko Maki, Noburu Kawazoe, and Koji Kamiya–were invited. The Big Roof was a container for activities and not only around but inside of it. Being an aerial settlement it had to be a walkable and inhabitable space frame which would function as a real city. The Big Roof was a built example of a Megastructure.

Changing the scale

All the prototypes designed at CoLab TU-Berlin could provide a completely different use just by changing their scale. All of them have been made of modules which are following several geometric rules. Changing the module dimensions they could achieve large structures which could, at the same time, accommodate the small scale; the living unit. The deployable structural system enables what Ron Heron had imagined: a Walking City. The macro structure could be folded together and deployed again in other parts of the word. The idea of mobility became real not only for the ‘cell’ but for the infrastructure too. It is an abstract way to go from the macro to the micro what proves the flexibility of the systems that have been designed.

8 Kisho Kurokawa. Kisho Kurokawa. From Metabolism to Symbiosis. Academy Editions/St. Martin´s Press. Japan. 1992.



REDEFINING PARAMETRIZING **EFFICIENCY**

At the same time as the course was being developed, parallel to the work generated by the students, we observed that it was necessary to establish criteria that would allow us to quantify the obtained results.

The idea of efficiency was already analyzed in previous workshops by CoLab Madrid, and since 2009, different magnitudes and diagrams were established to allow us to measure the quality of a design[1]. What do we exactly mean when we say that prototypes had to be efficient? How could we measure that efficiency?

The fact of raising these questions in the contemporary industrialized context in which the process can not be separated from the manufacturing methods and their restrictions means that their possible answer transcend the definition of efficiency in merely structural terms or a material's resistance.

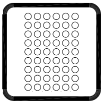
Of course, it was desirable that the prototypes were built using the least amount of material possible, in the shortest time possible and that the number of assembly components used were also reduced. But there are other architectural qualities that needed to be valued, parametrized and introduced in our concept of efficiency.

Considering all these parameters, we generated a multidimensional scale or ruler, endowed with several axes, that allows us to measure the efficiency of the generated prototypes. As a general criterion, one prototype would be more efficient than another, if its diagram, once represented on the aforementioned scale, had a smaller surface area.

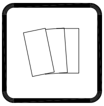
On the next pages we show the considered parameters.

1 Almudena Ribot, Ignacio Borrego, Javier G.-Germán y Diego G.-Setién. CoLaboratorioetsam 2009. Ed. Mairea Libros + DPA ETSAM + CoLaboratorio, Madrid 2010

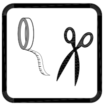
MATERIAL USED



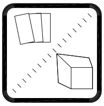
Maximum use of the cardboard (mUc) >> %
mUc >> Measures the relationship between the used and the total surface of a panel. Exhibits how efficient the design of a prototype is according to the wasted surface of a panel.



Number of panels (nP) >> number of units
nP >> Measures the total number of panels used to assemble a prototype. The less panels have been used the more efficient the prototype is.

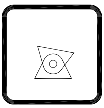


Cutting lenght (cL) >> m
cL >> Measures the total length of the cutted pieces put together in a line. It is an abstract way to test the materiality and the use of a product to achieve the desirable results.

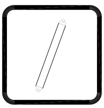


Panels/ volume index (pvI) >> index
pvI >> Relationship between the total number of panels and the unfold volume. The lower the index of a prototype means the relation between panels and volume is more efficient.

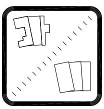
ASSEMBLY COMPONENTS



Number of joints (nJ) >> number of units
nJ >> Measures the total number of joints used to assemble a prototype. In the same way the less number of joints a prototype needs, the more efficient it is.



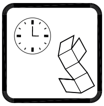
Number of bars (nB) >> number of units
nB >> Measures the total number of bars used to assemble a prototype. The less number of total bars a prototype needs, the more efficient it is.



Superficial module variation (smV) >> number of units
smV >> Different module variations used to design a prototype. More module variations made with the same numbers of bars and joints enrich the architectural proposal and its complexity.

TIMING AND DURATION

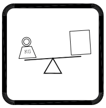
Duration of the cutting process (Dcp) >> min
Dcp >> Total time in minutes of the cutting process of the pieces of the prototype. The less time all the pieces of a prototype need to be cut, the more efficient it is.



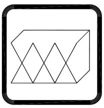
Duration of the assembly process (Dap) >> min
Dap >> Measures the time in minutes used to assembly a prototype once the pieces are made. The less time a prototype needs to be assembled, the more efficient it is.

Total manufacturing time (Tmt) >> min
Tmt >> Measures the total time in minutes used to produce and assemble a prototype. The less time, the more efficient it is.

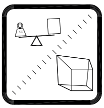
VOLUMETRIC PARAMETERS



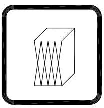
Weight (W) >> kg
W >> Measures the prototype's relative mass or the quantity of matter contained by it. Less weight indicates better mobility possibilities of the prototype.



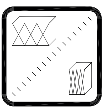
Unfolded volume (uV) >> m^3
uV >> Measures the volume of a unfolded prototype measured in m^3.



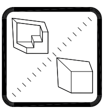
Density (D) >> kg/ m^3
D >> Measures the quantity of mass per unit volume of a prototype. Less density means more transportability in terms of efficiency.



Folded volume (fV) >> m^3
fV >> Measures the volume of a folded prototype measured in m^3. More foldability means more prototype efficiency due to the module and joints used.



Foldable index (fI) >> %
fI >> Relationship between the folded and unfolded volume. The lower the index the more efficient is the foldability.



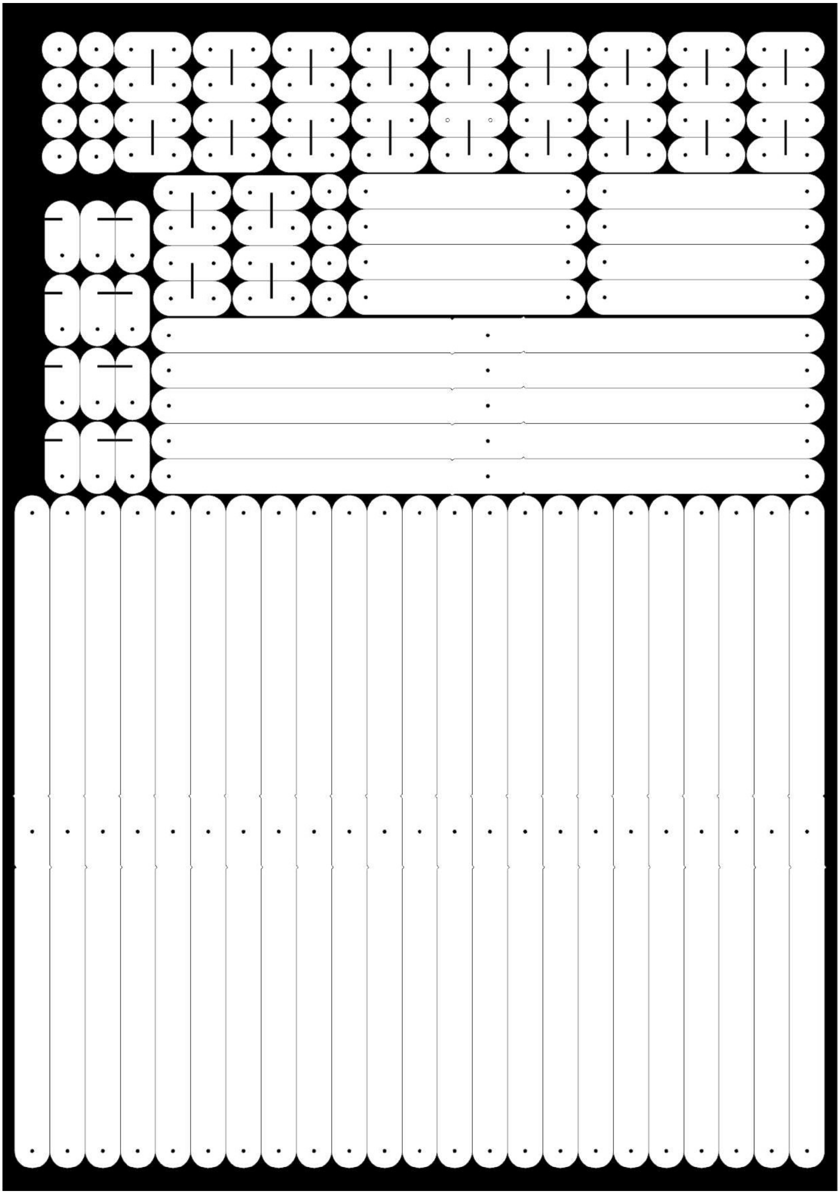
Empty module index (emI) >> %
emI >> Relationship between the unfold volume and the volumetric contour proposed. It shows the projects complexity. A lower index means more complexity inside the model.

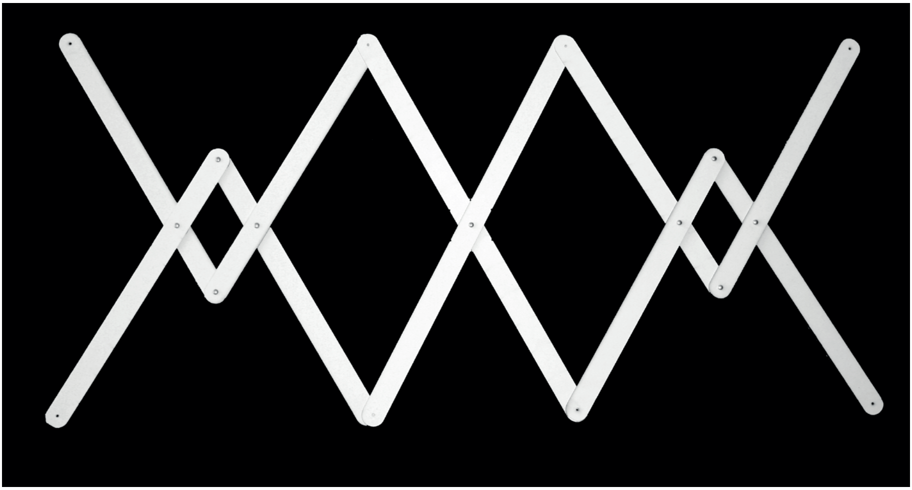
>>> Model / A

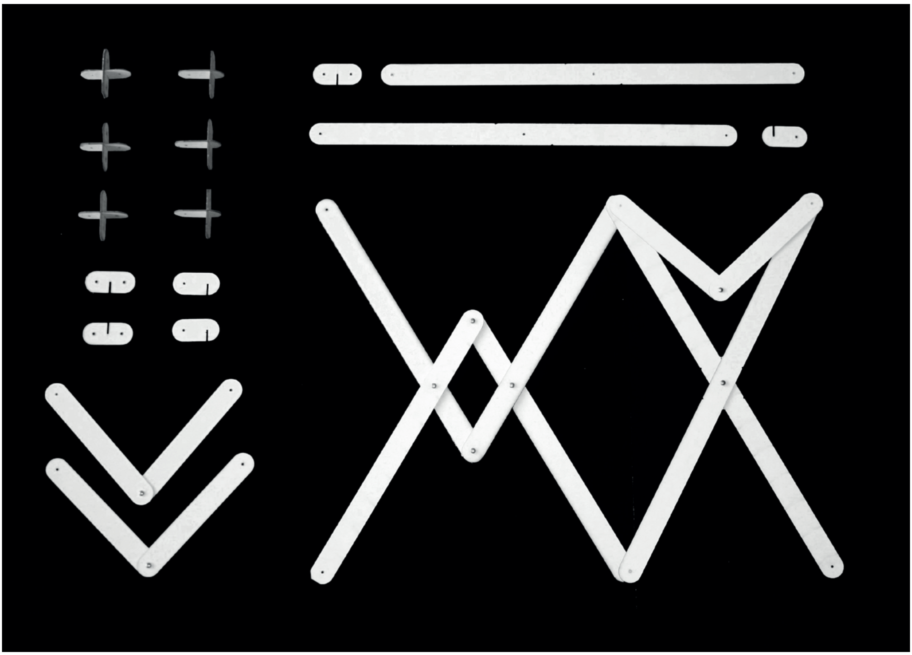
>>> Mirza Vranjakovic
>>> Sebastian Labis
>>> Jacob Bövner
>>> Leonhard Schönfelder

Use>>>
The proposal is a mobile furniture as a storage rack or a space divider screen that could be located anywhere in a given room. In this way it provides different alternatives to be used. It is important to have a variety of dimensions which is achieved by the chosen module in order to provide as many variations as possible, what enriches the architectural proposal and its functionality. First of all, different positions have been selected to sit and read, a place to store books and plants and as partition between two areas. As an autonomous artefact it has to be thought as an entity in a way that it is unknown where it is going to be initially located, that is why all of its sides are relevant and have to be planned.
Type>>>
According to the definition made by Félix Escrig, foldable systems can be made by adding different modules which are foldable themselves. The one chosen for this prototype is the so called Regular Quadrangular Prism and it consist of two bars connected in the middle, on each side of the prism, having a quadrangular symmetrical plan. All the bars are connected in a scissor system that allows them to be folded together. In order to achieve more variety, the module has been tuned. Therefore the two sides of the prism made of two bars have been replaced by four which are not connected in the middle anymore. This action changes the main module dimensions and makes different settings possible.
Stability>>>
These two module configurations achieve all the required functions by the artefact. Due to the chosen quadrangular geometry, it is necessary to brace them once they have been unfolded to give the prototype enough rigidity. Therefore two strategies have been developed; the first one is a pair of scissors which can be placed inside two modules, to join them vertically. The second strategy is to set a special bar (Bar C) between two given knots to brace the module, this could be made in the two main directions and the special designed bar has to allow all the foldable movements. The connections or knots have been adapted to permit the different positions mentioned above which have been achieved by using a main knot and modifying it.
Conclusions>>>
The structure enables perfect folding and unfolding movements, without the need of any extra piece to allow the expected deployability. The rigidity due to the well designed pieces allows the prototype to be located in any place, having complexity and diversity in variation of modules and possibilities of use at the same time.

