HYPERBODY **MSc2**

THE REPORT

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GENERAL OBJECTIVES

- CREATING A DESIGN THAT FOLLOWS THE FLOW OF THE **HUMAN MOVEMENT** AND REFERENCES **HUMAN BODY** IN VARIOUS ACTIVITIES, INFORMED BY ENVIRONMENT.
- USING DIFFERENT TECHNIQUES TO **BEND WOOD** TO ACHIEVE THE **DOUBLE-CURVED GEOMETRY** THAT DERIVES FROM THE **FLOW OF THE HUMAN BEHAVIOUR**.
- **REPLACING TRADITIONAL WAYS** OF PROVIDING COMFORT TO THE USER WITHIN A SPACE WITH **ADVANCED TECHNOLOGIES** BY USING **CONTEMPORARY DEVICES** FOR **HEATING** AND **LIGHTING**.

SCALES

THE PROJECT WILL BE PRESENTED IN THREE DIFFERENT SCALES, NAMELY: **MACRO**,**MESO** AND **MICRO**.

ALL THESE SCALES HAVE INFUENCED ONE ANOTHER DURING THE PROCESS OF THE DESIGN AND THEY ALSO SHAPED THE PROTOTYPE THAT WAS PRODUCED.

WITHIN THE SECTIONS OF THIS REPORT THESE SCALES AND THEIR INDIVIDUAL CONTENTS WILL BE EXPLAINED.

THE PROTOTYPE

STARTING WITH THE WORKSHOP IN DESSAU AND CONTINUING WITH THE ONE IN DELFT, THE PRE-PROTOTYPES WERE PRODUCED IN ORDER TO FURTHER UNDERSTAND THE METHODS AND EXPLORE OUR CAPABILITIES AND LIMITS IN REALIZING THE FINAL PROTOTYPE.

DURING BOTH WORKSHOPS TRIALS WERE MADE WITH FOAM AND WOOD. EVEN THOUGH A CERTAIN METHOD WAS REFINED IN THE DESSAU WORKSHOP, ANOTHER TECHNIQUE WAS INTRODUCED IN ORDER TO FACILITATE THE UNDERSTANDING OF TOPOLOGY AND BEAHVIOURS. EVENTUALLY, IT WAS FOUND THAT TWO METHODS EXCEL IN DIFFERENT WAYS. ONE COULD ACHIEVE HIGHER BENDABILITY AND THE OTHER HIGHER STRUCTURAL STRENGTH. THIS SHOWED THAT THE INTEGRATION OF THE TWO COULD BE IDEAL.

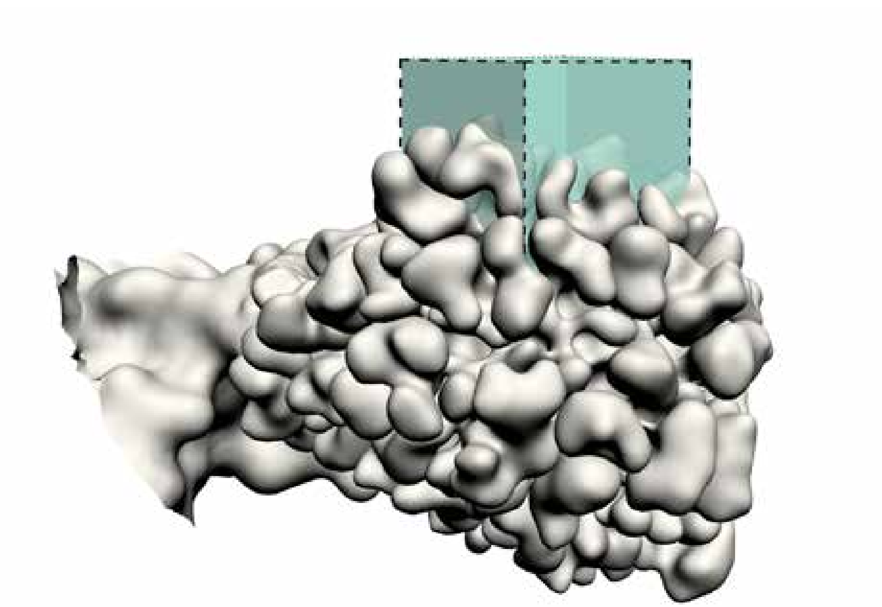
THE MATERIAL

WOOD WAS THE CHOSEN MATERIAL TO BE USED DURING THIS STUDIO FOR THIS PROJECT AND VARIOUS TECHNIQUES TO BEND IT WERE RESEARCHED.

MACRO SCALE

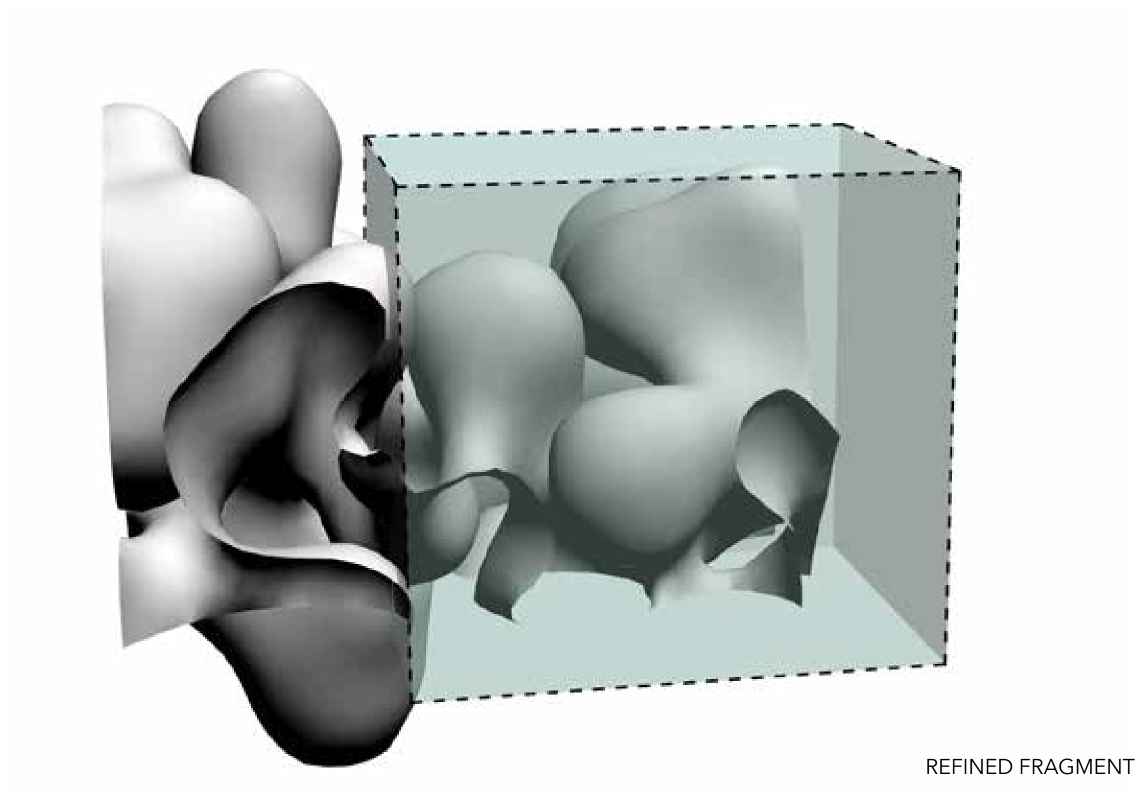
AN EARLY SKETCH OF THE NIEGHBOURHOOD

Starting from this sketch, the aim was to focus on the verticality of the space. The activities and the environmental factors were roughly mapped as a thought excercise.