// pattern

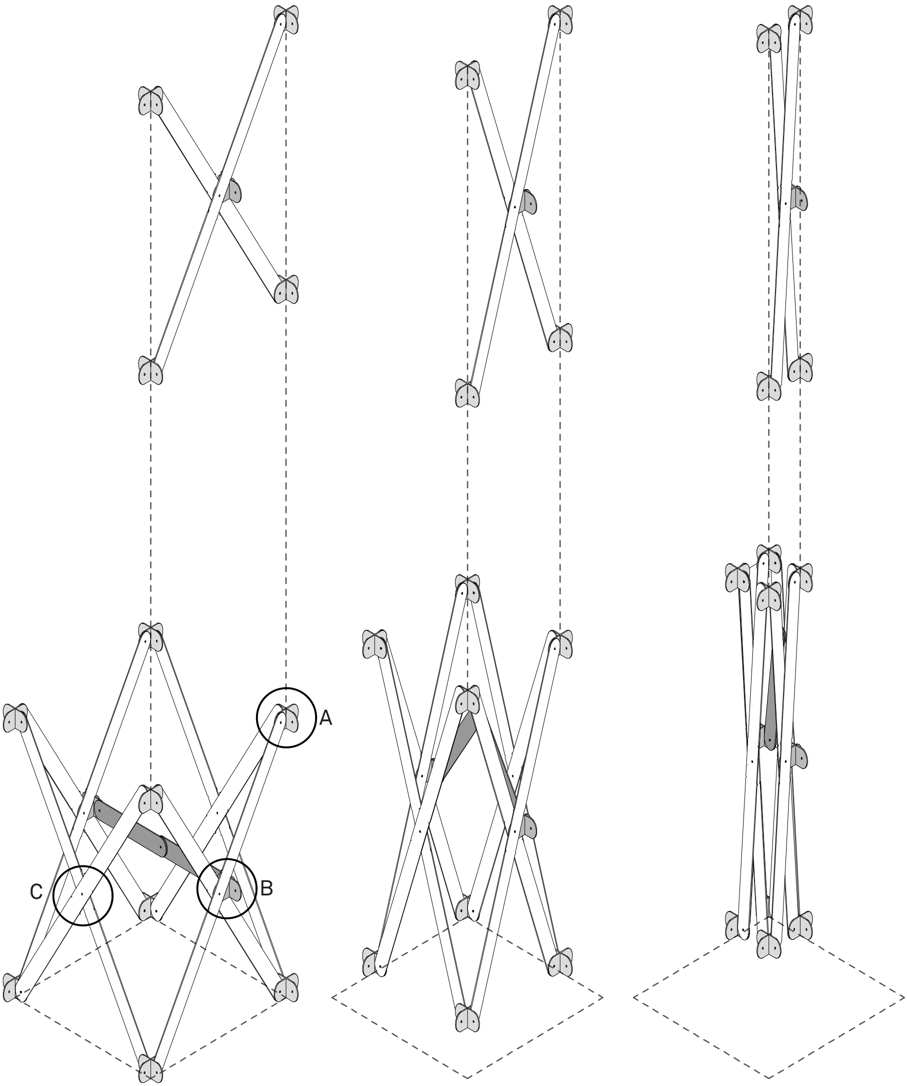






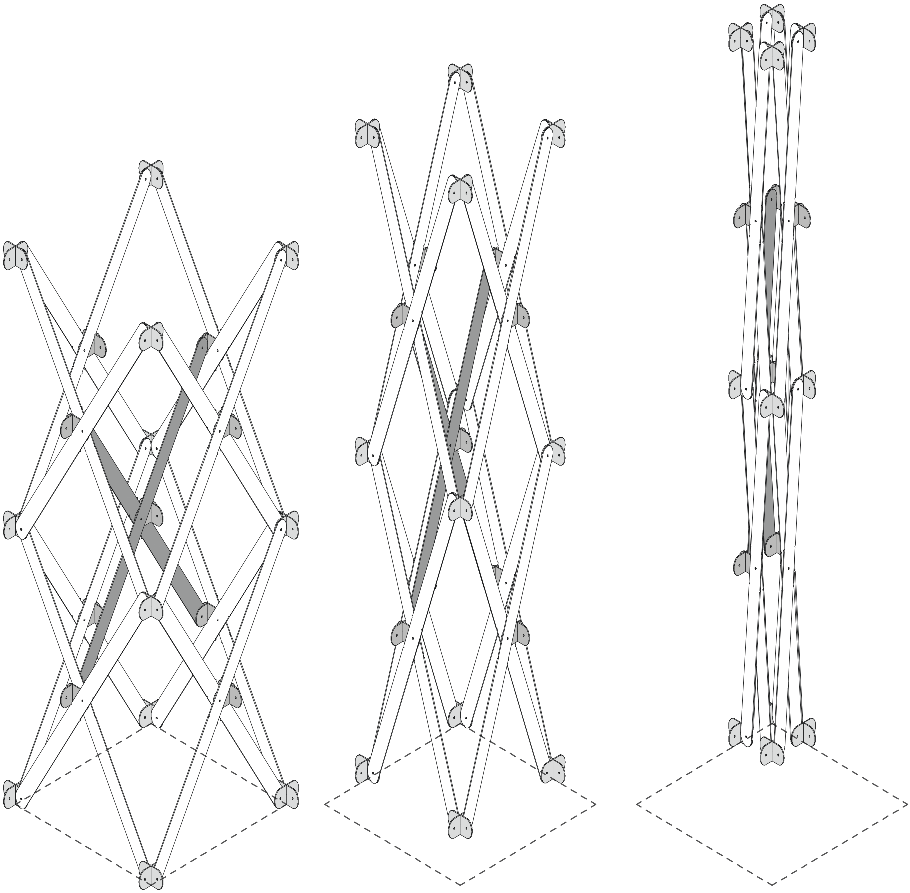
// module

>> Module// 01 of the structure



>> Opened module >> Half opened module >> Closed module

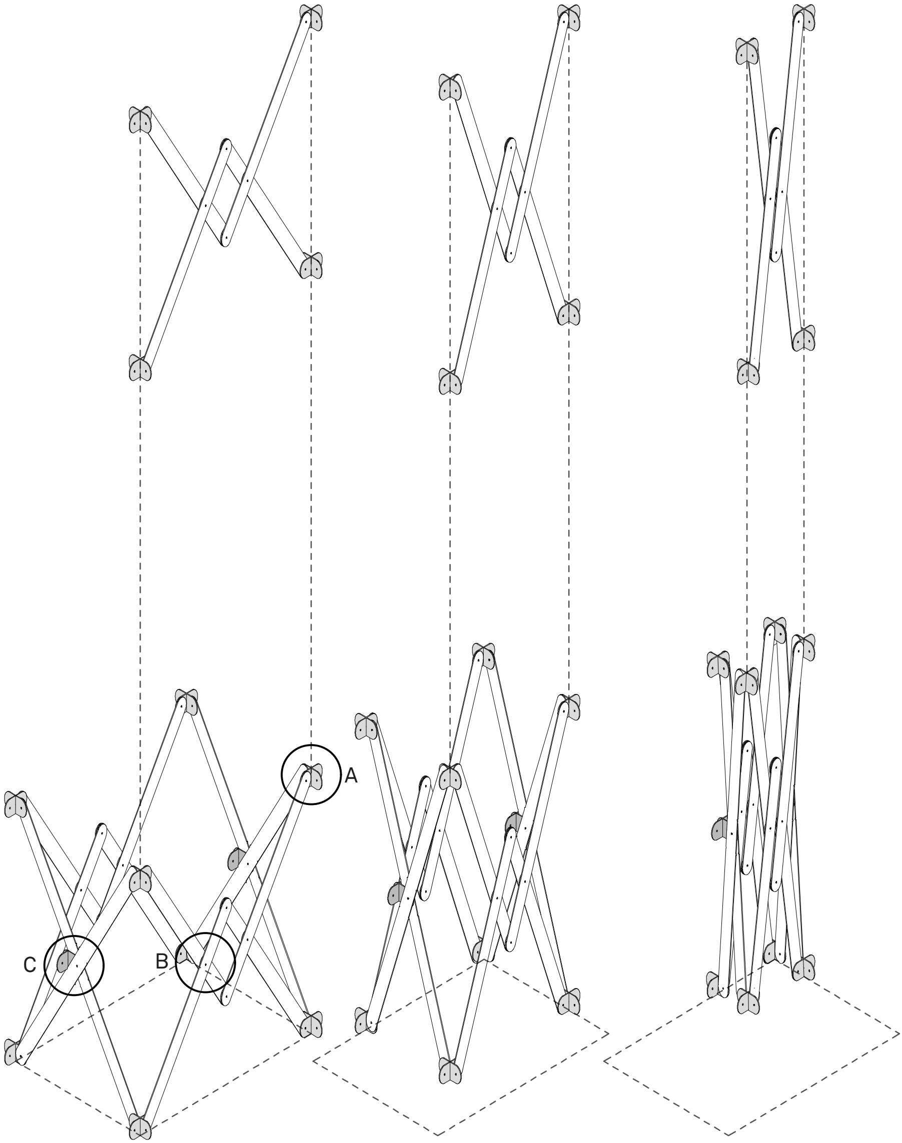
>> Connecting two modules// 01



>> Opened module >> Half opened module >> Closed module

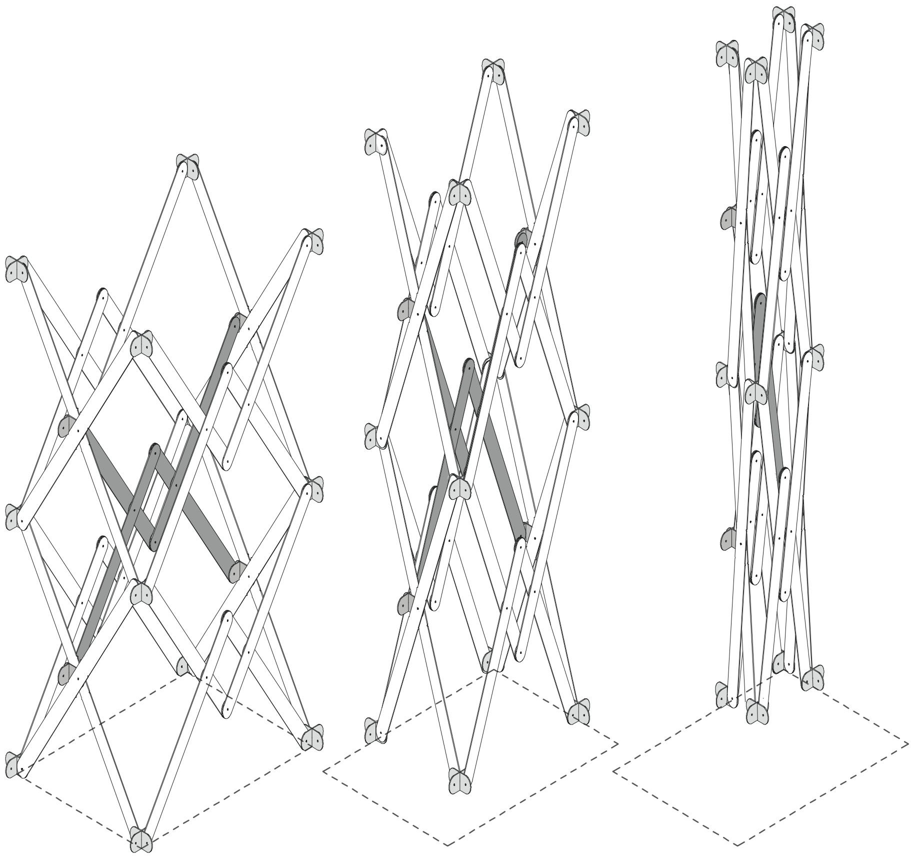
// module

>> Module// 02 of the structure



>> Opened module >> Half opened module >> Closed module

>> Connecting two modules// 02

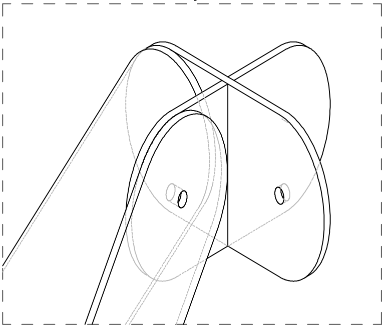


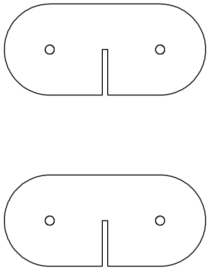
>> Opened module >> Half opened module >> Closed module

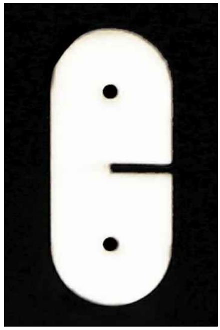
// nodes

>> Type of connectors

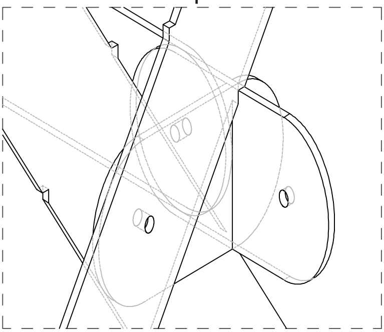
>> Node A// two pieces

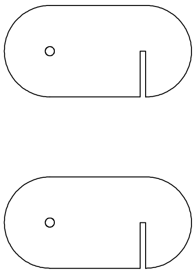


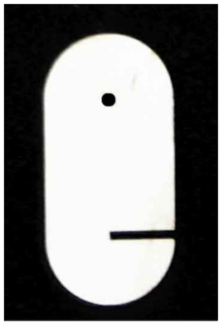




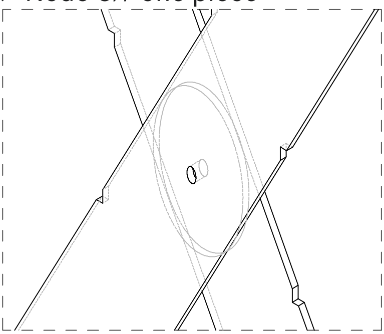
>> Node B// two pieces

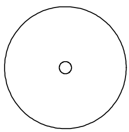


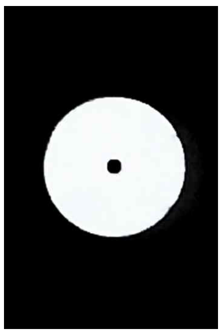




>> Node C// one piece

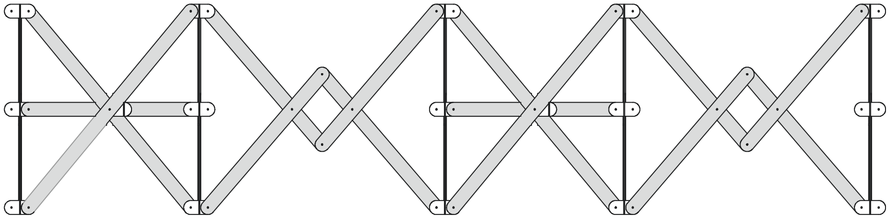






>> Type of bars

>> Pattern bars// connectors

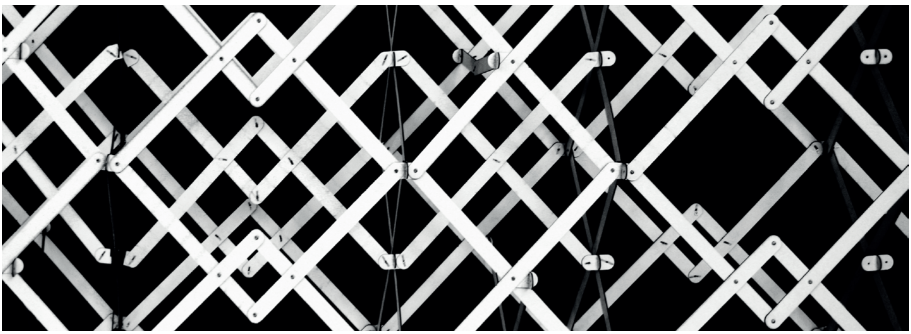


>> Bar A_Short bar for Module 02//

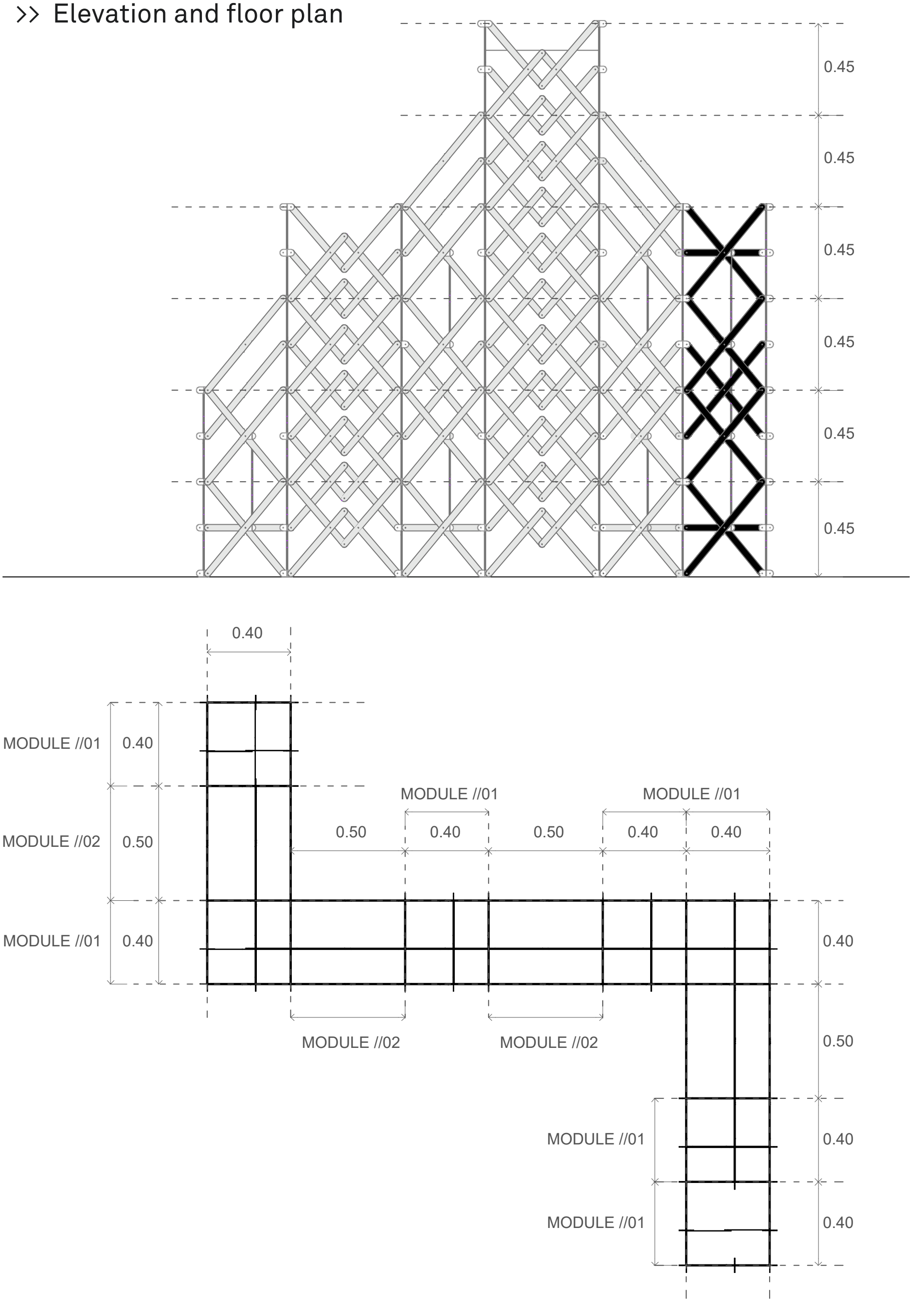
>> Bar B_Long bar for Module 01// Module 02//