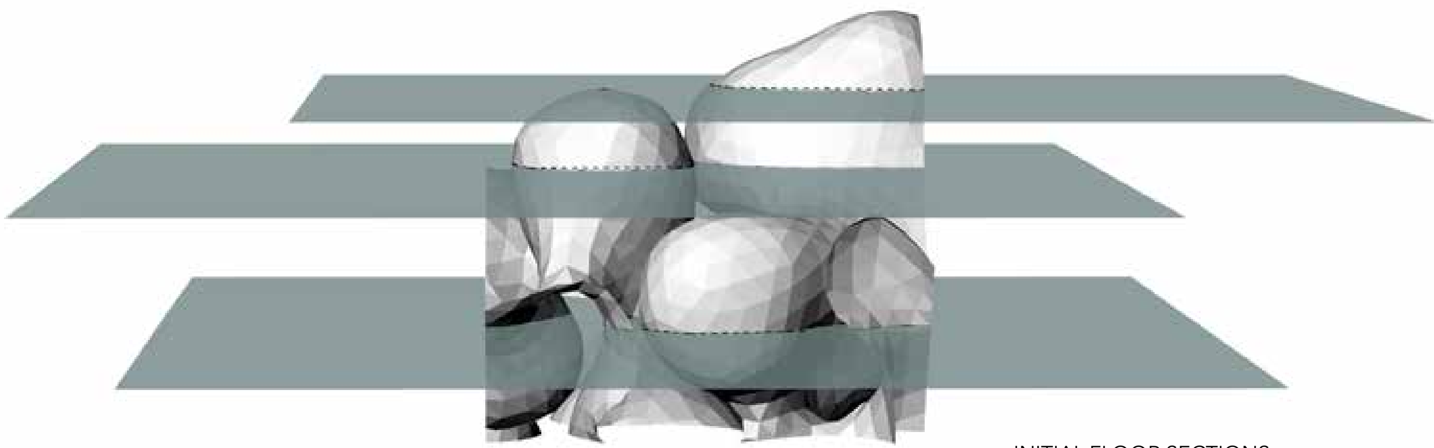
INITIAL POSITION OF THE FRAGMENT

Next, from the initial base geometry that was provided. The fragment that fit the best to the ideas around the sketch was selected.

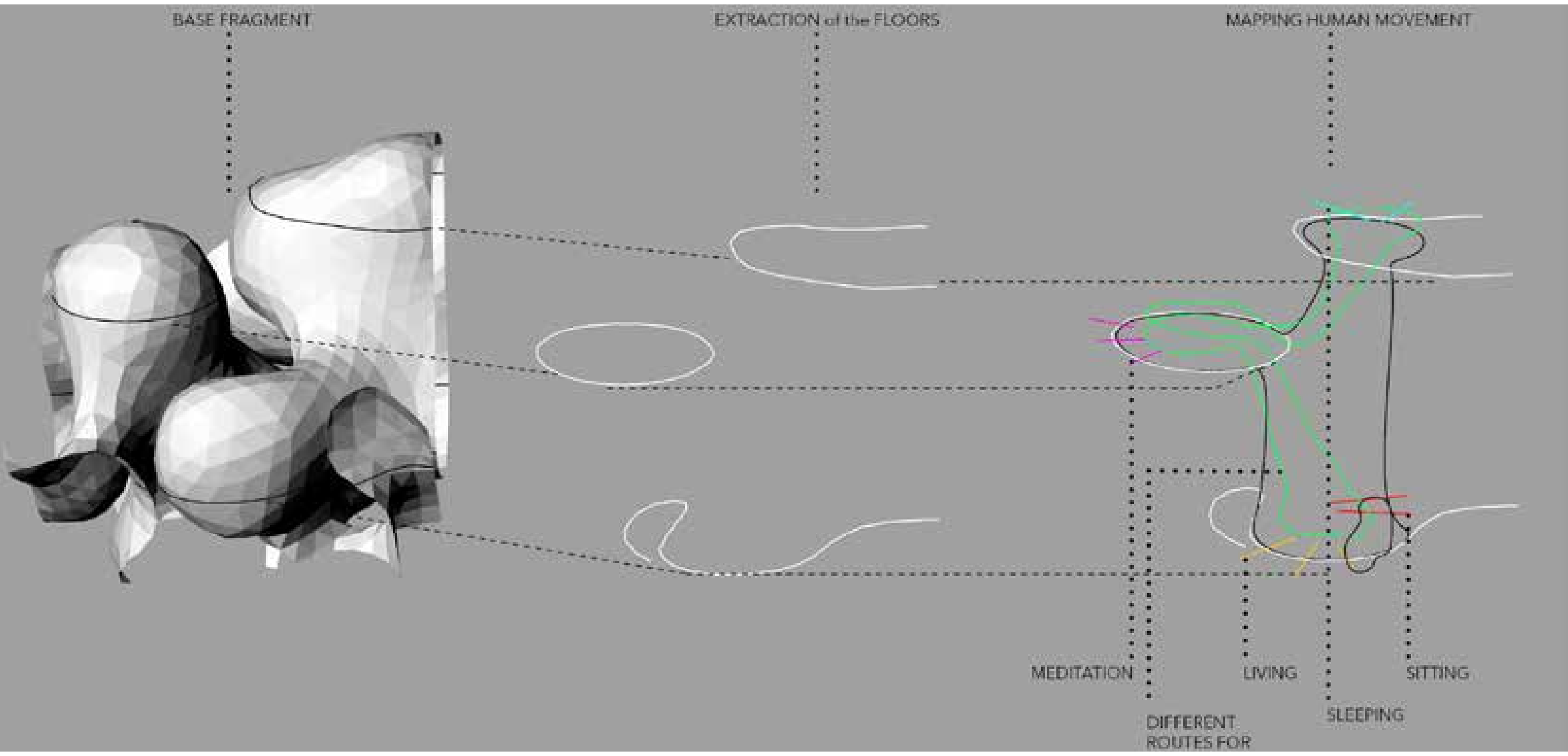


REFINED FRAGMENT

After refining the fragment a little, the possible floor sections were marked. As seen from the images the fragment fits the verticality need of the design.



INITIAL FLOOR SECTIONS

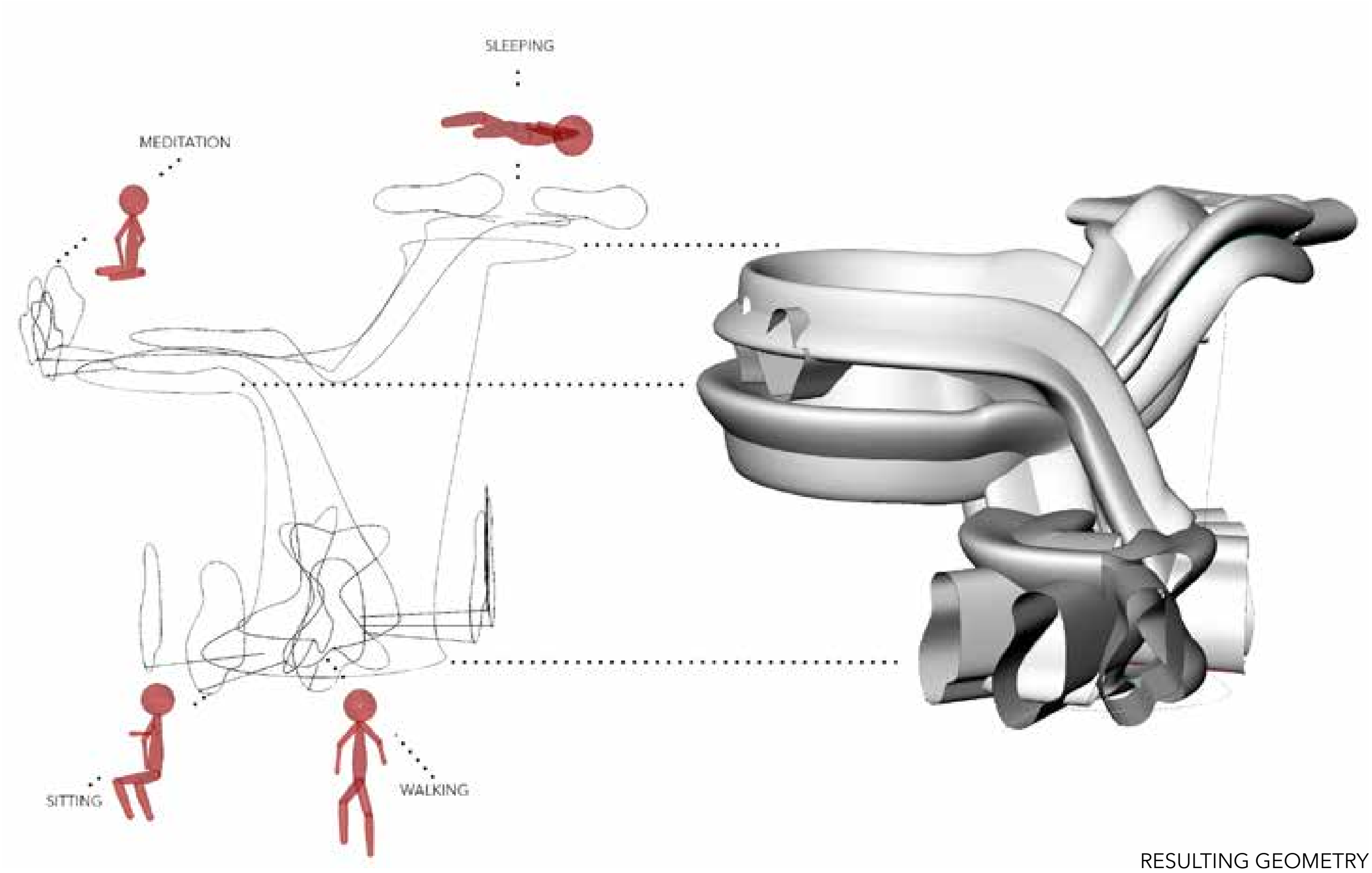


DEFINITE FLOORS AND THE INCORPORATION OF THE HUMAN BEHAVIORAL FACTORS

Defining the exact place the floors will cut the geometry. By extracting the floor lines as, allowed us to use these as reference lines and map the human movement and activities on them. In the above image the basic mappinfg of the human movement flow is illustrated.

In this unit there are three main spaces, from bottom up: living, meditation and sleeping. A general walking pattern was introduced to obtain a general form for future use and the individual activites per space was defined in the basic terms.

Walking pattern was later differentiated between two possible routes that can be taken. Resulting geometry takes its form from a blend of the walking patterns and activities.