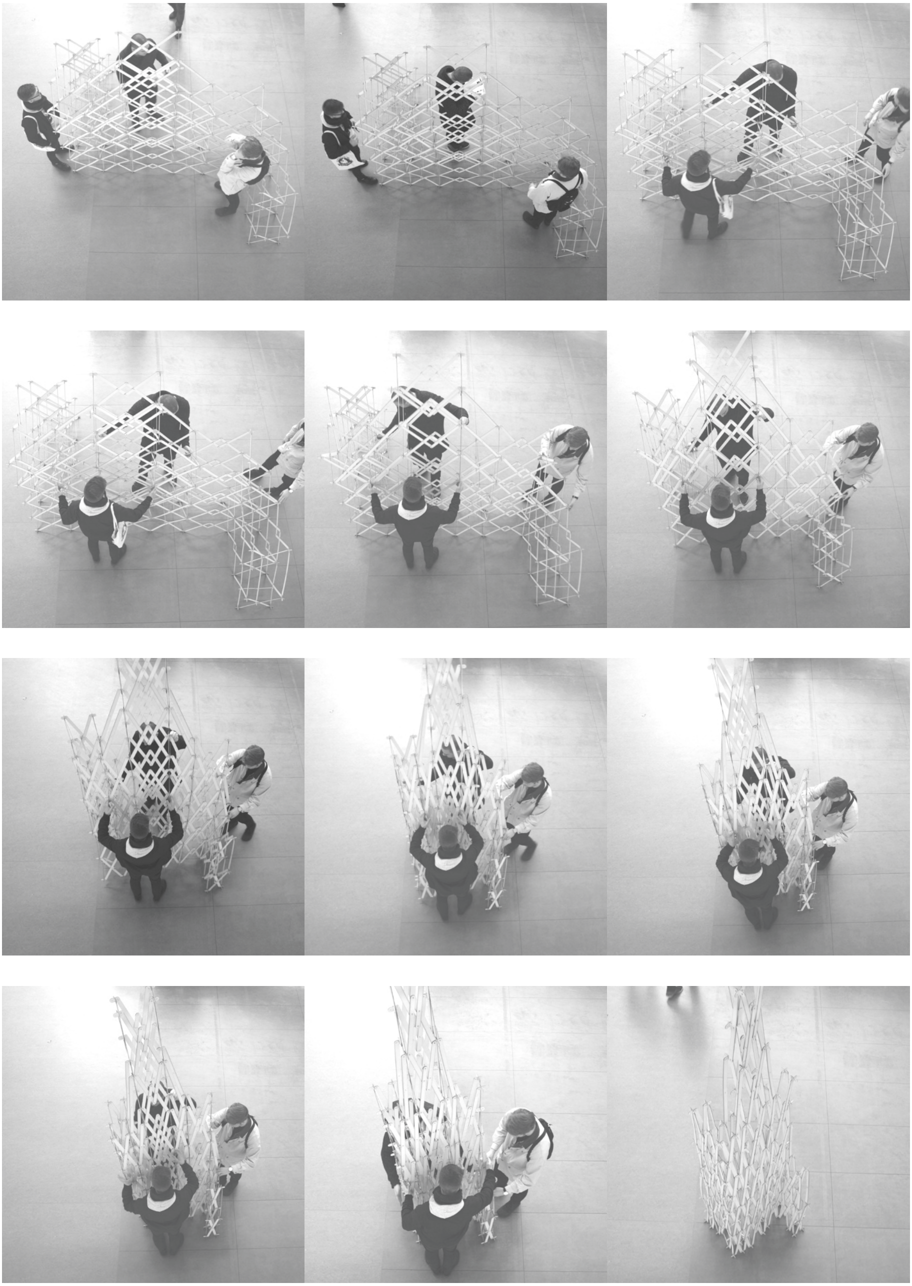
>> Bar C_Reinforcement for Module 01//

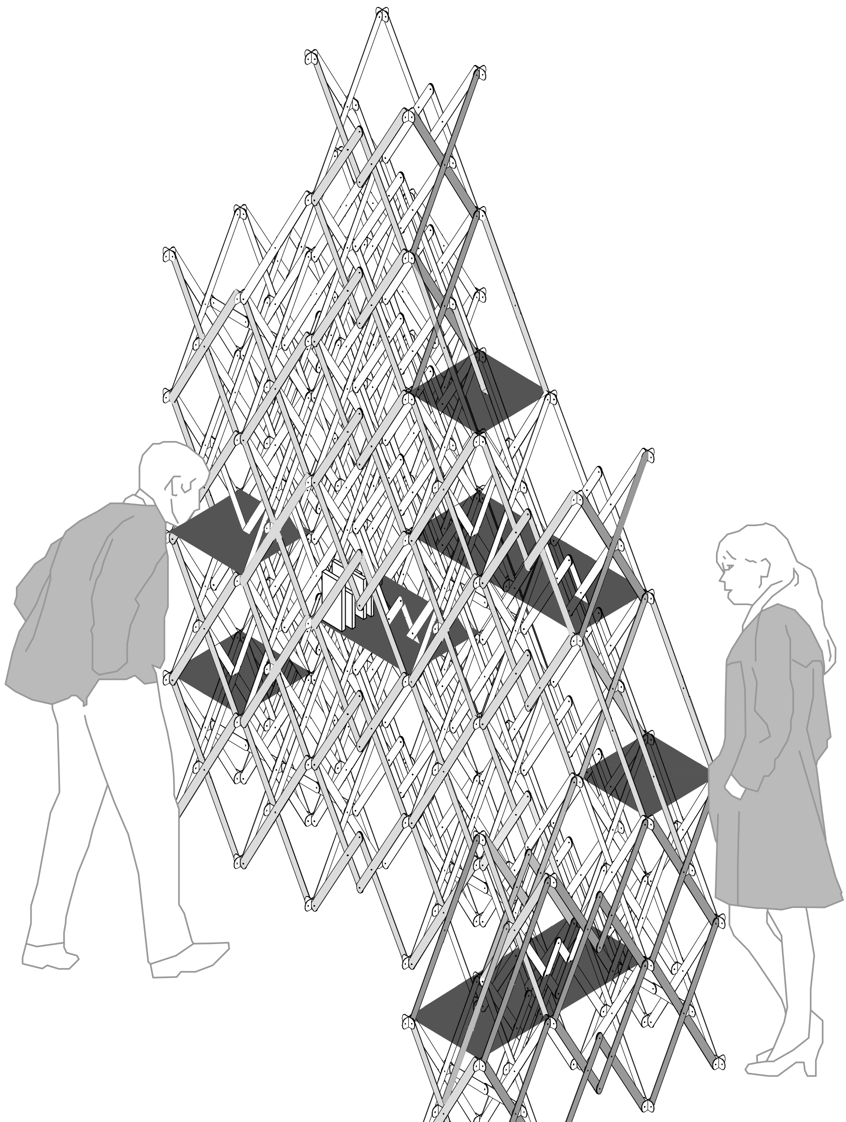
>> Detailed photo of the prototype

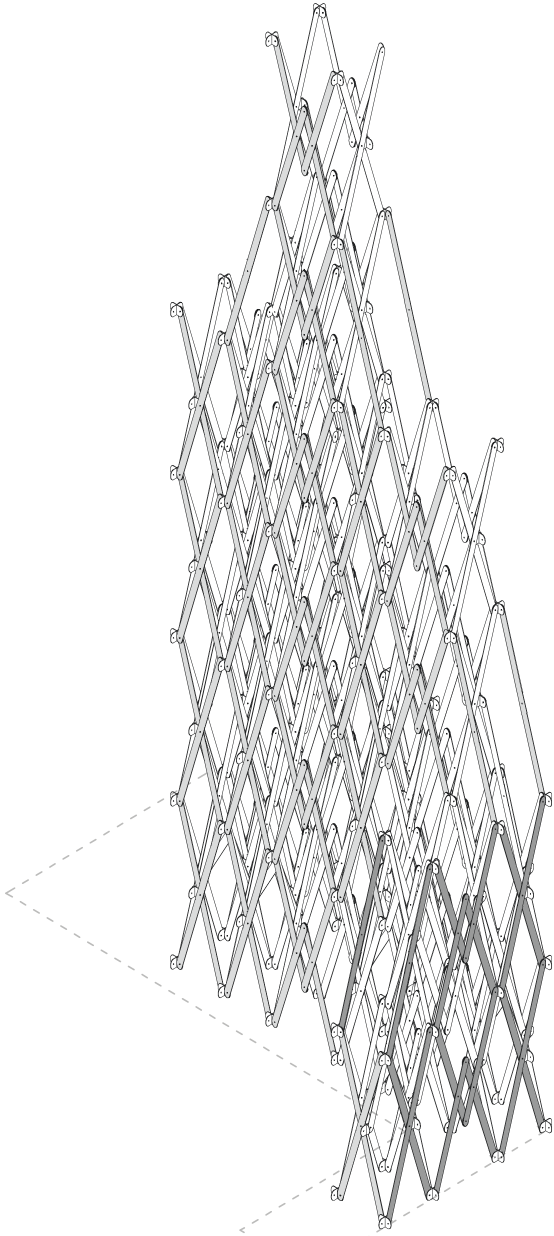


>> Elevation and floor plan



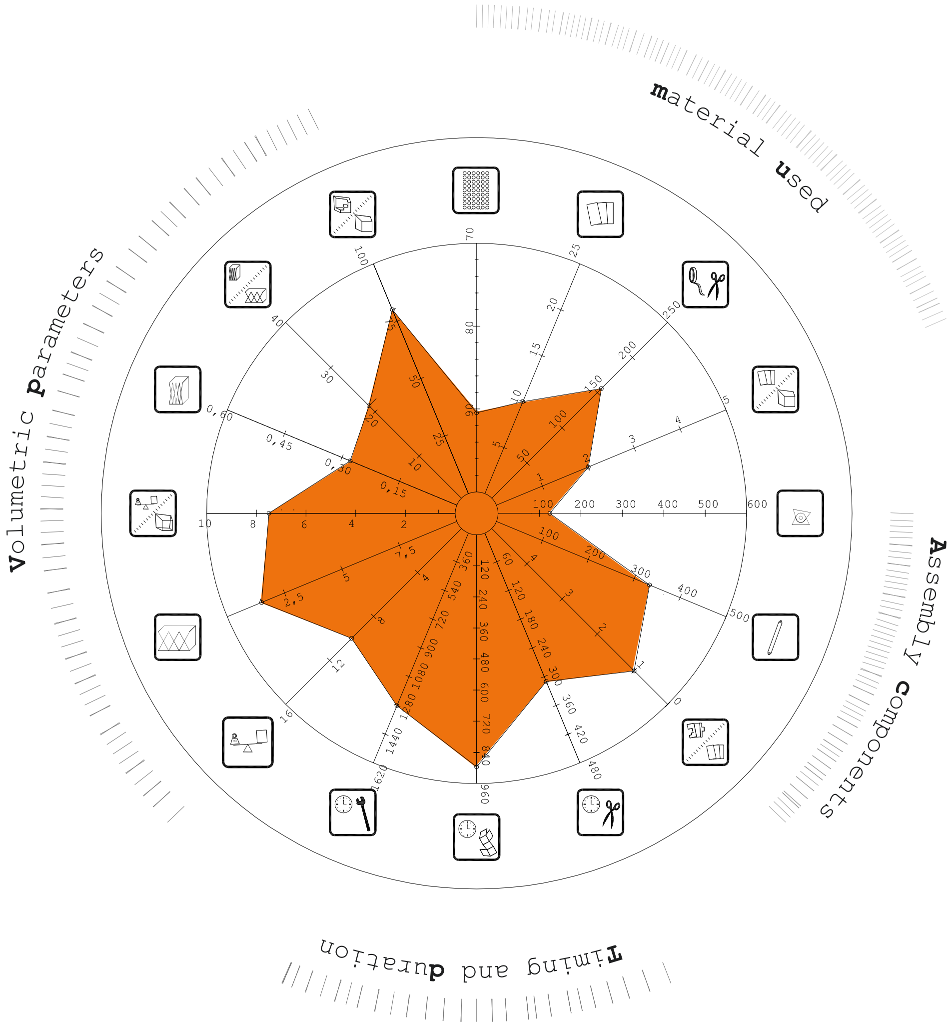






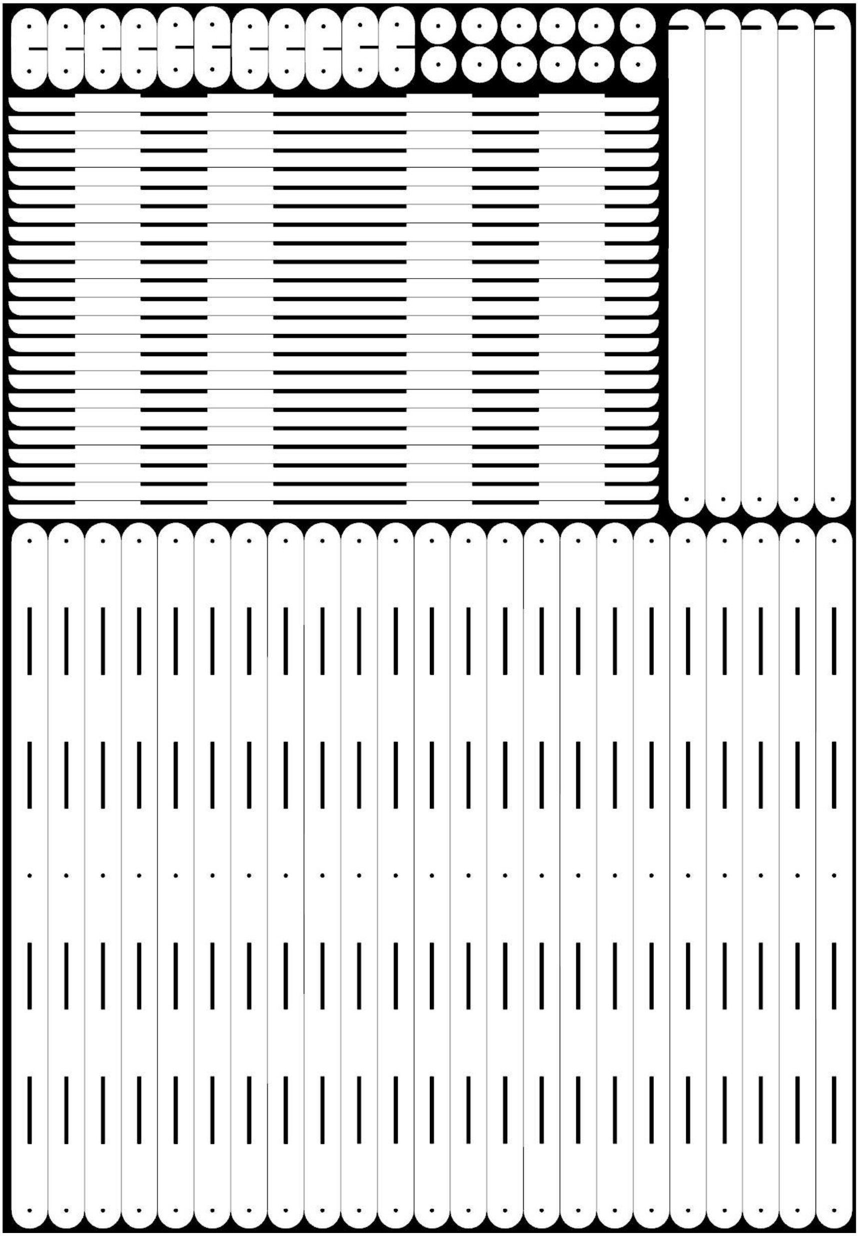
>>> Model / B

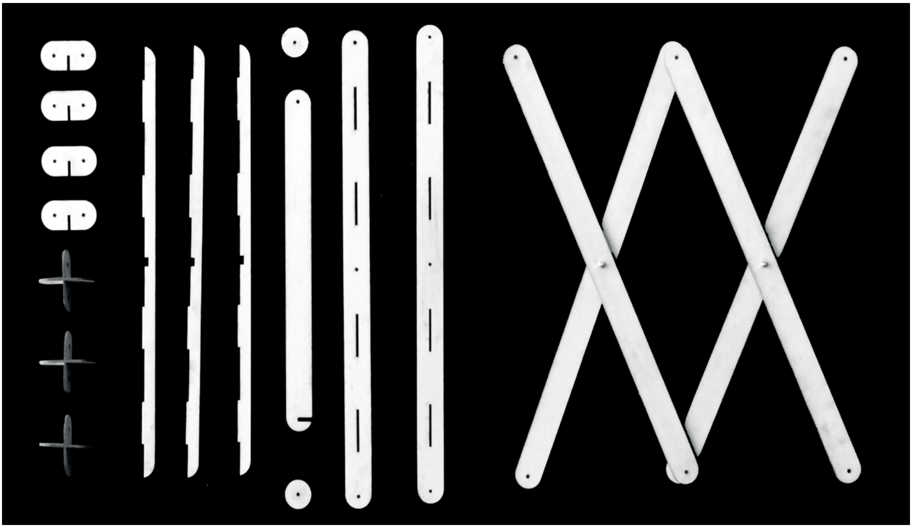
>>> Iris Huneau
>>> Elise Helm

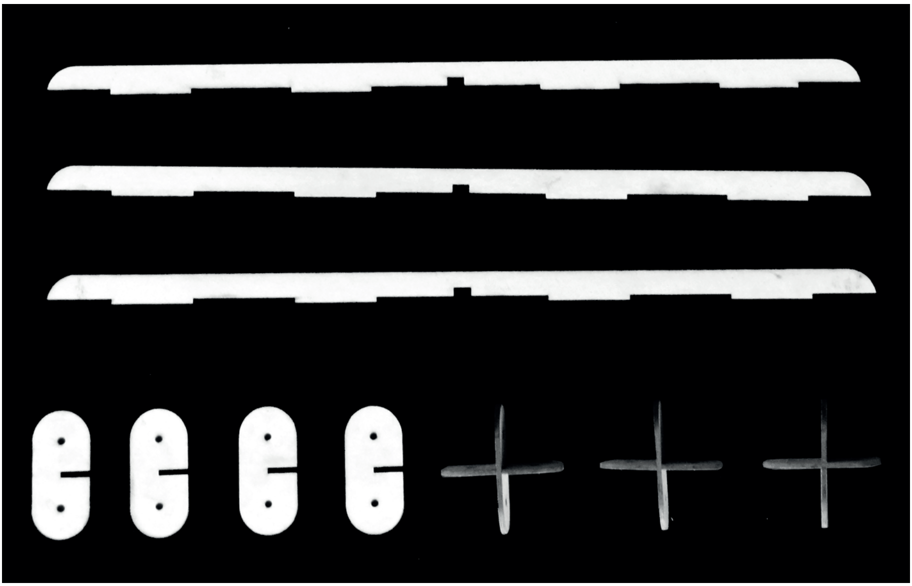


Use>>>
The prototype is part of two designed components that originally enclose a cube which was planned to be a space to read and relax. The artefact could be placed inside of a given interior space or on the outside, a textile covering the deployable structure was envisioned to complete this idea. The entire different settings are planned with solely one modular variation, which is why its dimension is very important. The same module has to be used as a chair and in this case as book storage as well. Its main function - as a place to sit - was chosen as a dimension that enables to also host the other required functions and possibilities by simply opening the sides of the cube and taking away one or more modules.
Type>>>
As in group A, the chosen module is the so called Regular Quadrangular Prism and it consists of two bars connected in the middle, forming a pair of scissors placed on each side of the prism, thus forming a cube with equal sides. The pair of scissors is connected to other pairs of scissors using a general knot at the end of both bars. Within this knot all joints are solved which simplifies the assembly process. As it has been said above it was important to choose only one module dimension, a cube in particular, to build the artefact which was originally thought as a bigger cube which could be placed in a given space.
Stability>>>
As it is already known, the cube is not a stable figure in a structural way, and needs to be stiffened in one or two directions. To brace the diagonal one would achieve a triangulated structure, though it would make the prototype difficult to fold. For this reason it was decided to brace the cube edge using a special bar (Bar B) and reinforce the bars itself. The main long bars (Bar A) have openings to place bracing elements (Bar C) in the perpendicular axe. With this strategy more resistance at the bottom of the modules, where the total weight of the prototype is focused, have been achieved.
Conclusions>>>
Although all these bracing strategies have been used, the desired goals were not achieved. The prototype shows a lack of rigidity when unfolded and the stiffening elements turn the folding process into a very complicated one. As mentioned above, although only a part of the artefact has been built, the planned space ensures the calm and comfort needed to read and its deployability makes it possible to place it anytime anywhere.