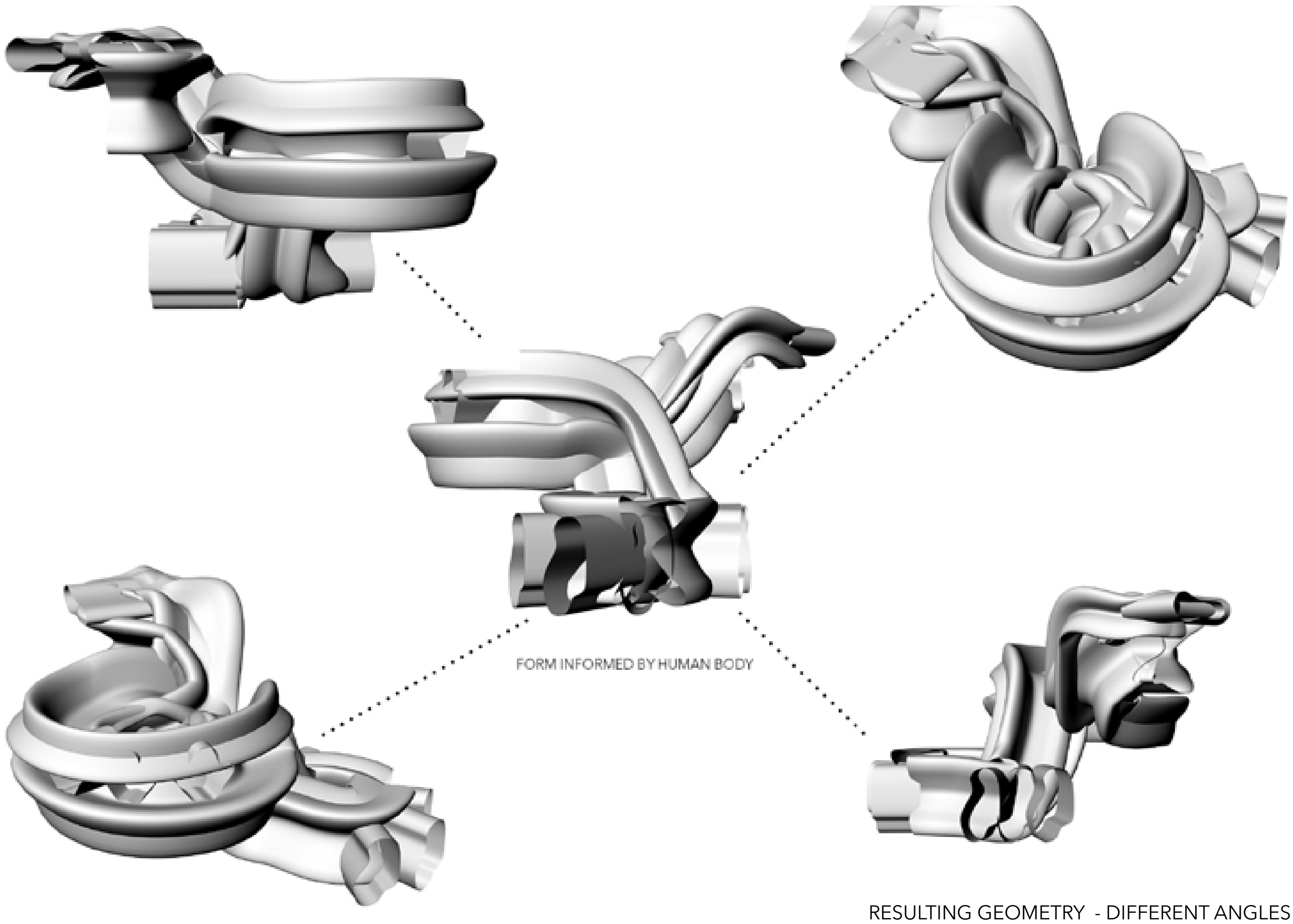


RESULTING GEOMETRY

Resulting geometry gives an initial indication about the flow and the usage of the space. As shown above vertcality plays a big role in shaping the geometry.

Also displayed above, are an abstract illustration of the human outline and the walking line. When obtaining the outline instead of immediate limits of the human body, an offset of the maximum capabilities were prefered for providing comfort in the space.

This geometry paved the way to the final un-refined geometry to work on further.

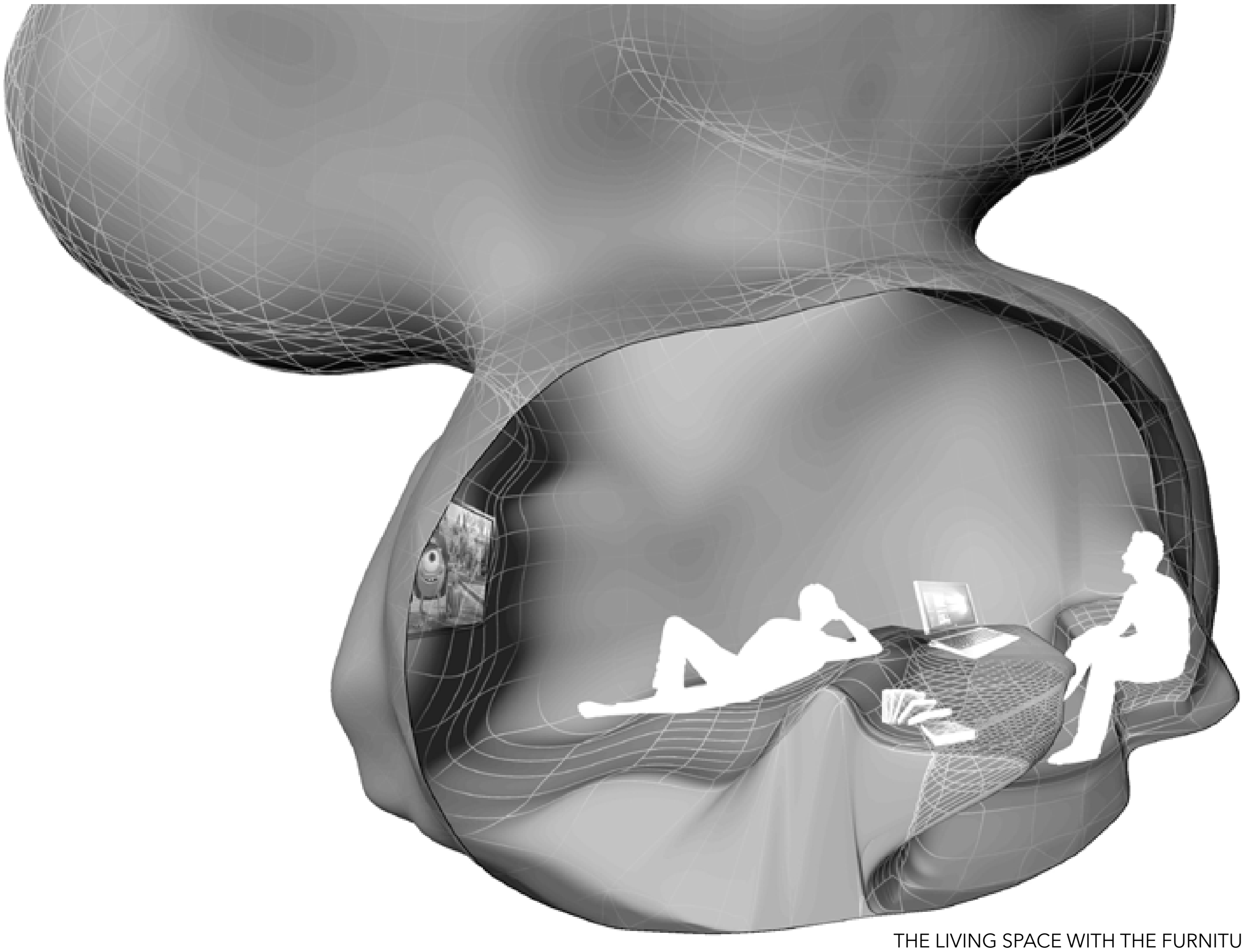


RESULTING GEOMETRY - DIFFERENT ANGLES

As shown above, the resulting geometry is only adequate for use as a reference rather than a final product. The complexity enabled us to have a more comprehensive understanding of what was expected to provide comfort to the user based on the movements and the activities. In the next step, this geometry was used as a base geometry and refined further.

Each activity was mapped further. For each, a variety of possibilities were grouped in different ways to ensure a viable space for this activity. After this, the offset of the human's outline was placed in every one of the possiblities and the points were extracted from all of them. These points later were made sure to enclose a greater space then the imminent limit to provide visual and behavioral comfort.

Each point became the center of a sphere to get the spatial definition out of all this information and these spheres differed in size based on their relevance to the activity. In the next step metaballs were used to refine the geometry to fit into the ultimate limits and form a unified space rather than individual speheres of information.