// pattern

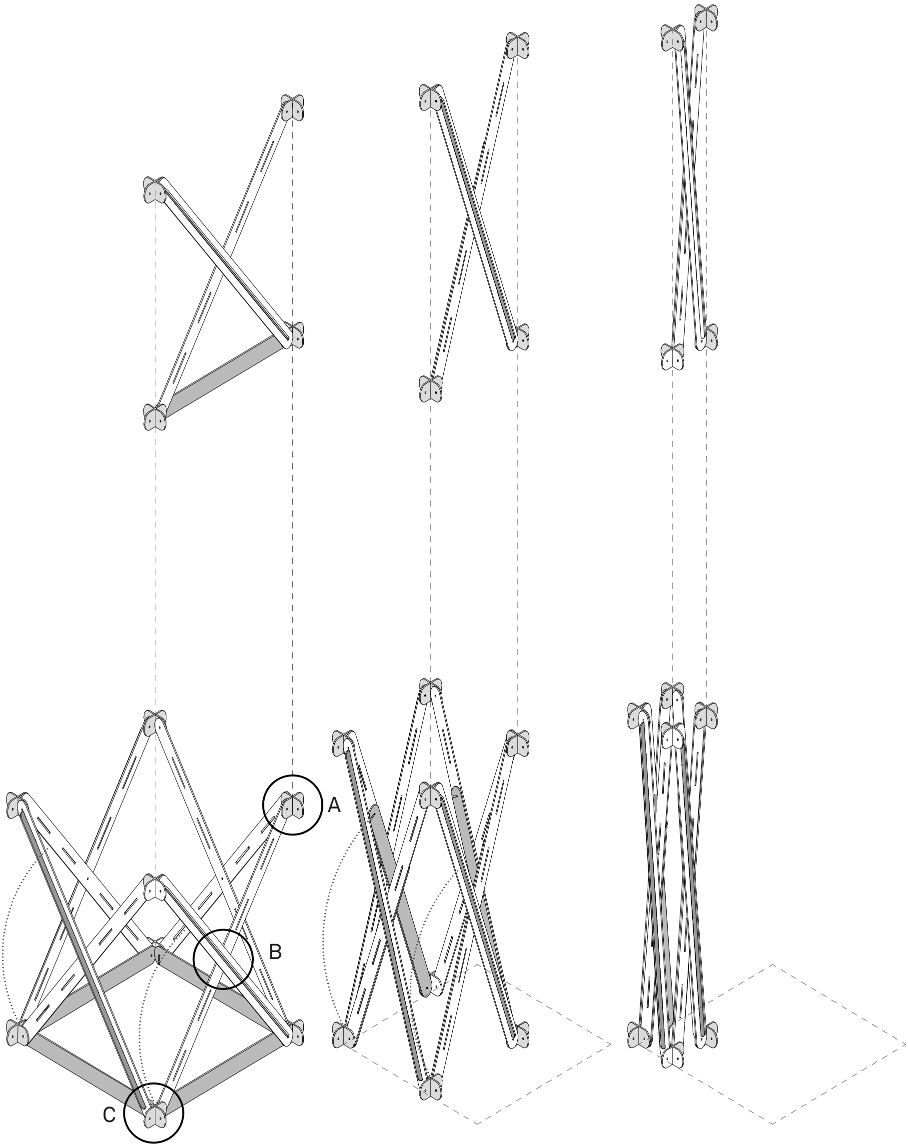






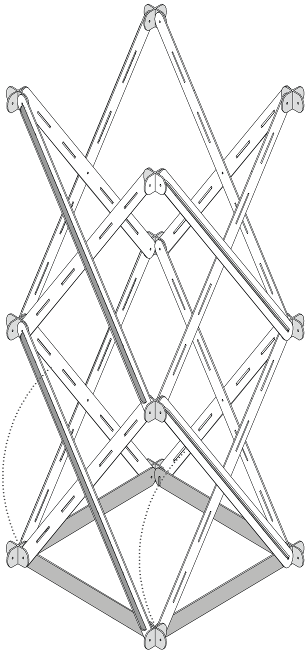
// module

>> Module// 01 of the structure

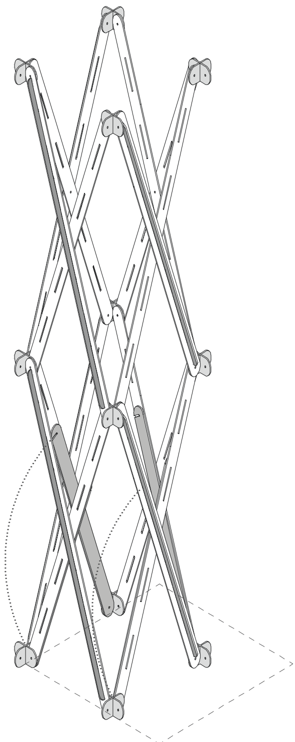


>> Opened module >> Half opened module >> Closed module

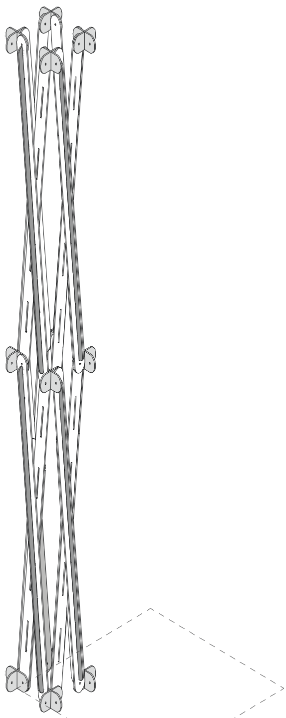
>> Connecting two modules// 01



>> Opened module



>> Half opened module

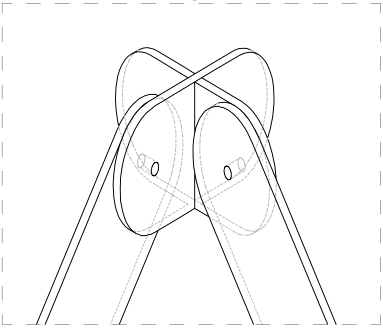


>> Closed module

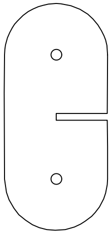
// nodes

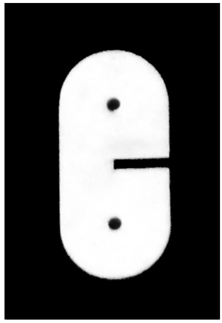
>> Type of connectors

>> Node A// two pieces

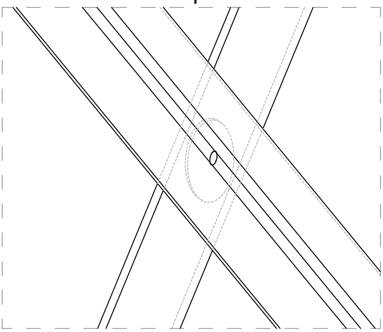


x 2

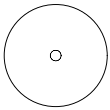


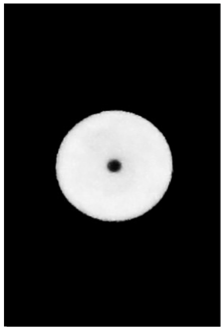


>> Node B// one piece

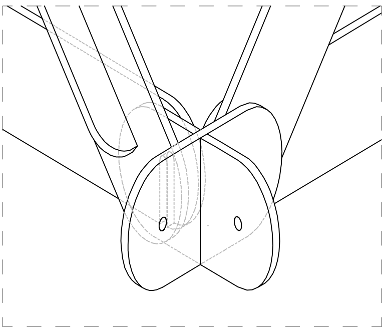


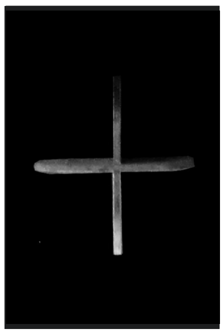
x 1





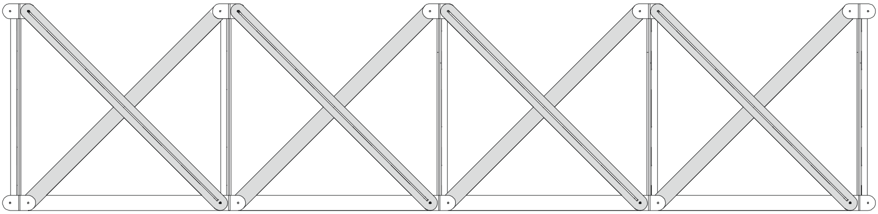
>> Node C// lower intersection



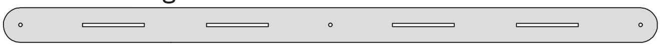


>> Type of bars

>> Pattern bars// connectors

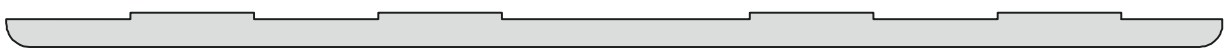


>> Bar A_Long bar for Module 01//

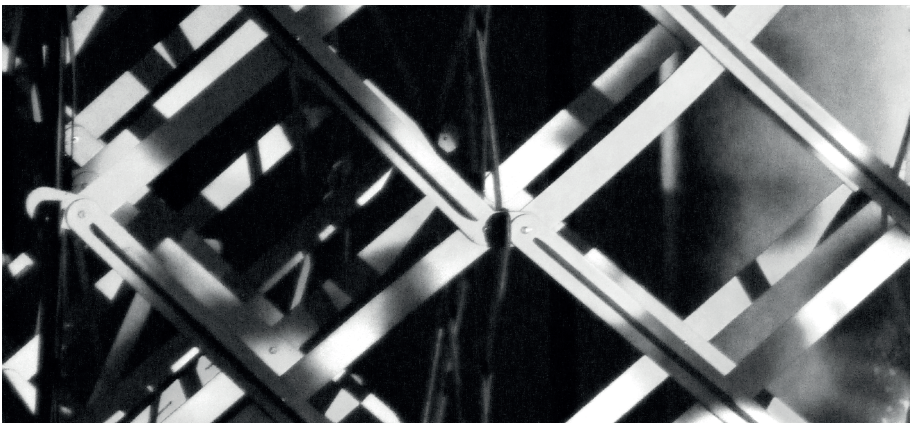


>> Bar B_Reinforcement for Module 01//

>> Bar C_Reinforcement for Bar A_Module 01//

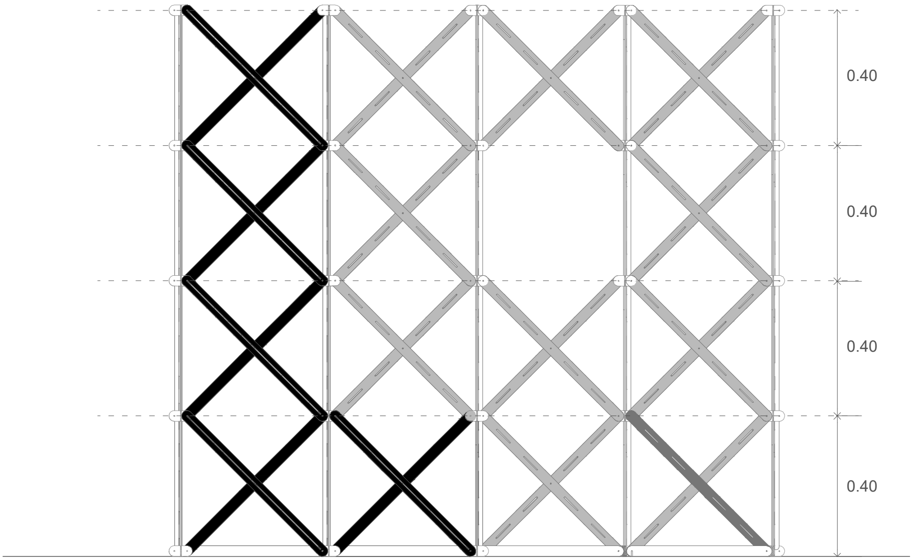


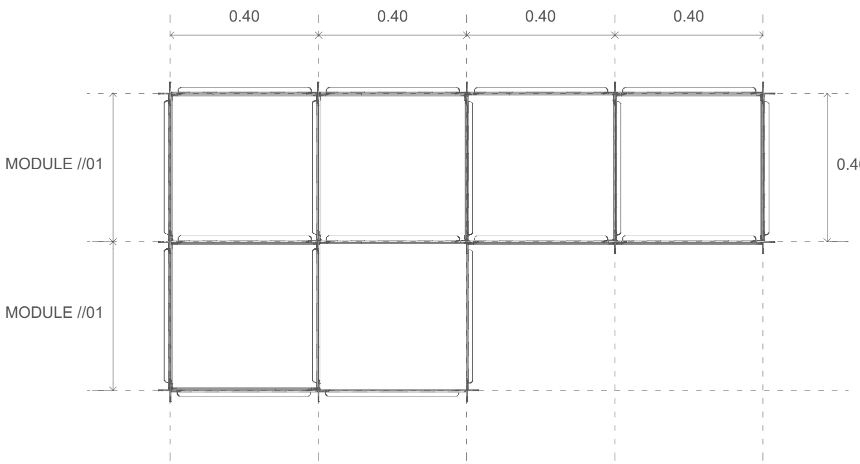
>> Detailed photo of the prototype

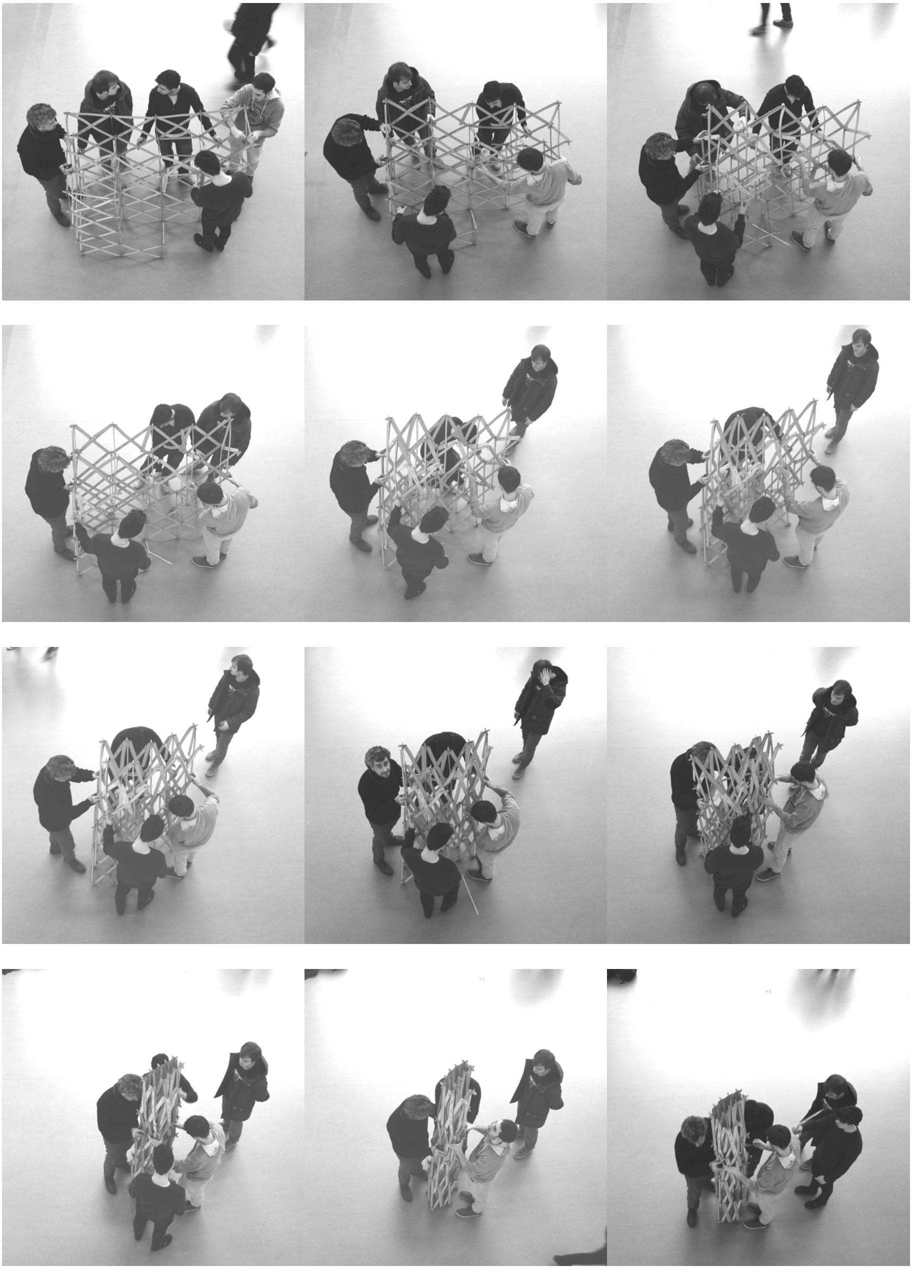


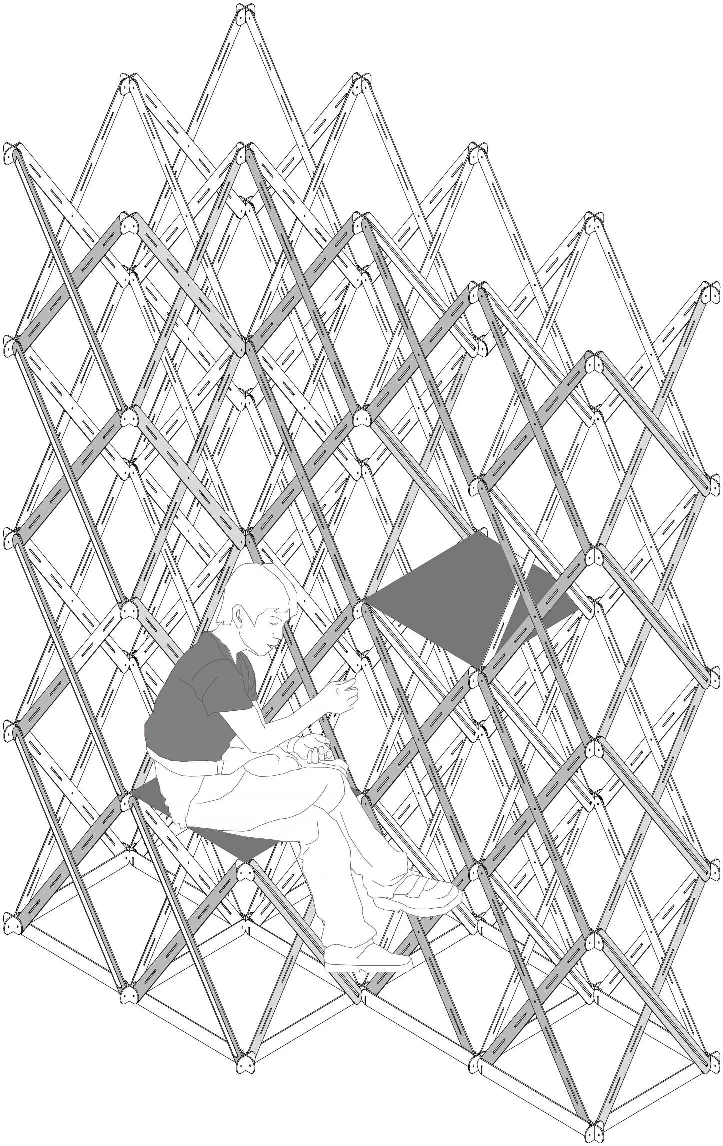
// plans

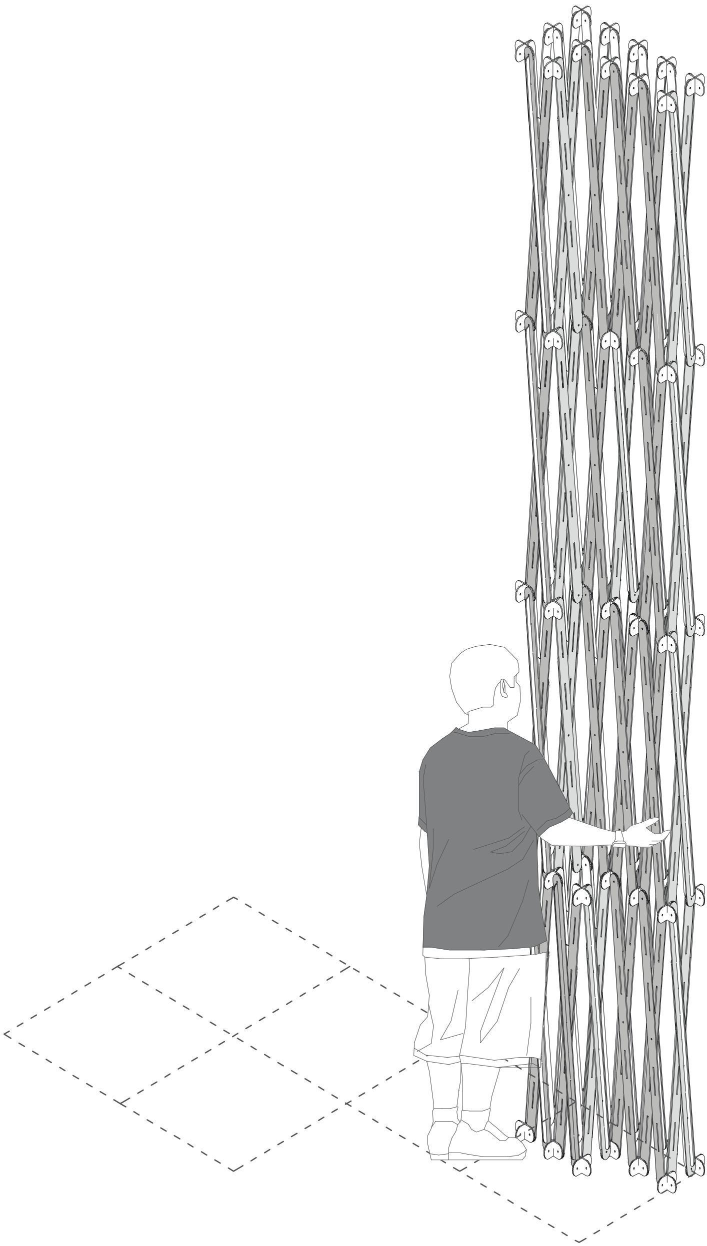
>> Elevation and floor plan







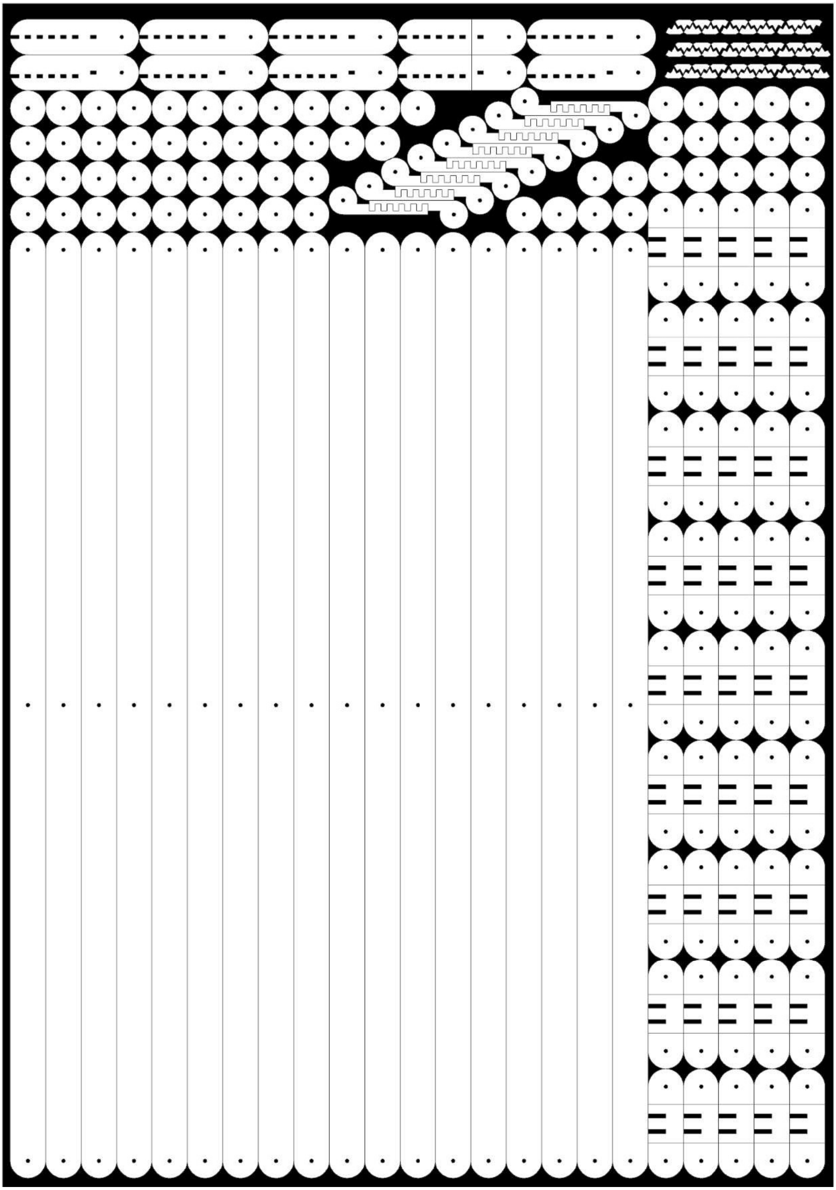


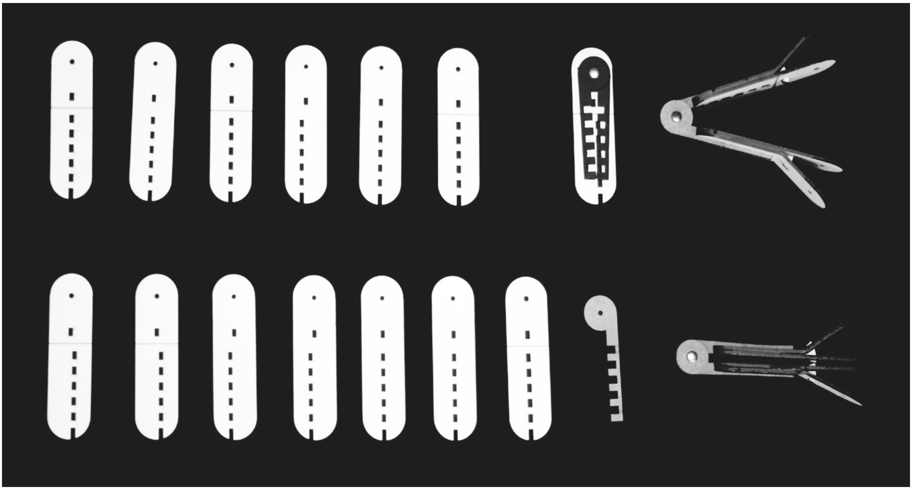


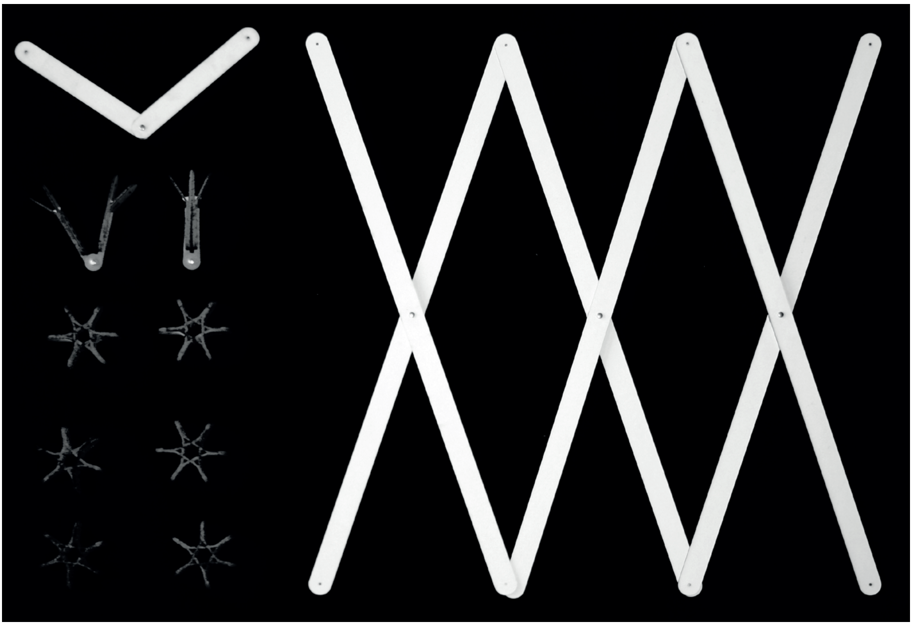
>>> Model / C

>>> Ángel Armando Arquero Ramírez
>>> Tomás Rosselló Barros
>>> David Masip Vilà
>>> Tan Phong Nguyen

Use>>>
The proposal is a hexagonal enclosed space which could be open for customizing different settings. Each side of the hexagon could move freely due to a linkage with the other sides. In this case three sides of the figure are shown but it could be possible to have three more to enclose the hexagonal space, a living unit. In the same way the artefact could be opened to configure a space divider screen to be placed in an interior space. Due to its multifunctionality it is important to design all sides. Having the prototype closed, as a hexagon, the sides create the limits of a habitat. If the artefact remains open it will be facing two different sides of a given interior space operating as furniture, locker or storage place.
Type>>>
The chosen module type is the so called Regular Triangular Prism, according to the definition made by Félix Escrig in his patent from 1984. In this case the figure consists of a prism with a triangular base and three vertical sides. A pair of scissors made of bars connected in the middle are placed on each side of the prism. That is the main module which allows for the addition of horizontal and vertical triangles, configuring a side of the hexagon. Each side of the hexagonal figure is joined at the other side within a special knot which lets them move freely. In the same way a general knot has been designed to connect the ends of six bars which allows them to fold and unfold freely.
Stability>>>
The triangle is the only figure which is non-deformable. By choosing a triangular base for the module a great stability can be achieved. Other strategies have been developed to gain more rigidity. The bar type B is a reinforcement of the whole system. It can be folded together within the prototype which enables all the movements necessary to fold and unfold. They are mainly located on the bottom of the prototype, where the loads are bigger and the artefact needs more resistance. The bar type B is half the length of the main bar, therefore two of them are needed to brace two knots.
Conclusions>>>
It is a very good solution using only one module variation, by using the triangle as a base high rigidity can be reached. On the other hand the prototype, due to the linkages between the hexagonal sides, provides many setting possibilities which enriches the architectural proposal. Strongly innovative are the knots used to joint all the parts of the system, particularly the ones designed to permit the different configurations as closed or open space.