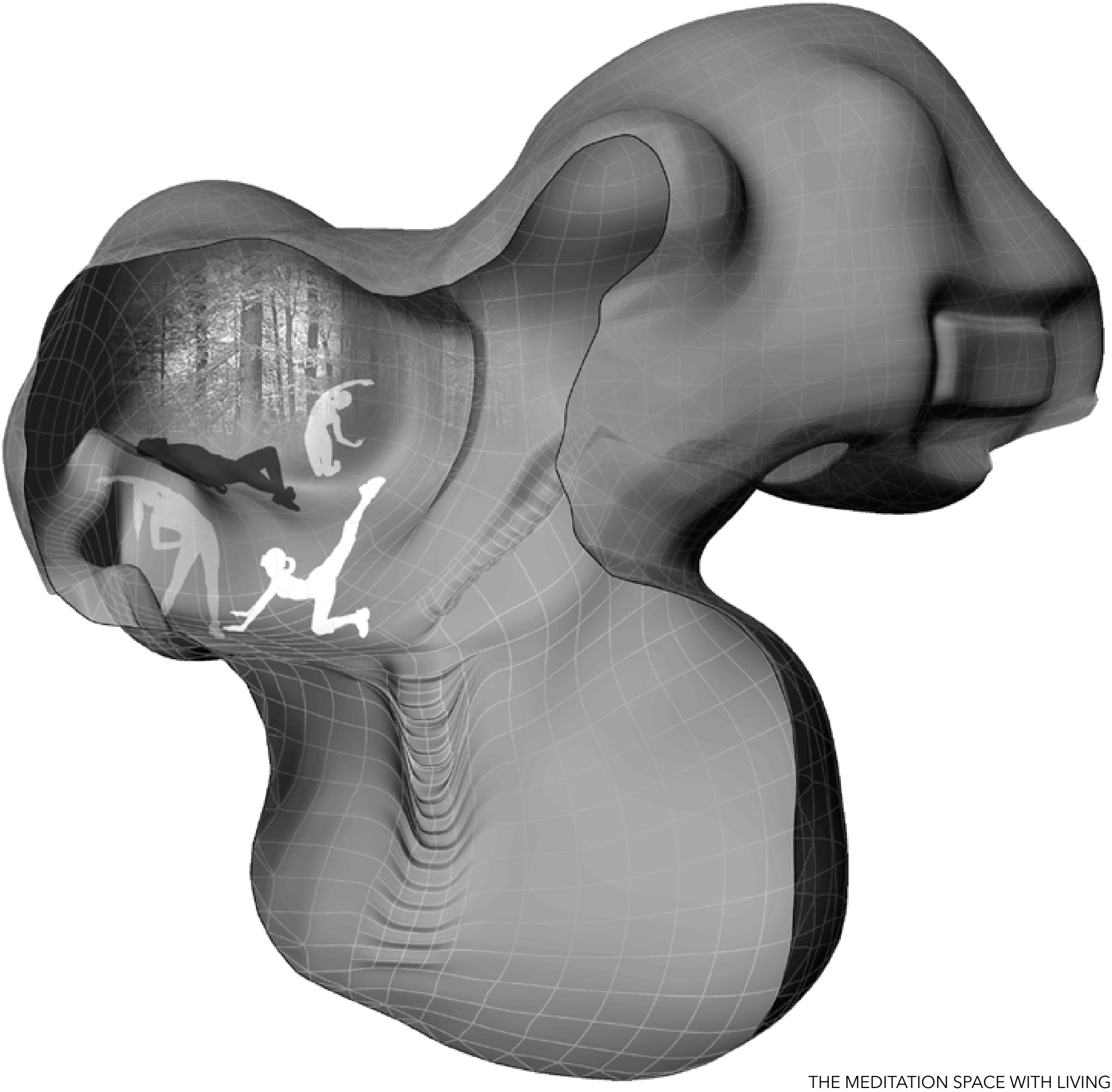


THE LIVING SPACE WITH THE FURNITURE

After obtaining the shape the refining process started. Each section of the unit was indivdually handled. Above shown is the living area.

As shown, the geometry was refined by the further consideration of the usage of the space this time integrating the furniture as well.

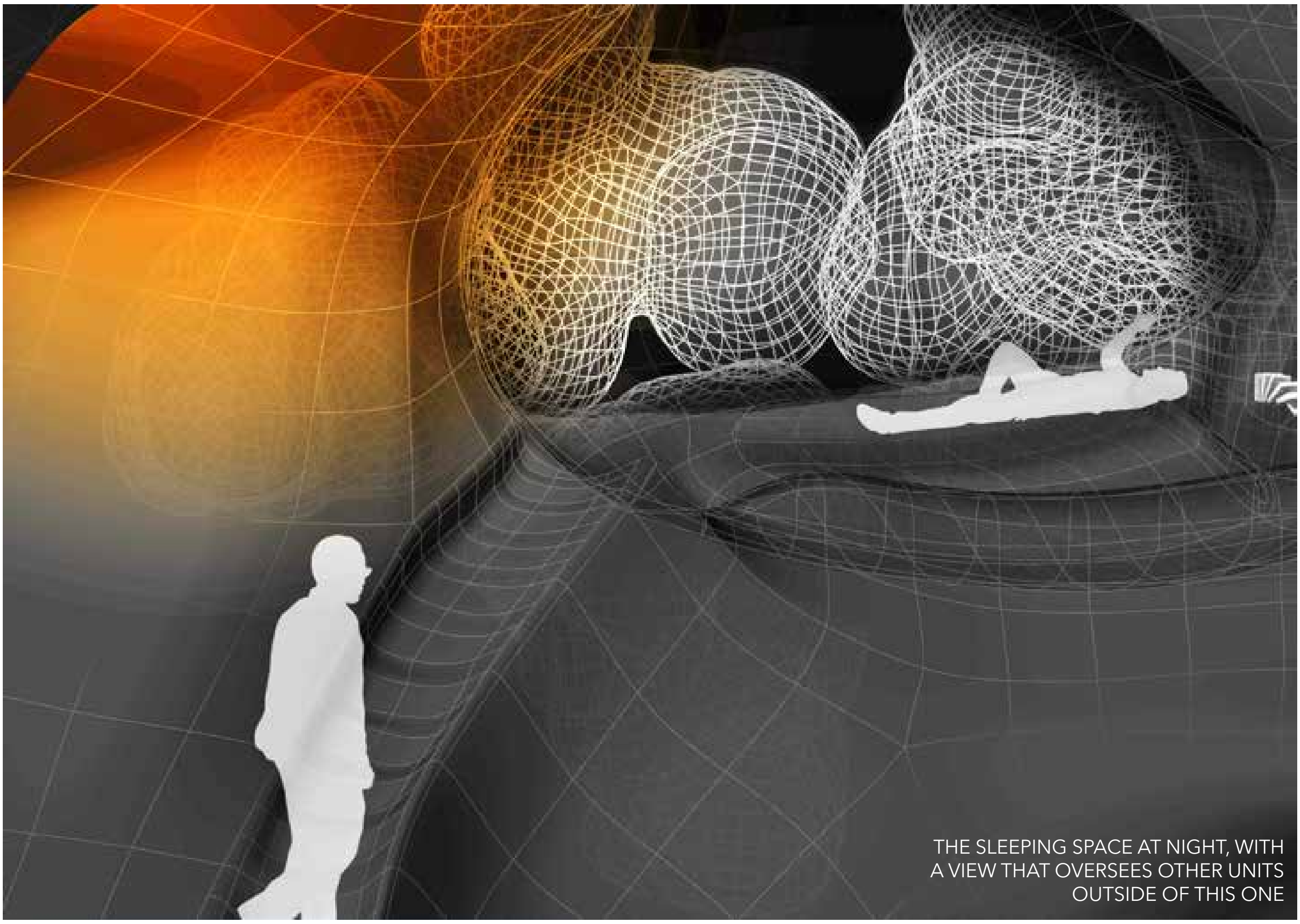
Even though the furniture is formed based on the human body as reference their position in the space and the environmental factors such as light also played a role in their final shape. As a return, the furniture helped with refining the geometry to its final shape.