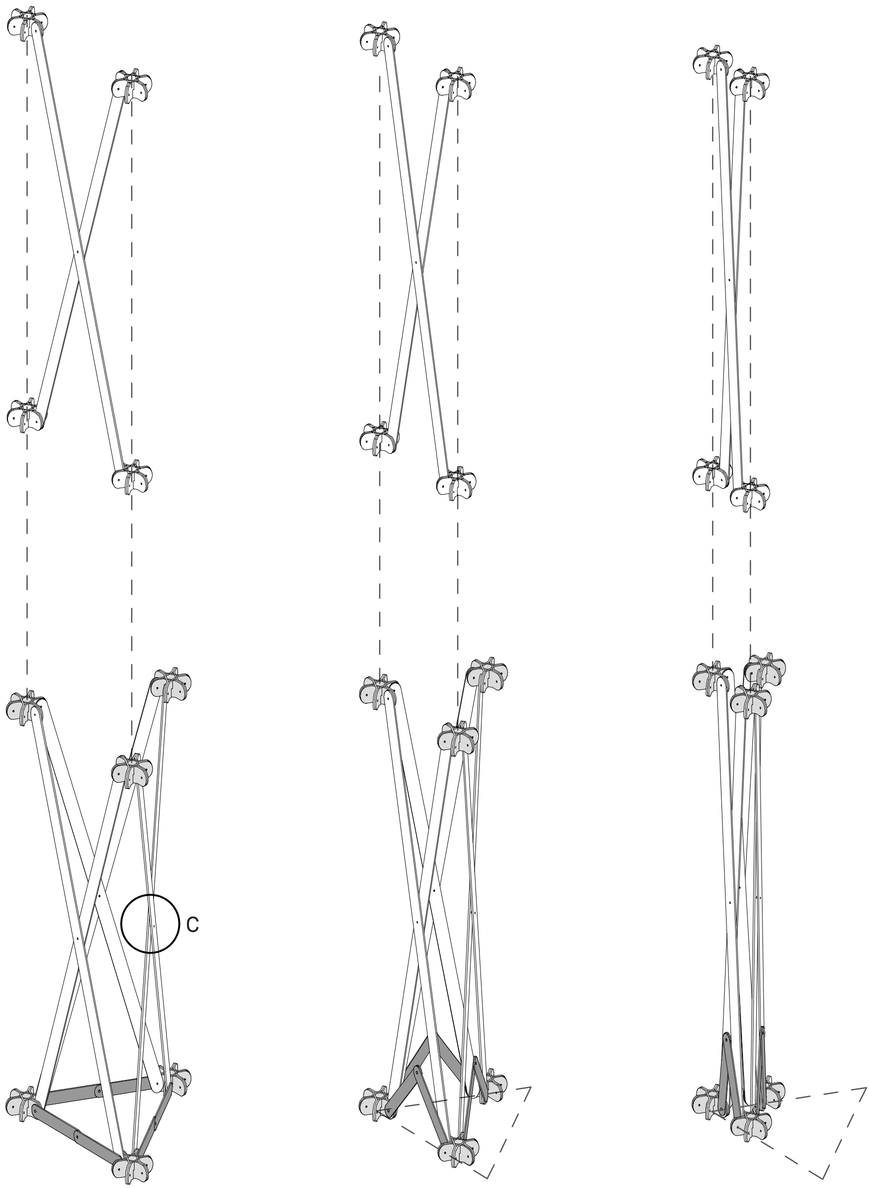






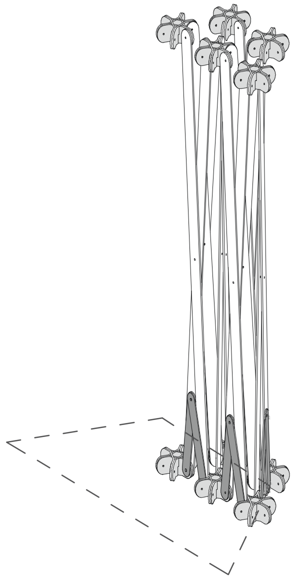
// module

>> Module// 01 of the structure

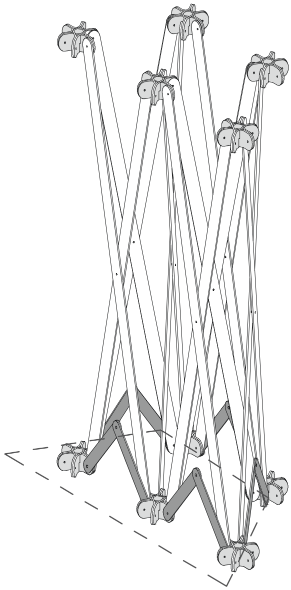


>> Opened module >> Half opened module >> Closed module

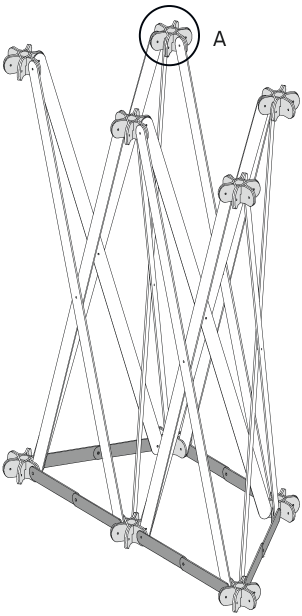
>> Connecting modules// 01



>> Closed module



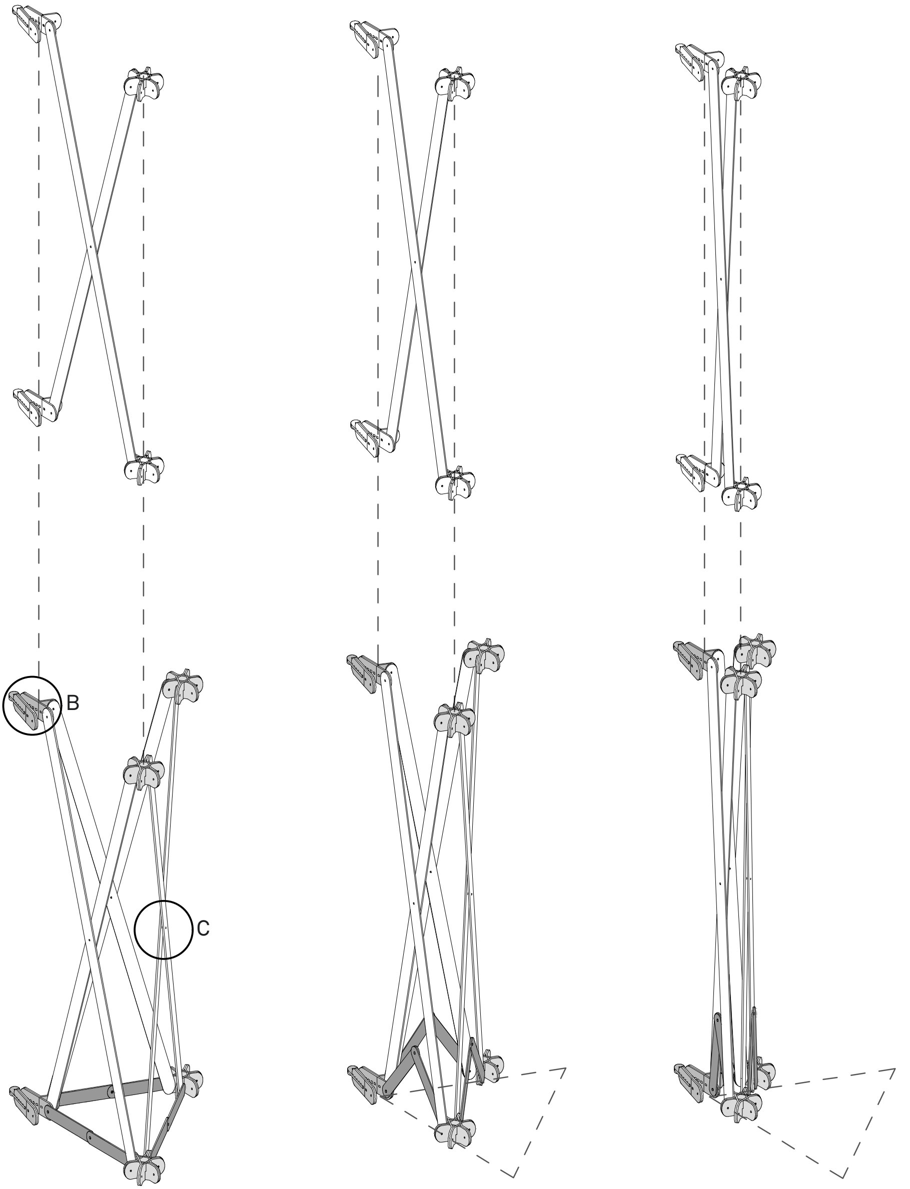
>> Half opened module



>> Opened module

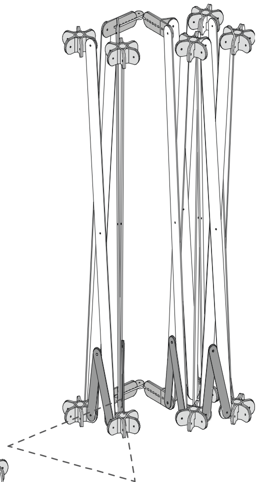
// module

>> Module// 02 of the structure

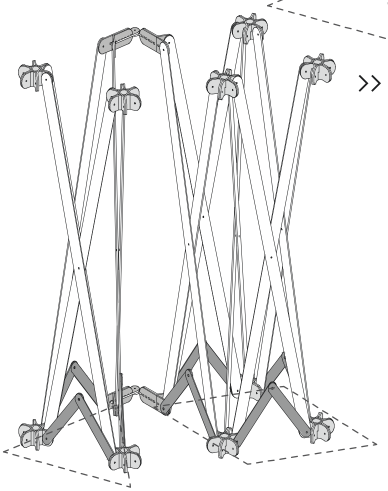


>> Opened module >> Half opend module >> Closed module

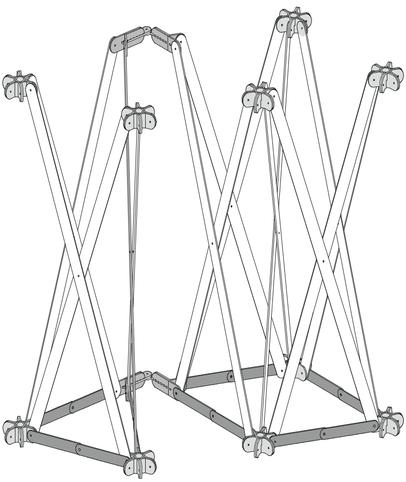
>> Connecting modules// 01// 02



>> Closed



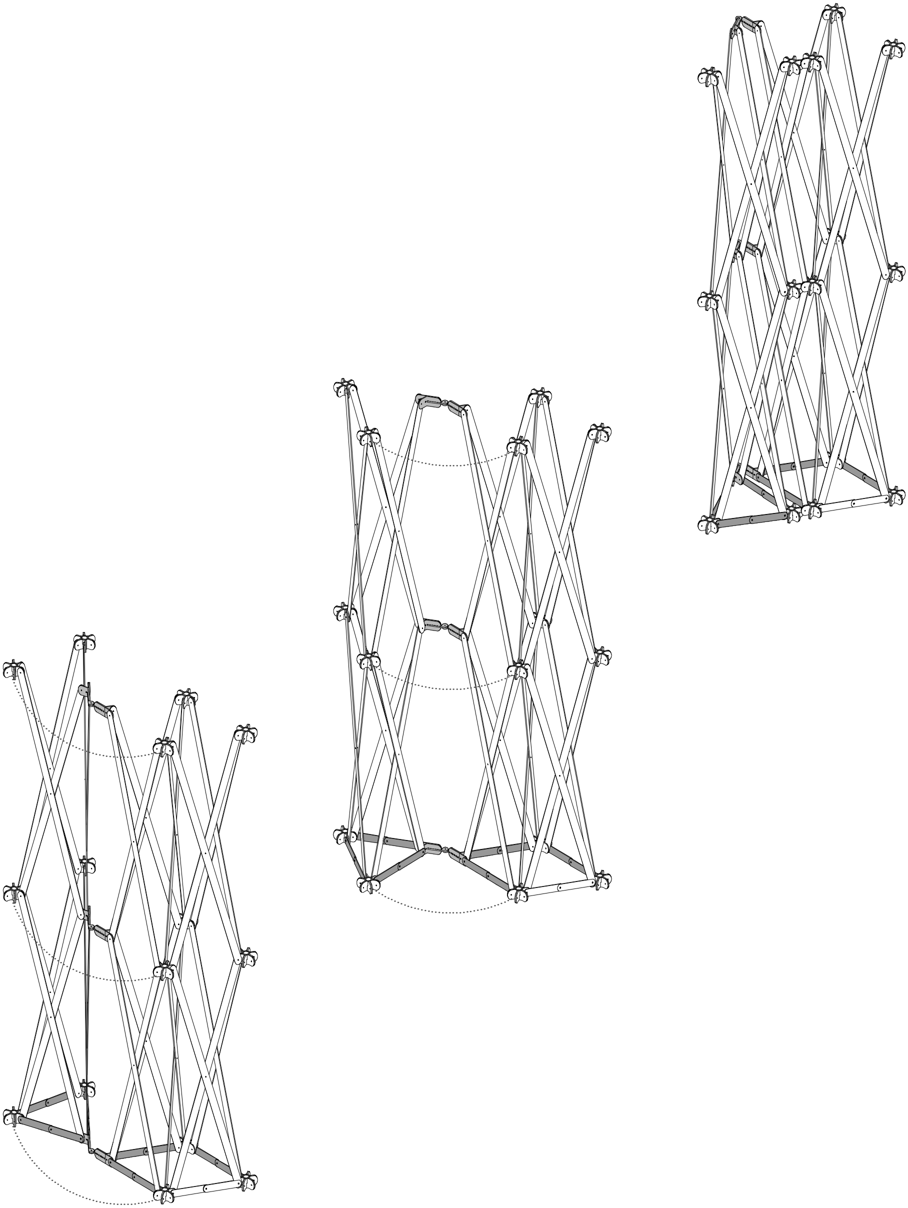
>> Half opened

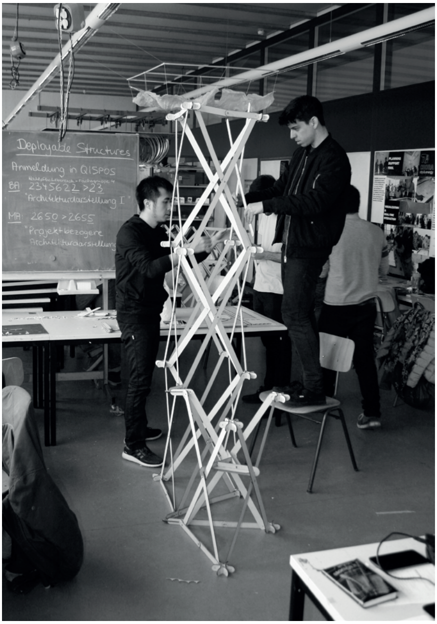


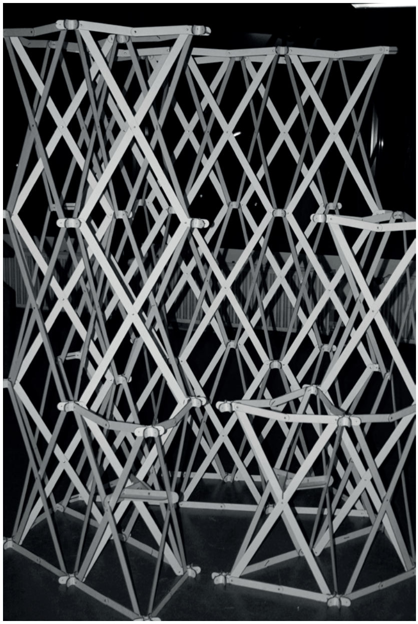
>> Opened

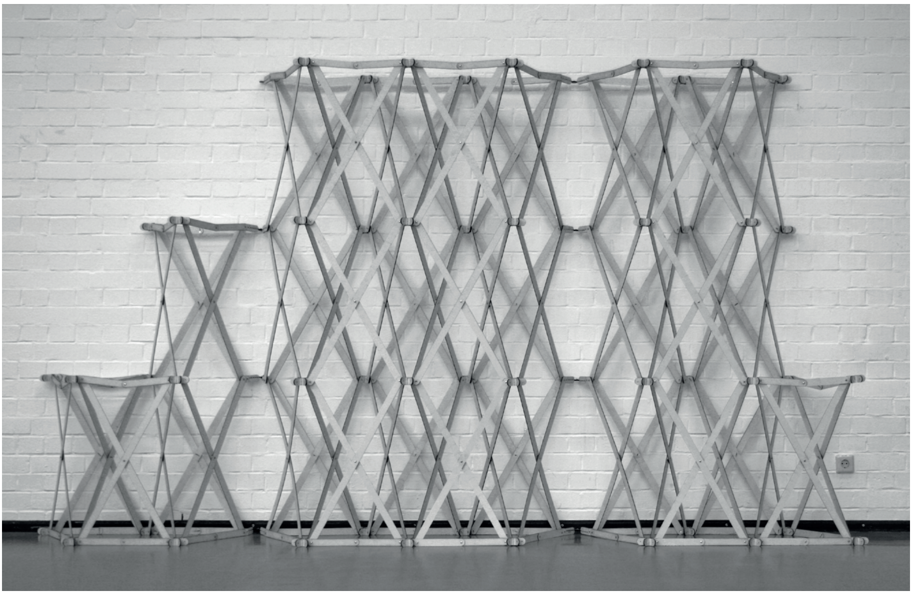
// assembly

>> Module// 02 movement




Deployable Structures
Anmeldung in QISPOS
BA 2345622 >23
"Architekturdarstellung I"
MA 2650 > 2655
"Projektbezogene
Architekturdarstellung

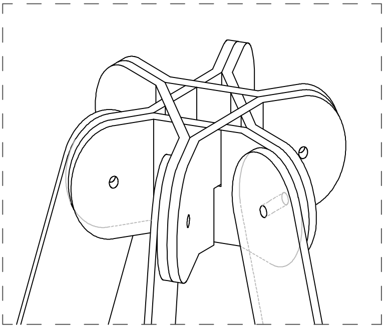




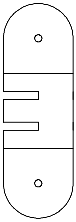
// nodes

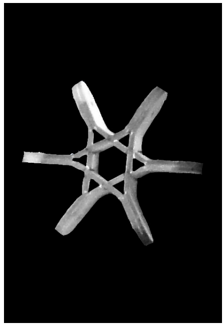
>> Type of connectors

>> Node A// for Module 01// Module 02//

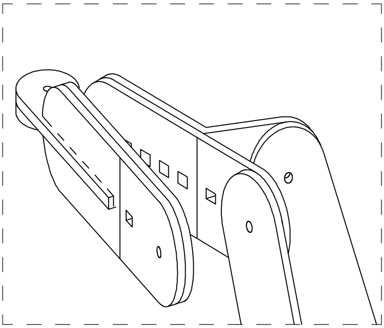


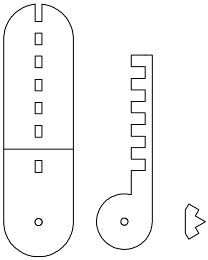
x 6



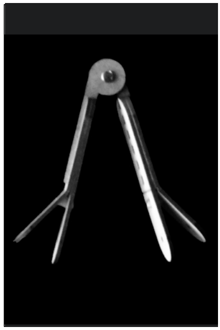


>> Node B// for Module 02//

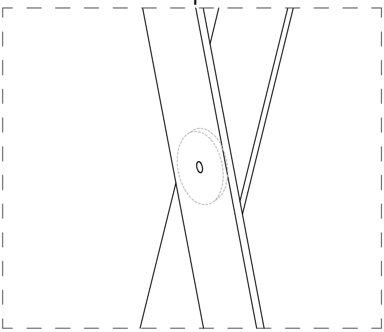


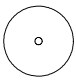


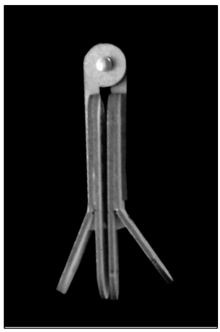
x 4 x 2 x 1



>> Node C// one piece

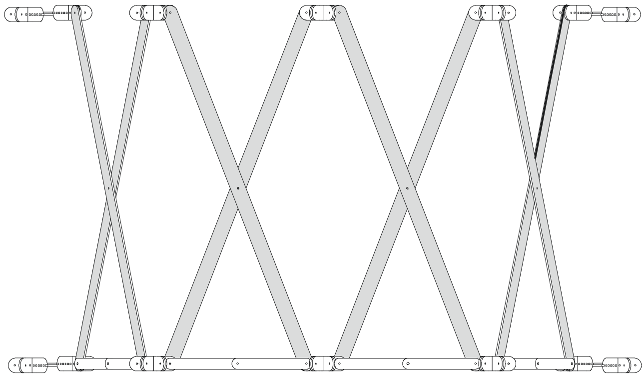




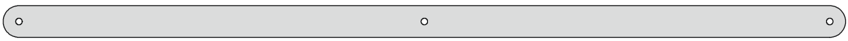


>> Type of bars

>> Pattern bars// connectors

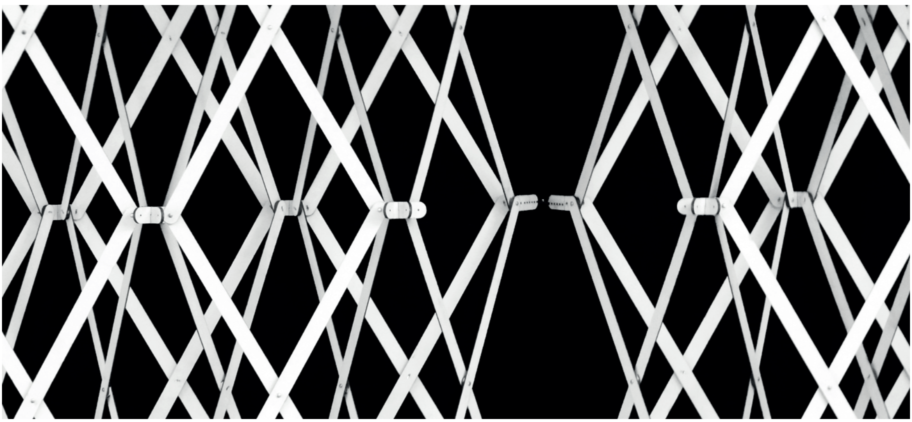


>> Bar A_Long bar for Module 01// Module 02//



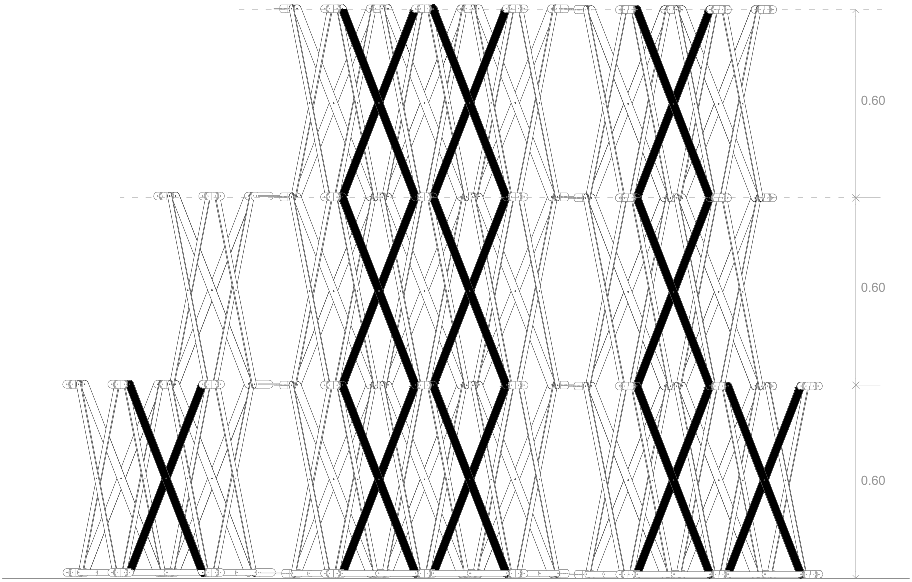
>> Bar B_Reinforcement for Module 01// bar for Module 01// Module 02//