THE MEDITATION SPACE WITH LIVING
BELOW AND SLEEPING ABOVE

Image above provides a ore clear illustration of how the space was refined using multiple factors from human body to movement and the view and light factor.

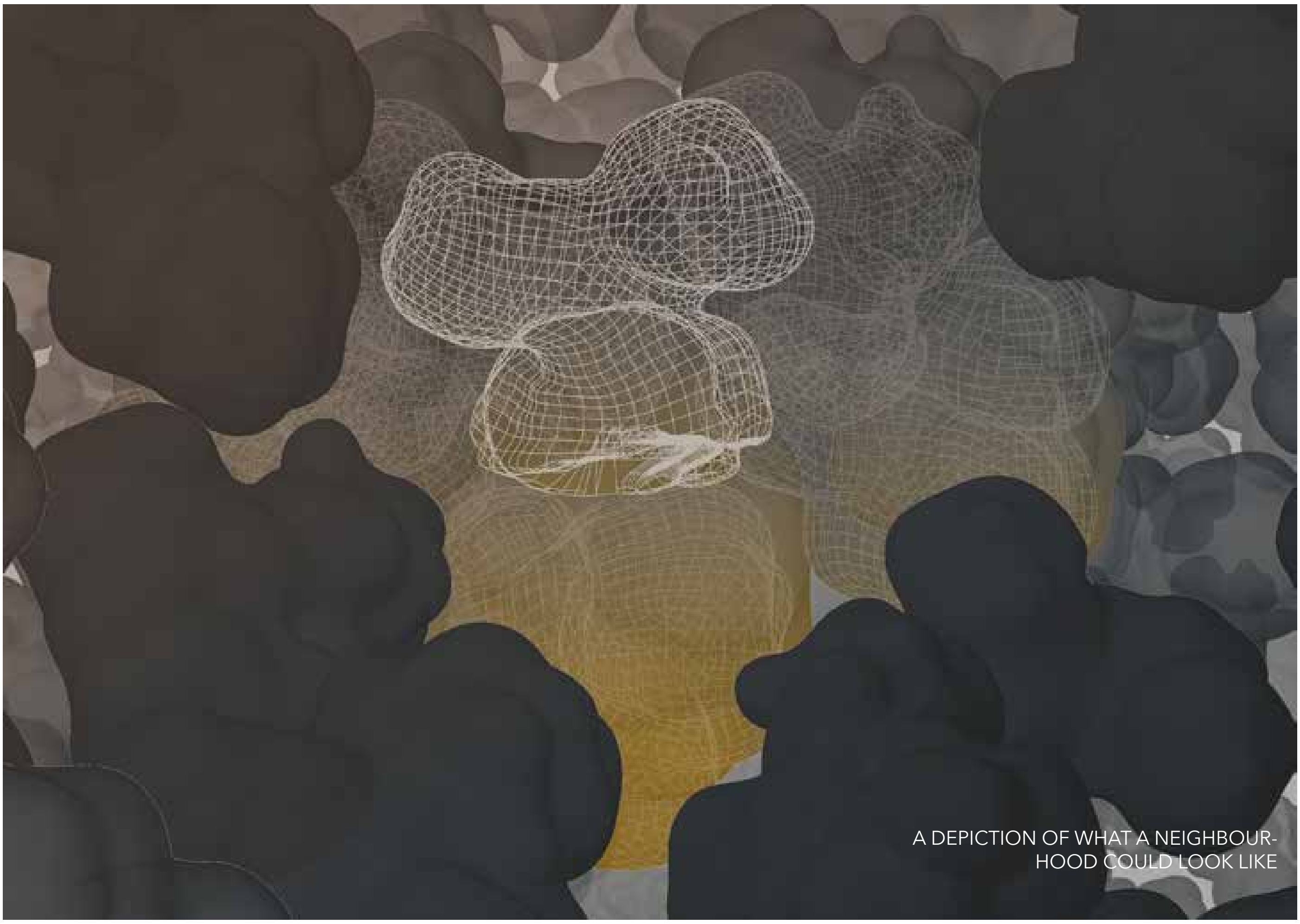
Stairs that are visible from this angle lead down to the living area and we also get a glimpse of one of the refined outer walls of the sleeping space.



THE SLEEPING SPACE AT NIGHT, WITH A VIEW THAT OVERSEES OTHER UNITS OUTSIDE OF THIS ONE

Above shown the sleeping space and the stairs from the meditation that lead up to it.

From the window the other units forming a neighbourhood is visible. Also visible the different shaping of the space depending on the different furniture that serves different actions and a different type of space.



A DEPICTION OF WHAT A NEIGHBOUR-HOOD COULD LOOK LIKE

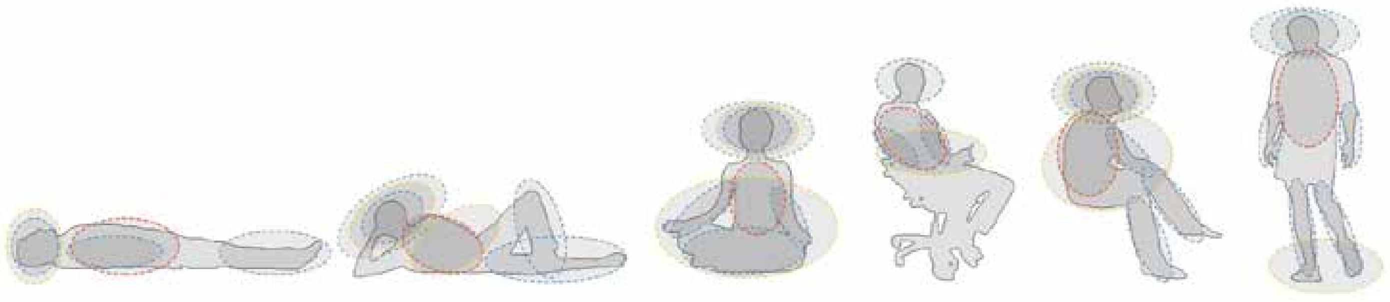
In the above image one of the possibilities of this unit forming a neighbourhood is illustrated. Each unit will house different types of people with different preferences and these units will be subjected to differnt environmental conditions as well.

Meaning, each unit and each space will be customized and crafted based on these differences forming a unique unit. At the same time these units will create semi-open and open common areas and public spaces and they will have their particular way of connecting to one another.

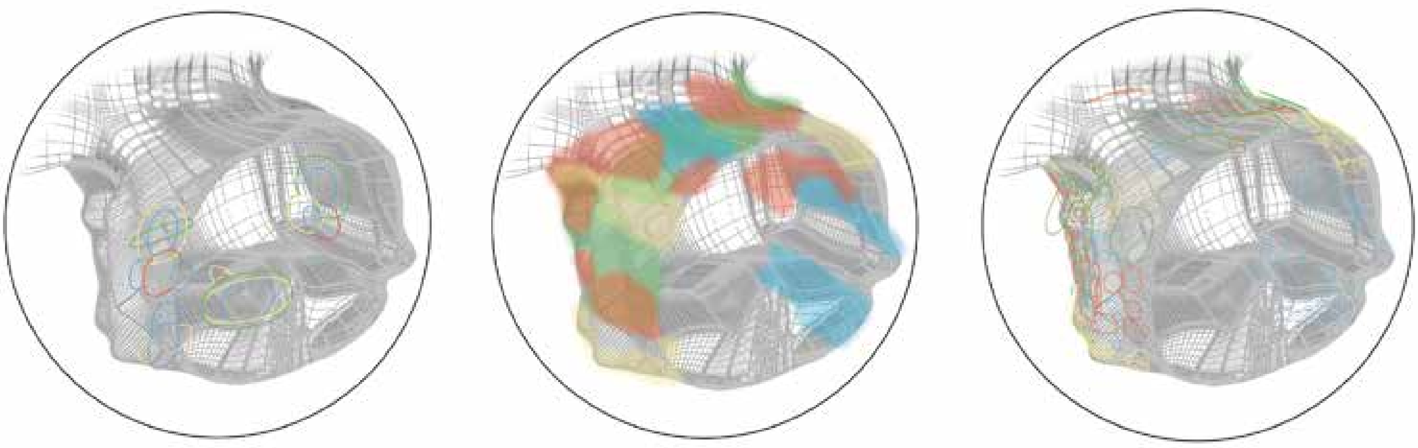
Next step would be to envision a community growing out of this design that functions well.

Starting with the next scale we went more in depth and focused on one of the spaces and integrated structure and porosity. On this scale we introduce the wooden bent beams that forms the space based on the final macro scale geometry.

MESO SCALE



The centrality of the human in the design process is maintained at the meso scale. The focus here is on visual and thermal comfort. The aim was to create local responses to local and specific needs and for this reason the requirements and their position were mapped on the human body for each activity.

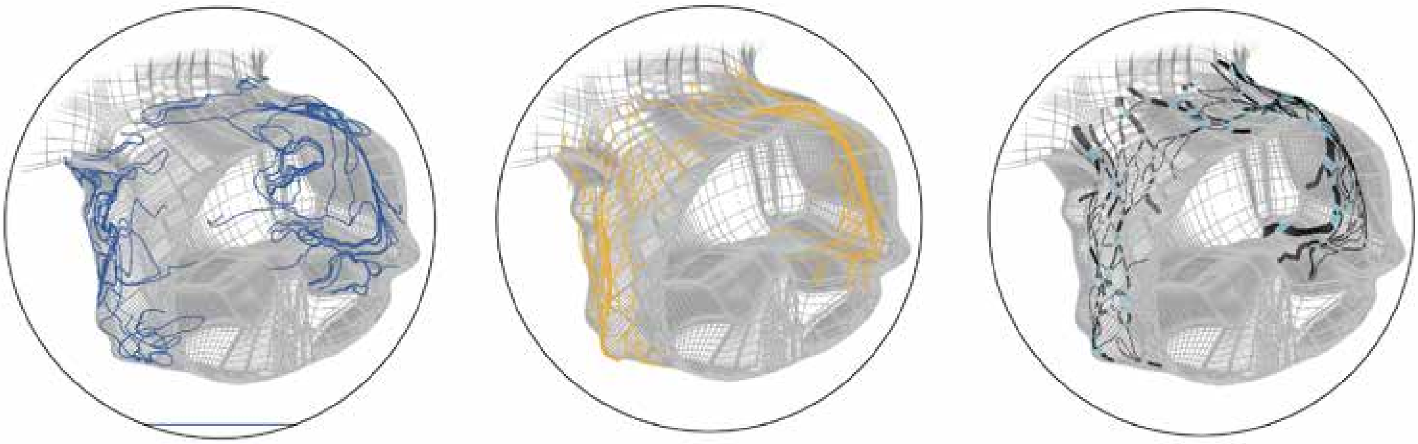


A central topic in this discourse is thermosensitivity, which asserts the importance of local thermal balance. It is based on the concept that the human body has different sensors for heat and cold, the latter situated mainly in the abdomen and the former in the head and exposed skin. Additionally, it also highlights the importance of the direction of the source of heat and cooling., the best generally found as perpendicular to the sensor area. This also affecte the porosity of the building skin following the type of devices that are intended to be used for each case.

Regarding light, a distinction was made between light used solely for illumination and light with the addition of views. The former require smaller but denser porosity, the latter larger openings.

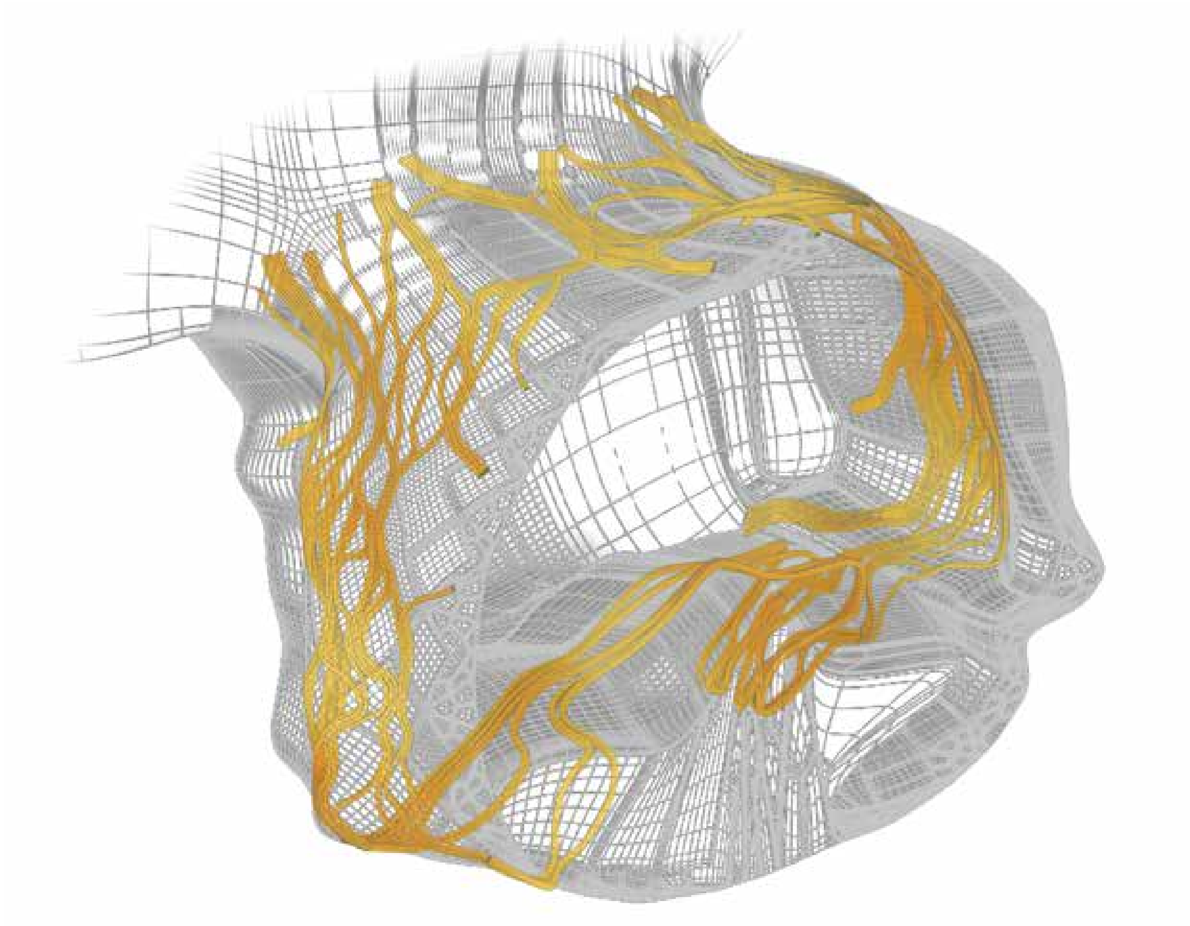
Subsequently, these needs were mapped on the building skin as resulting from the specific activity, comfort requirements and direction of the source.