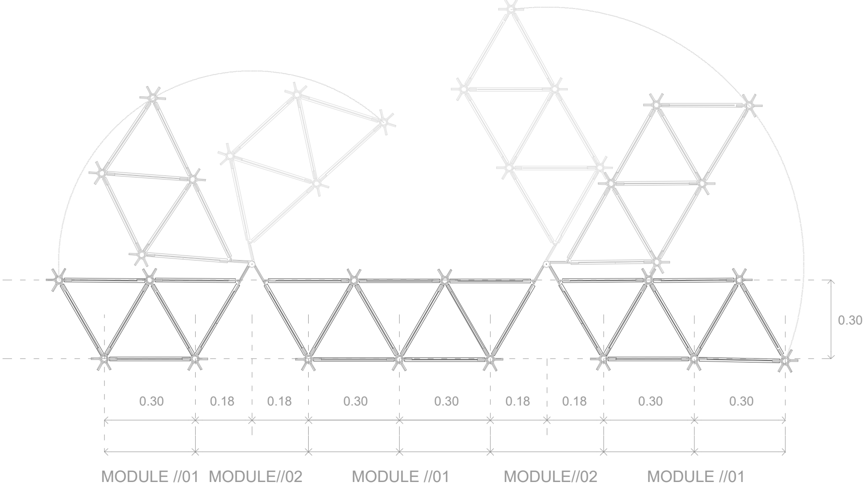
>> Detailed photo of the prototype

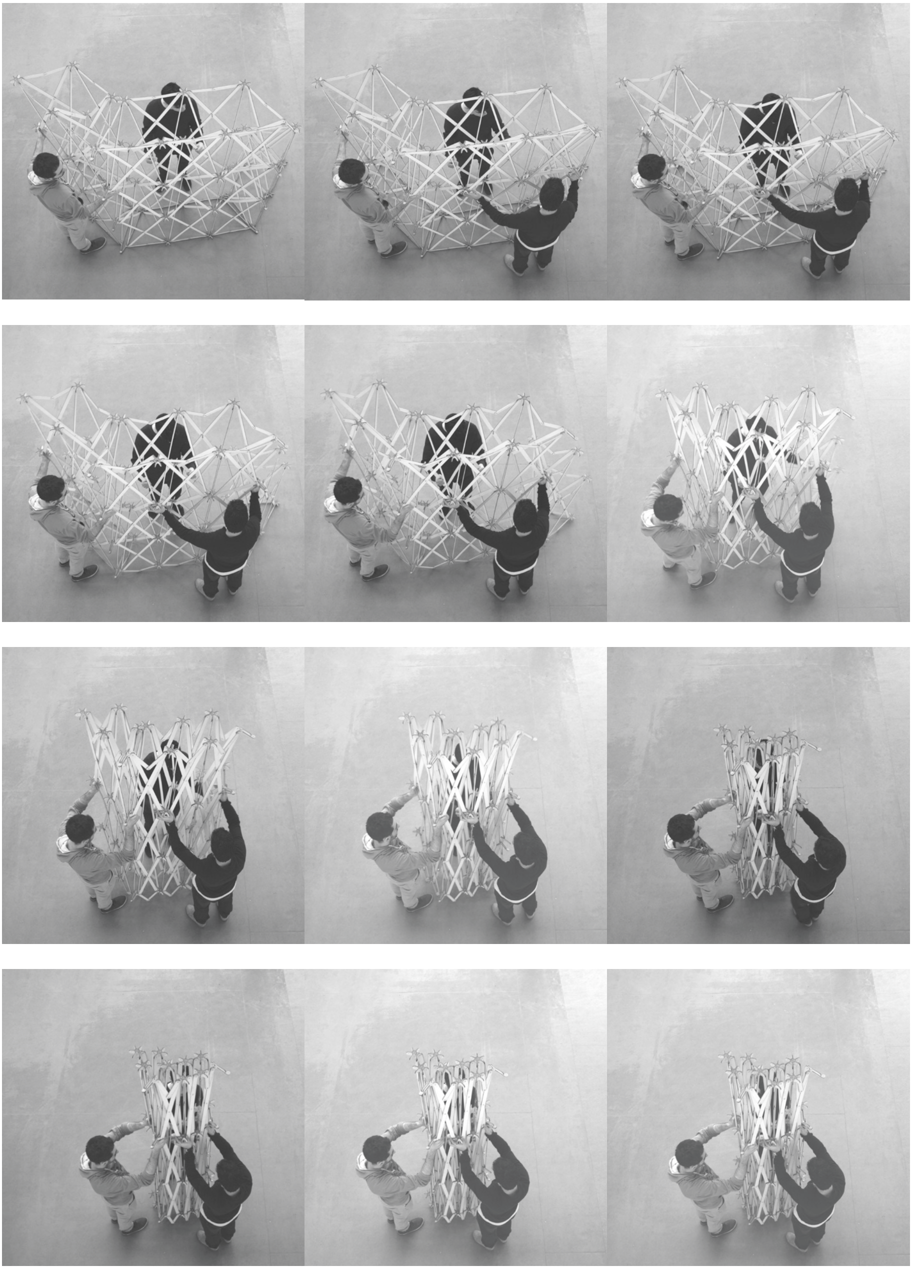


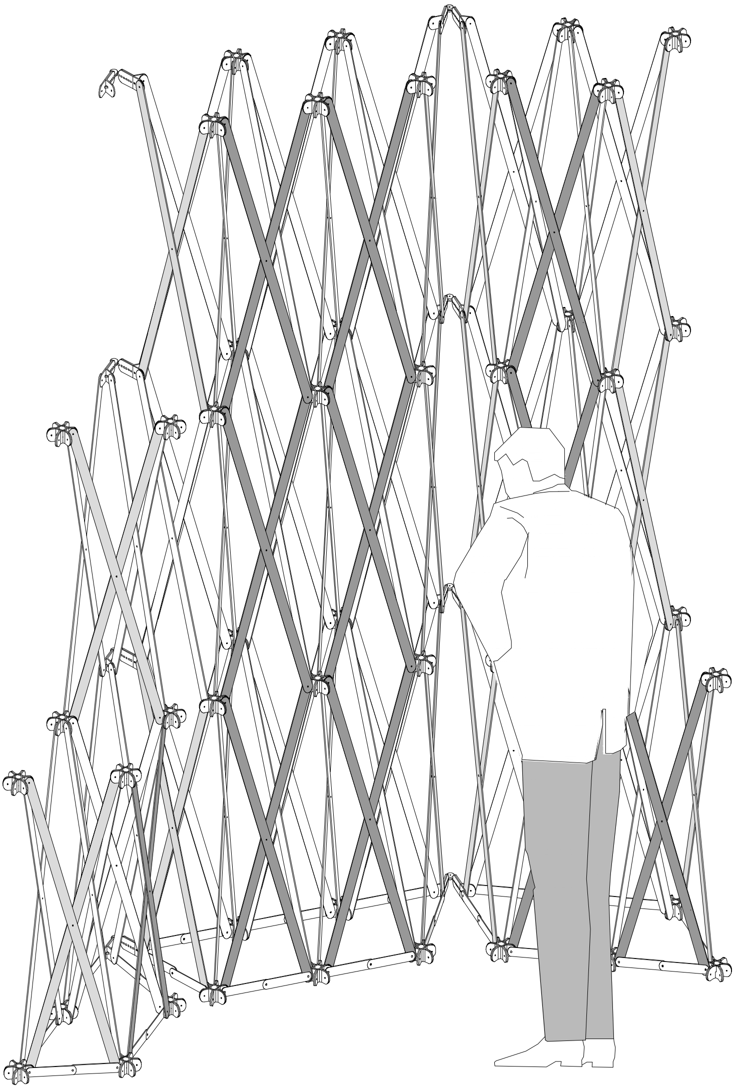
// plans

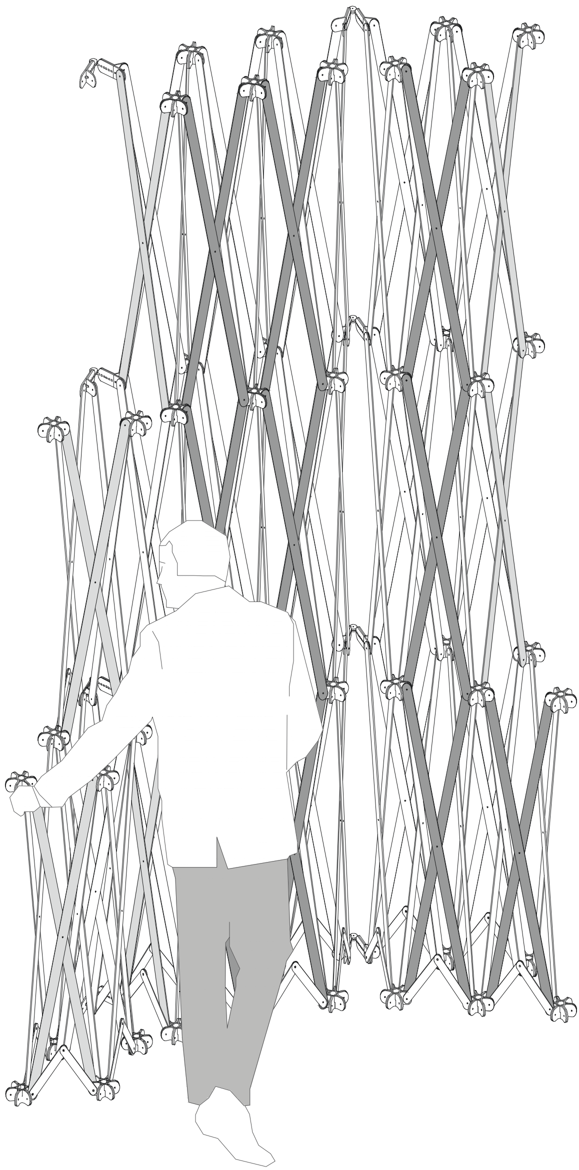
>> Elevation and floor plan





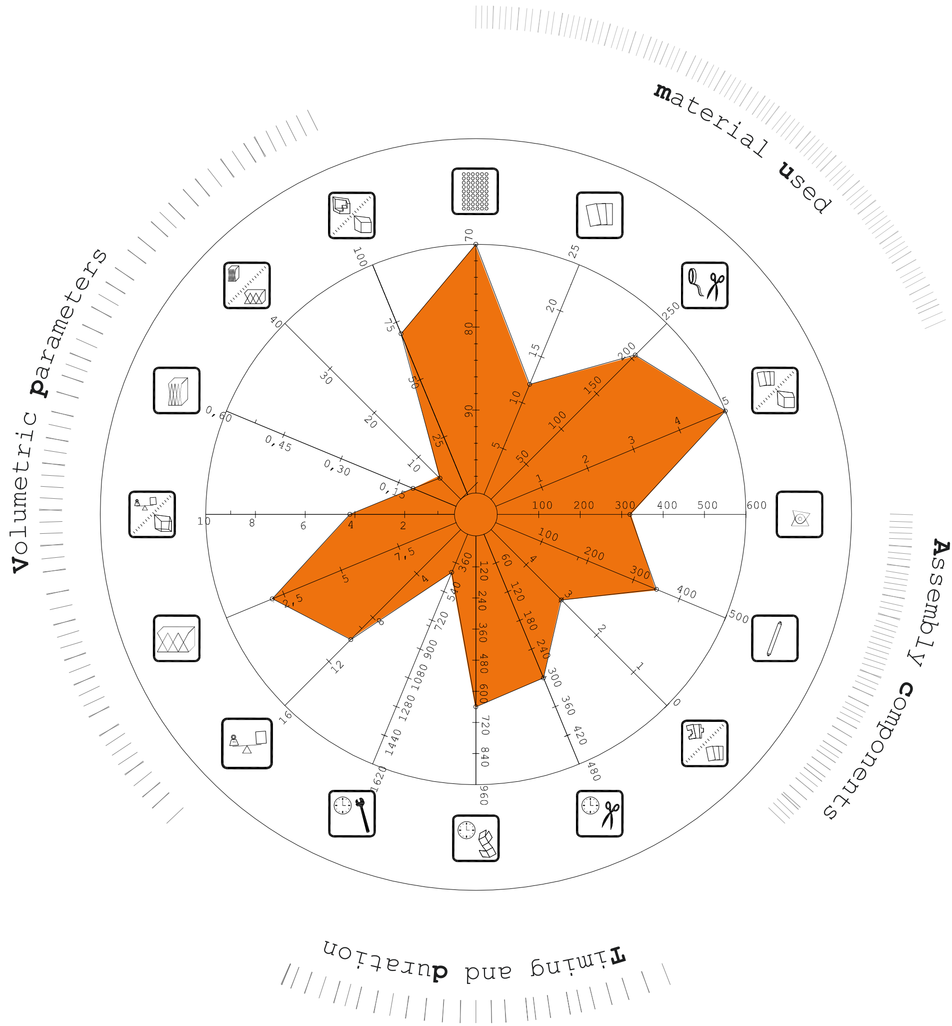




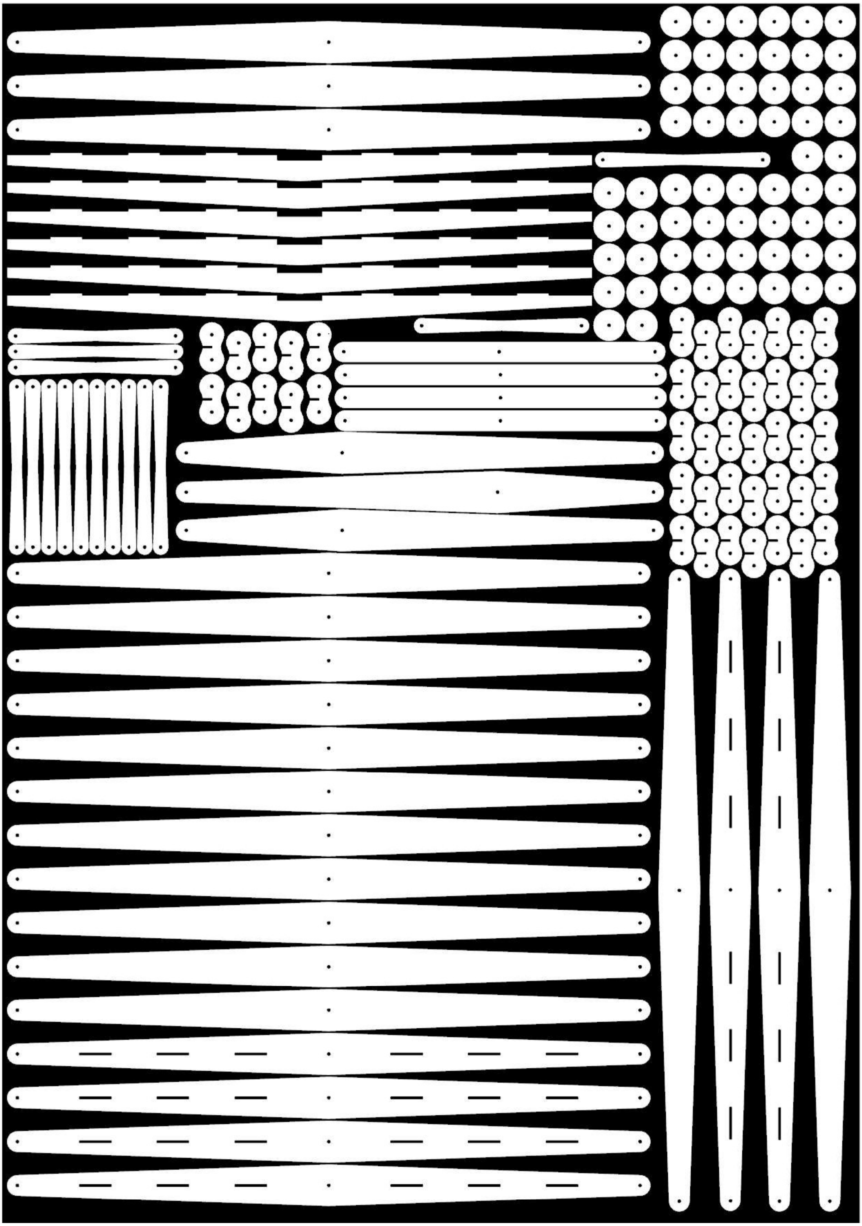


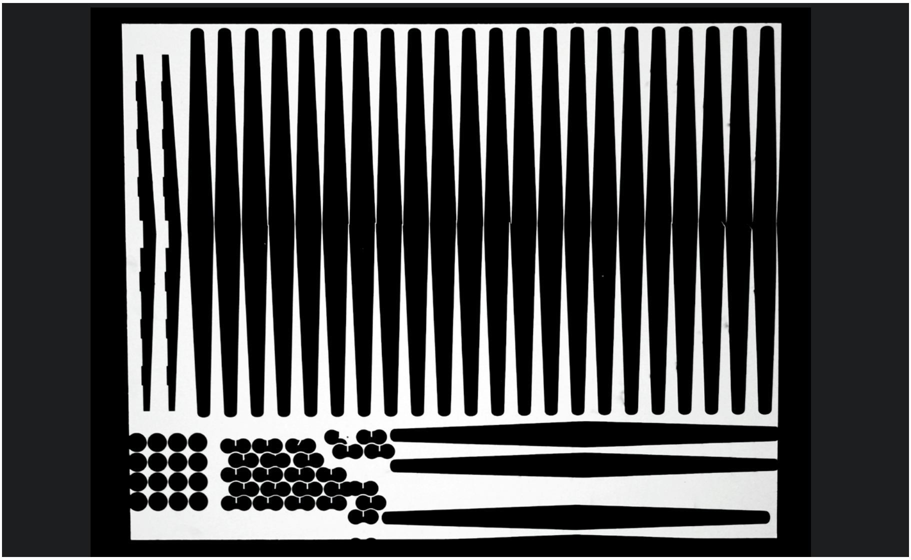
>>> Model / D

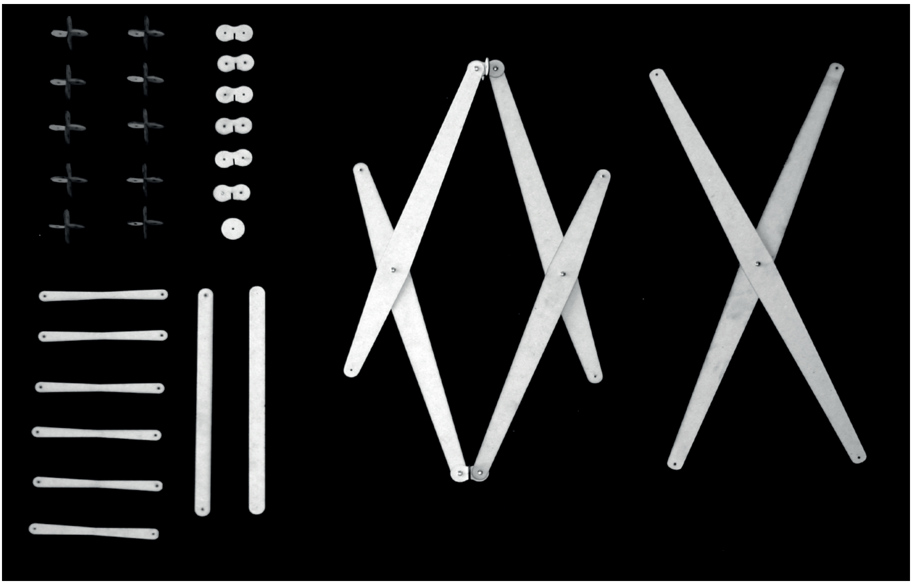
>>> Clara Almanza Andreu
>>> Miguel Delgado Rodríguez
>>> Laura Díaz Vizoso



Use>>>
A green house has been planned. Therefore the main function is to hold several pots and climbing plants which will fill the external vertical area. Another function to be realized inside the artefact is a place to sit and meditate quietly. In this way the module dimension has to provide all those different settings; it has to be able to become a chair to sit on, a place to store plant pots in and it has to serve as support for climbing plants. As an interior green house it can be placed in any given interior space and due to its properties it could be unfolded with all its components and relocated to another place which could support the plants development throughout all seasons of the year.
Type>>>
The chosen module is the so-called Regular Quadrangular Prism which consists of two bars connected in the middle on each side of the prism as mentioned above. Though in this case several variations have been done which enriches the architectural proposal. In the first place there are three different bar dimensions; a long bar (Bar A), a middle bar (Bar C) and a short bar (Bar D) which could be combined to build a pair of scissors. They can be combined to achieve different density variations following geometrical rules as it is shown in the detail `lattice deployable structure´ which will be filled with plants reaching the desired pattern of voids and solids.
Stability>>>
The chosen module, Regular Quadrangular Prism, is not stable itself and it is necessary to brace it once it has been unfolded to give the prototype enough rigidity. In the same way different strategies have been developed. In the first place, the bar shape has been modified and the bars are wider in the middle than at the ends which gives the prototype a more inertial moment, and therefore more rigidity. A special bar (Bar B) has been designed. This bar has openings to place stiffening elements in the perpendicular axe. At the lower part of the prototype two short bars joined at their ends have been located to block it in his unfolded position.
Conclusions>>>
A very interesting architectural proposal has been developed due to the diversity achieved by the different bar dimensions and the special design of the bar's shape. In this way the functional requirements mentioned above have been met. Furthermore the module dimensions allow the user to sit in a quite and peaceful environment and read a book inside the green container. Due to the different patterns gained with different bar dimensions, the plants could grow filling the space with different superficial intensity and density which are, of course, architectural properties.

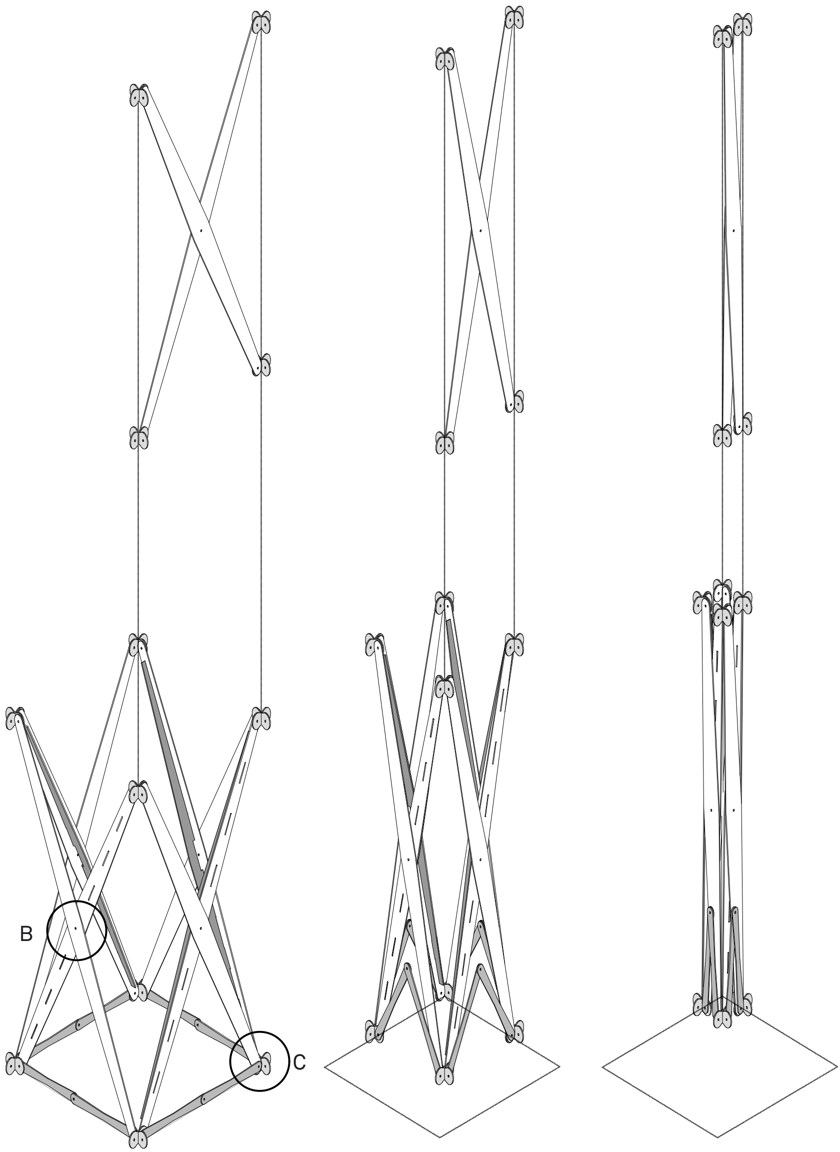






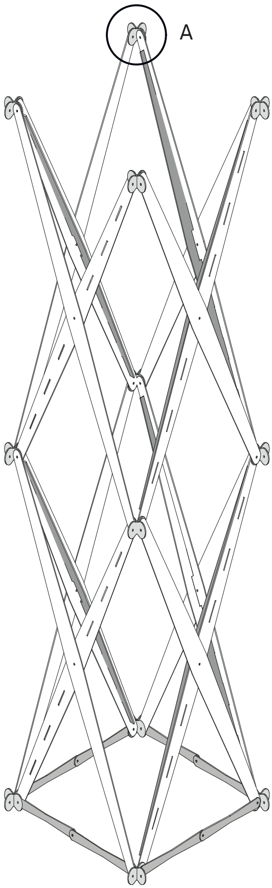
// module

>> Module// 01 of the structure

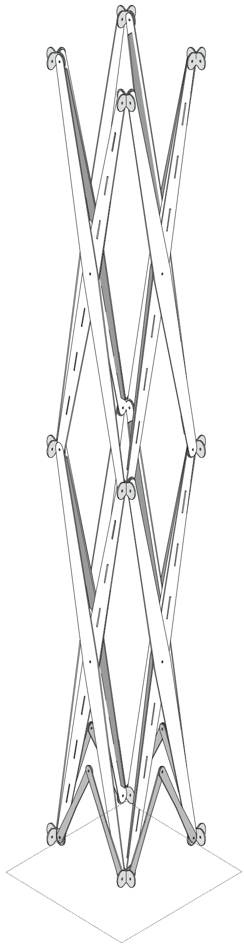


>> Opened module >> Half opened module >> Closed module

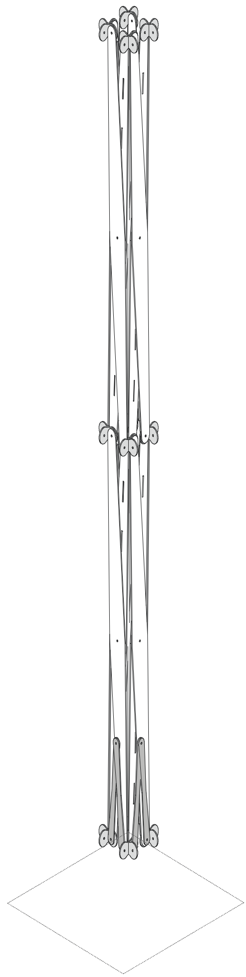
>> Connecting two modules// 01



>> Opened module



>> Half opened module

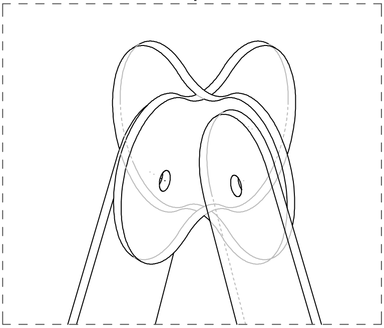
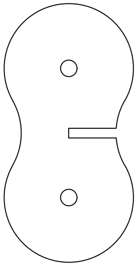
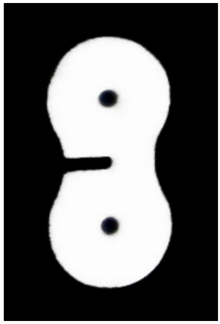


>> Closed module

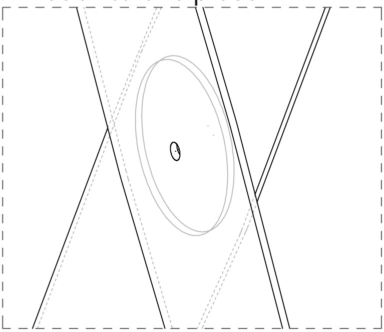
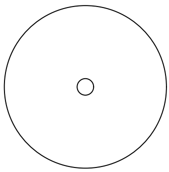
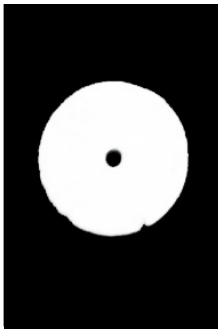
// nodes

>> Type of connectors

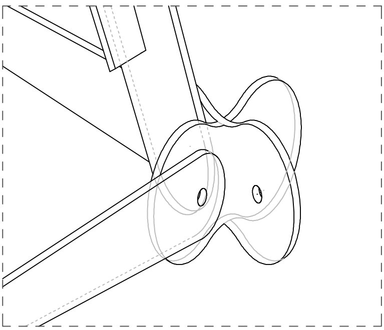
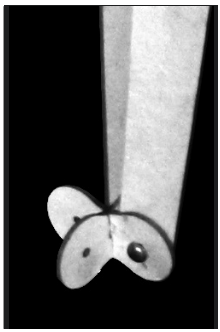
>> Node A// two pieces

>> Node B// one piece

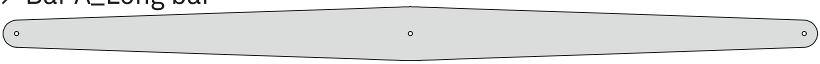




>> Node C// lower intersection

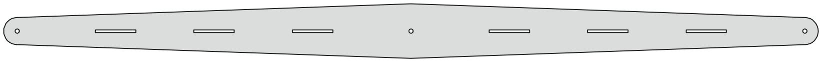



>> Type of bars

>> Bar A_Long bar

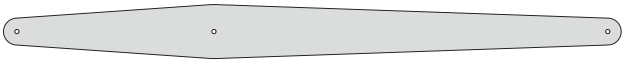


>> Bar B_Long bar with reinforcement



>> Reinforcement 01 for Bar B

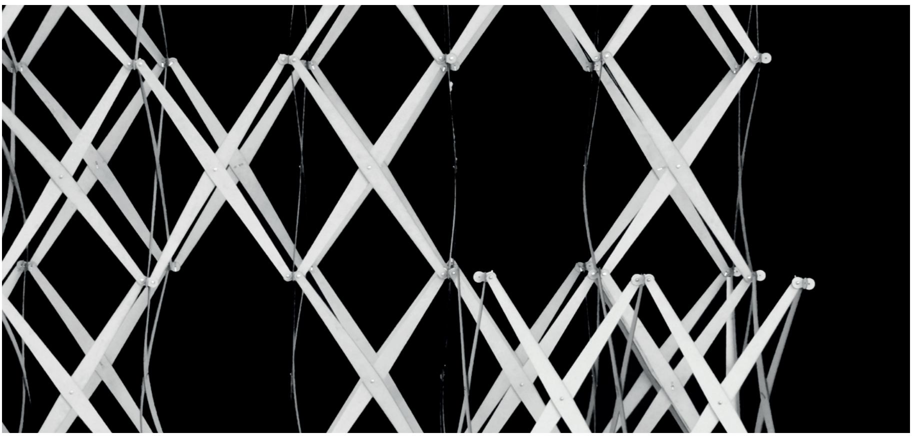
>> Bar C_Middle bar



>> Bar D_Short bar

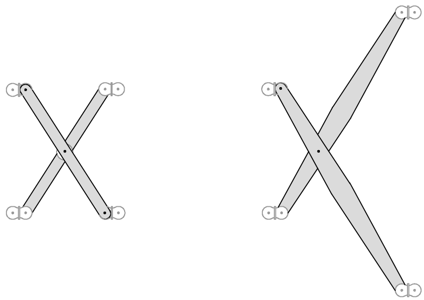
>> Reinforcement 02

>> Detailed photo of the prototype

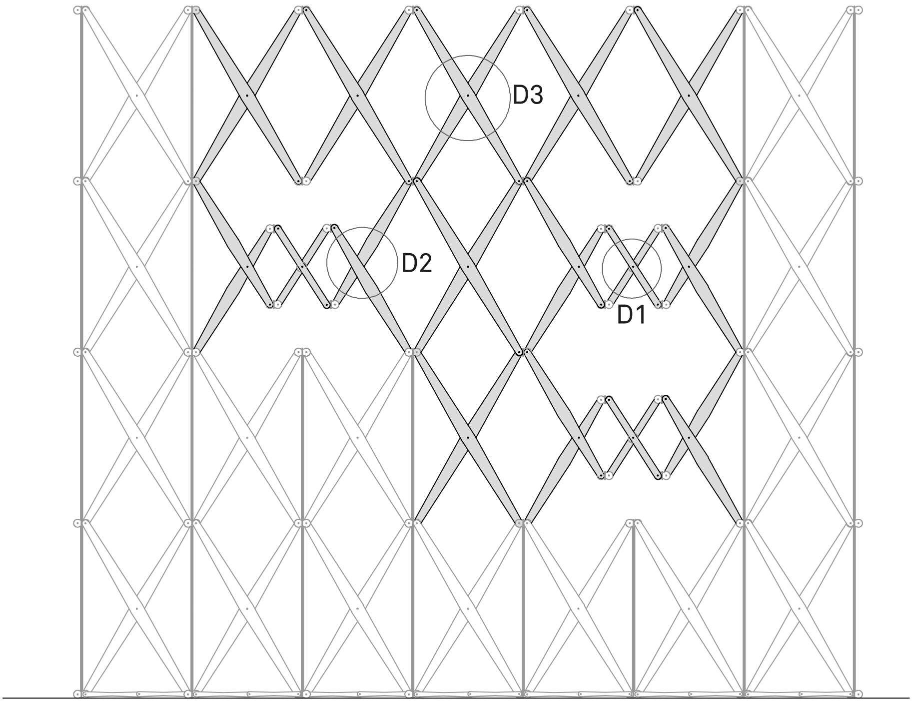


// lattice

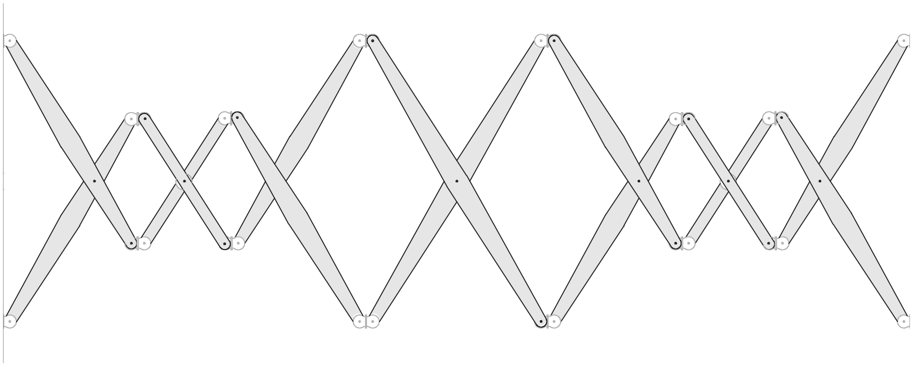
>> Join Type 1_D1   >> Join Type 2_D2   >>Join Type 3_D3



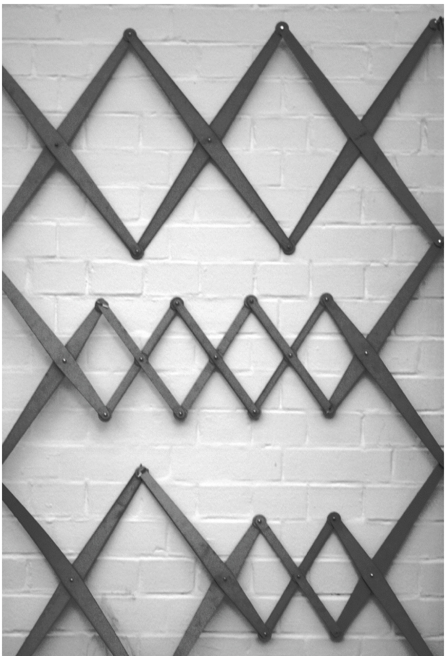
>> One plane lattice



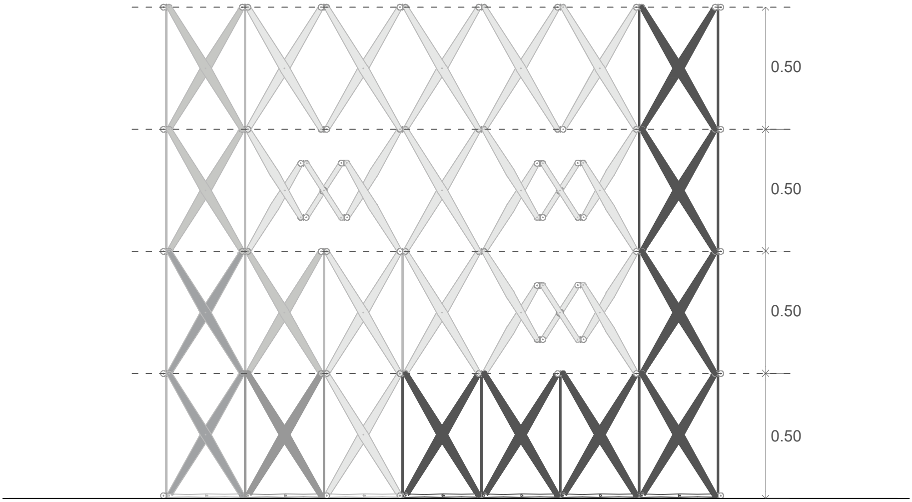
>> Detail lattice deployable structure

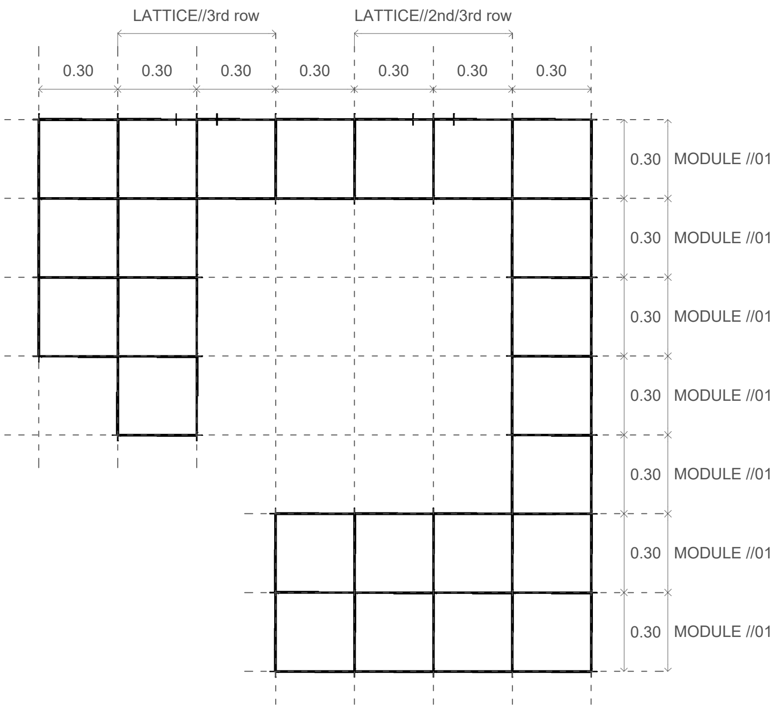


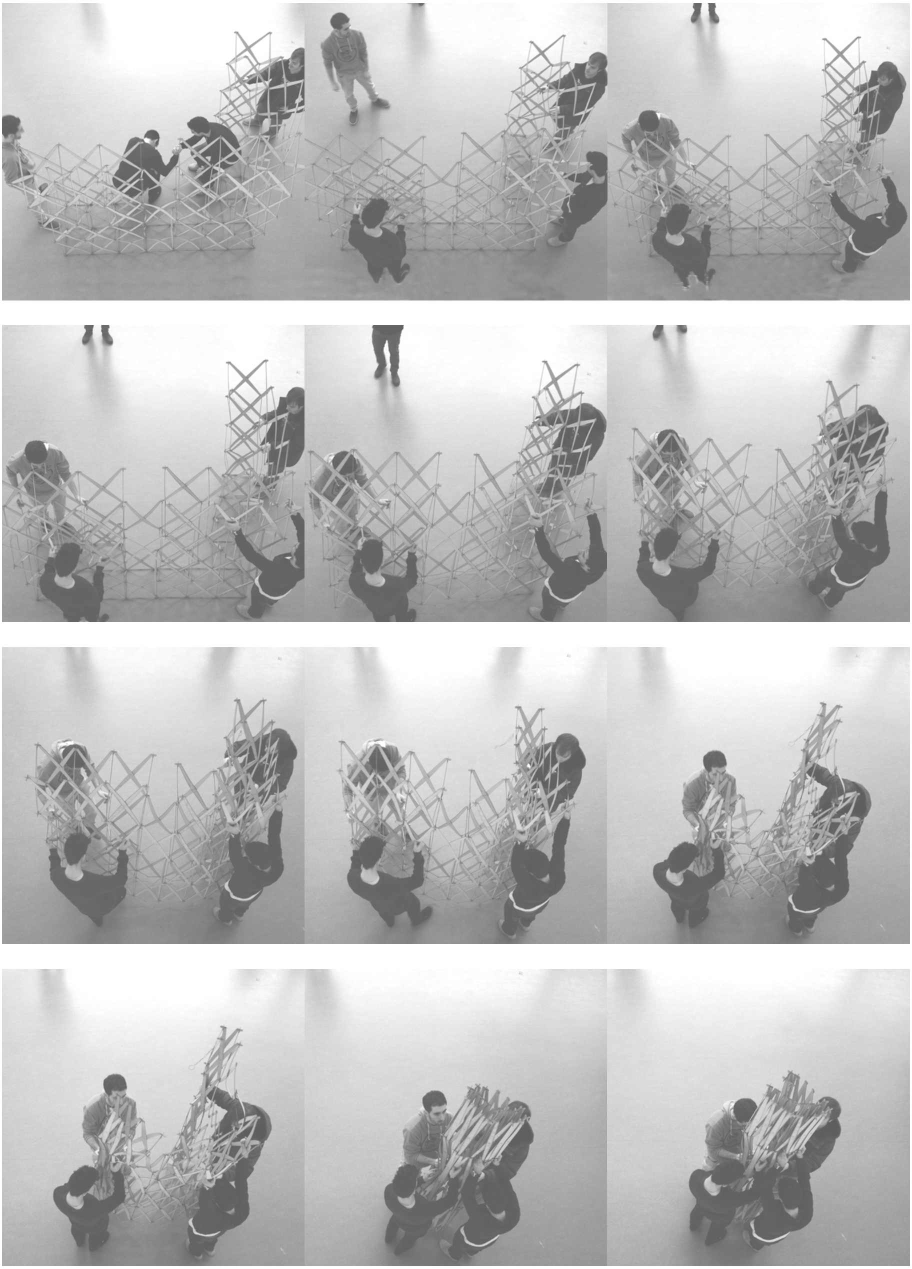
>> Detailed photos of the prototype

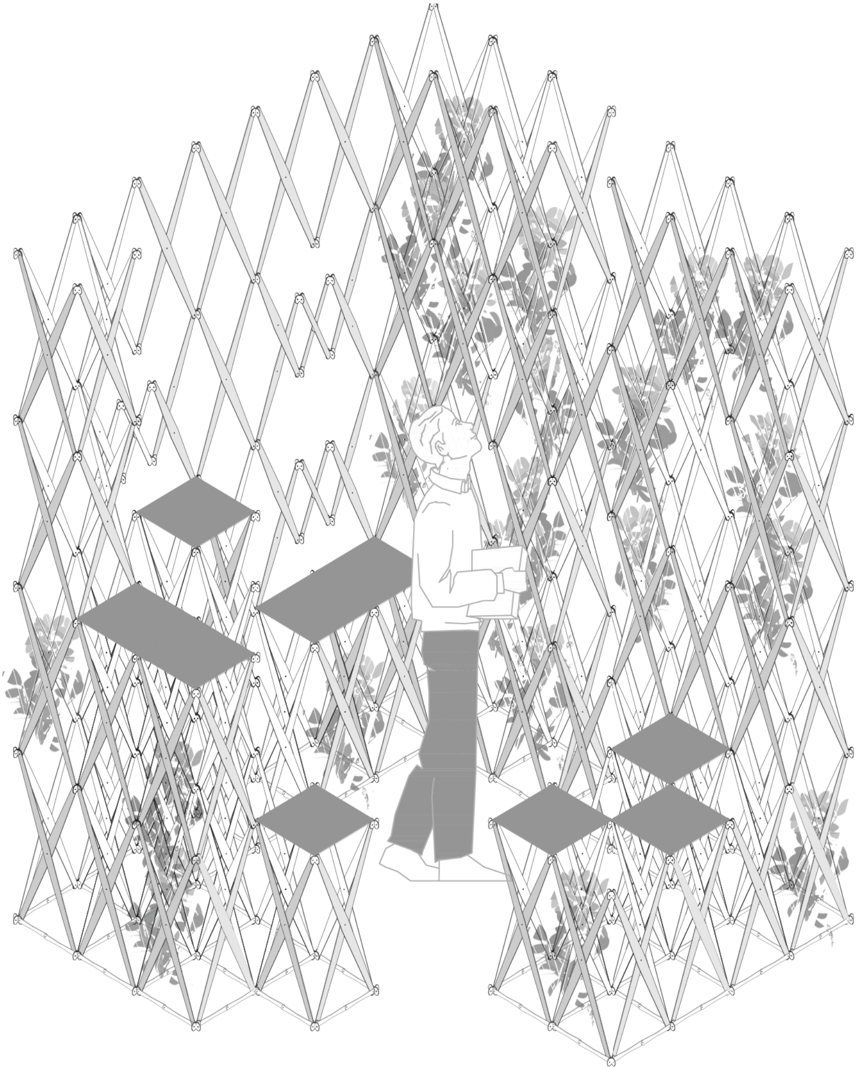


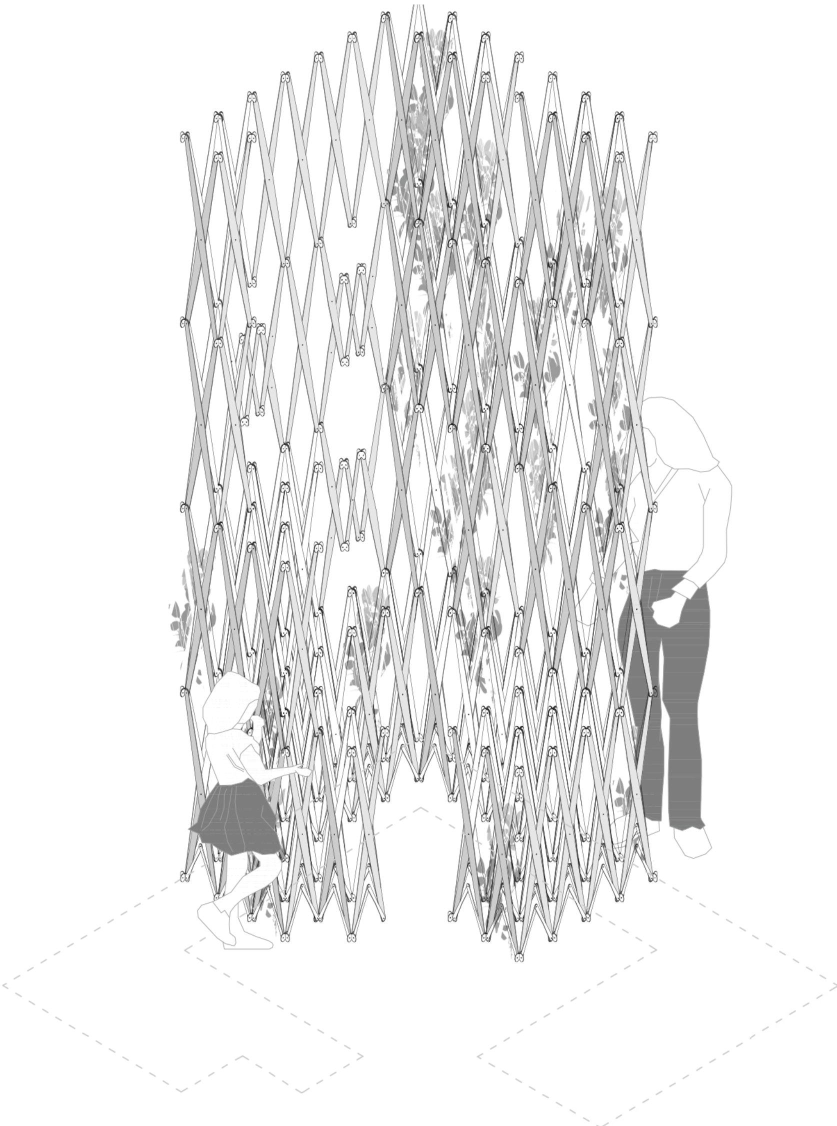
>> Elevation and floor plan

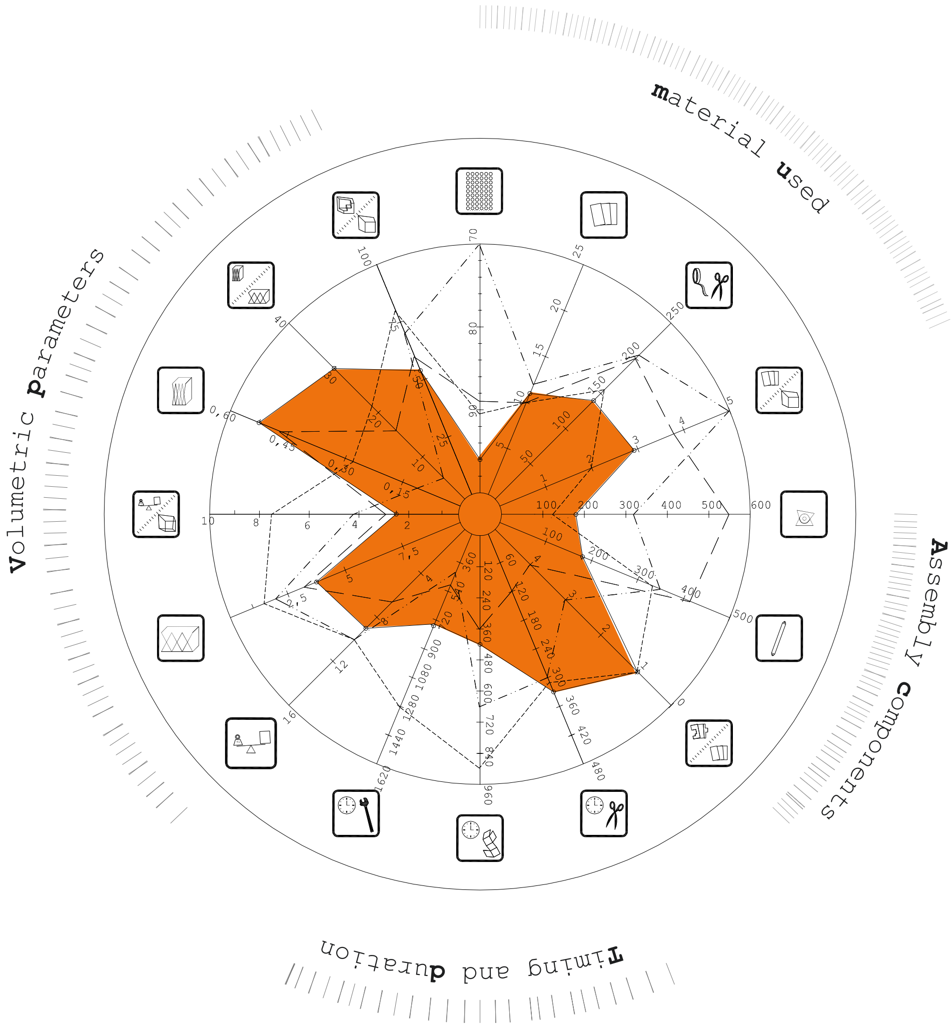


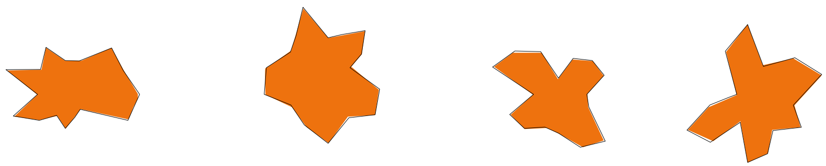












Group A 34.60 u^2 Group B 45.70 u^2 Group C 33.60 u^2 Group D 41.48 u^2

Top: efficiency diagrams superimposed.
Bottom: from left to right, efficiency diagrams of group A, B, C and D.

CONCLUSION

As seen in the previous pages, four different proposals were developed throughout this course by our students. Each prototype progresses or stands out in relation to different aspects that relate to efficiency, which were defined previously. In this way we characterized the diagrams that introduce and accompany each proposal according to the aforementioned definition. These multidimensional diagrams, which follow the efficiency diagrams used by CoLab Madrid since 2009, allow us to register in a quantitative way the degree of efficiency of each proposal once it has been built, as well as to evaluate and compare them.

Group C has obtained the best global rating, its diagram has a smaller area than the rest (33.60 u^2). This is because this group's prototype has been built using a similar amount of material than the others, but its geometrical and volumetrical properties allow it to fold and unfold in a more efficent way.

On the other hand, the prototype built by Group B shows the diagram with the largest area (45.70 u^2). This is mainly due to the fact that once folded, the prototype occupies a larger volume and that its manufacturing process is also slower. This may seem paradoxical, since this prototype contains fewer rods and knots. It confirms that there is not necessarily a direct relationship between a smaller number of elements (knots, rods and modules) and a better efficiency. In this case the key is that the way in which the rods were been built required more material, which has penalized too much the overall diagram.

This reasoning agrees with what is observed in Group A's diagram, where the assembly components' values are at a maximum, however the volumetric parameters of this prototype are significantly reduced. This implies that prototype A is more efficient than prototype B. The efficiency degree of the first one (34.60 u^2) is closer to the efficiency degree of prototype C.

Group D's proposal shows an efficiency diagram that ranges to 41,48 u^2 . Its prototype gets very good volumetric parameter values, as bars and knots have been redesigned in order to get a smaller volume once the structure is folded. Nevertheless, this porposal's global efficiency is reduced because in general terms it consumes more material.

These conclusions can be somewhat arbitraty, since they depend on previously chosen parameters and on how the different axes have been graduated, but nevertheless they show a willingness to quantitatively evaluate a creactive process.

Imprint

CoLab
Collaborative Design Laboratory

TU Berlin
Fakultät VI Planen Bauen Umwelt
Institut für Architektur
Sekretariat A28, Raum A812
Straße des 17. Juni 152
10623 Berlin

Telefon: +49 (0) 30 314 72730
info@colab.tu-berlin.de
www.colab.tu-berlin.de

Universitätsverlag der TU Berlin, 2018
http://verlag.tu-berlin.de
Fasanenstraße 88
10623 Berlin

Telefon: +49 (0) 30 314 76131
publikationen@ub.tu-berlin.de

Print: SCD StockCeroDayton

ISBN 978-3-7983-2974-4 (print)
ISBN 978-3-7983-2975-1 (online)

ISSN 2568-2865 (print)
ISSN 2568-2873 (online)

Published online on the institutional Repository of the
Technische Universität Berlin:
DOI 10.14279/depositonce-6631
http://dx.doi.org/10.14279/depositonce-6631

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data are available on the Internet at http://dnb.dnb.de.

www.colab.tu-berlin.de

Universitätsverlag der TU Berlin
ISBN 978-3-7983-2974-4 (print)
ISBN 978-3-7983-2975-1 (online)