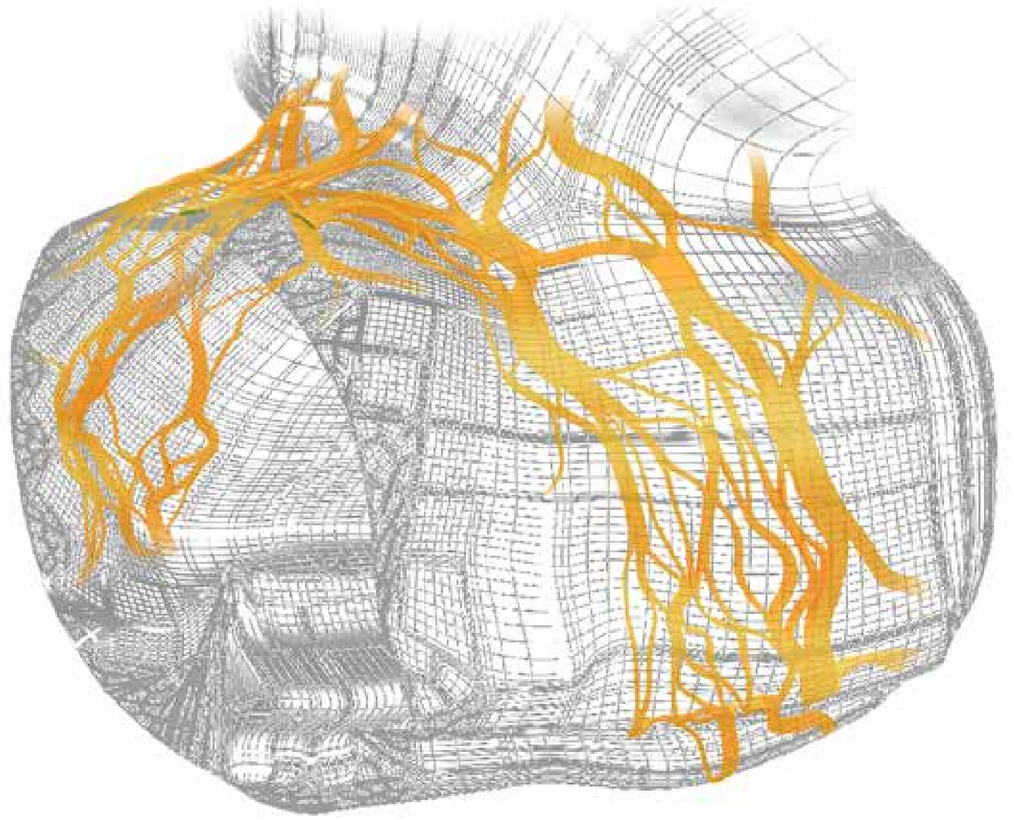
The resulting porosity was used to create an initial pattern on the surface.



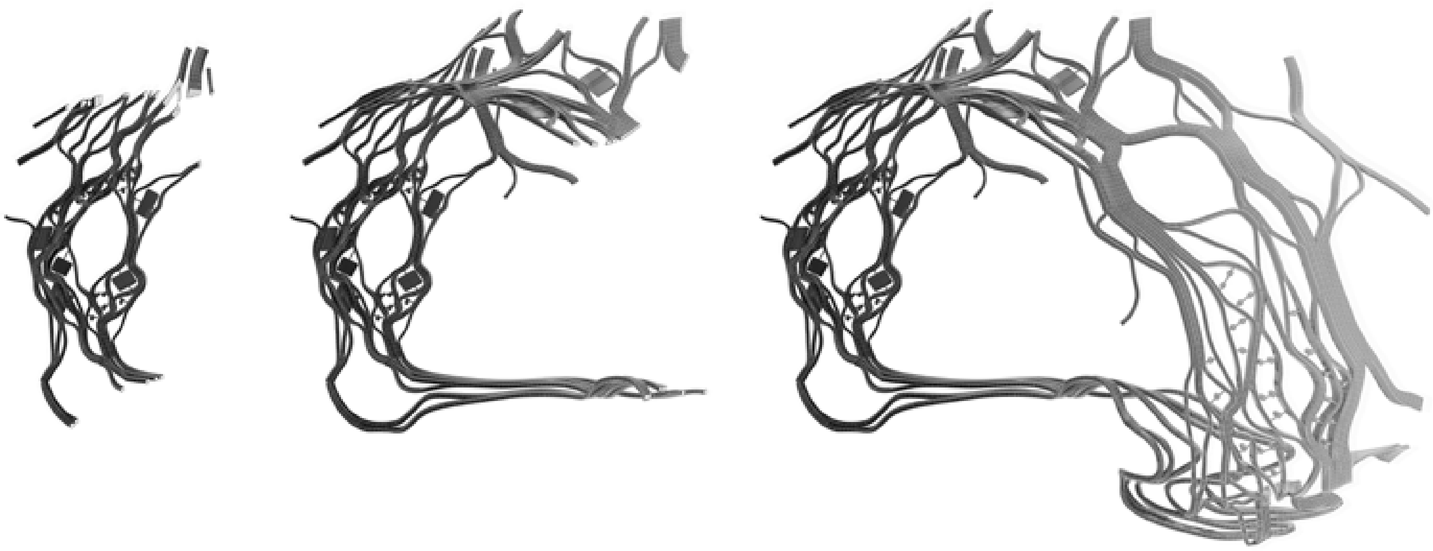
The design was materialized as a system of continuous wooden beams, which means that branching would never be present. Instead, the beams converge and create areas of high density and lower density in accordance to the porosity previously established. The absence of subdivisions meant that it was necessary to calculate the number of beams at each point throughout the system in order to guarantee that each of the porosity openings would be covered on the sides. This would naturally create overlapping beams, which were instead “offseted”. These paths had later to be reorganised at each converging point so that they would not intersect each other.

By using the same logic, a higher density of beams was generated in the proximity to structural lines. Therefore higher strength was achieved by means of aggregation.

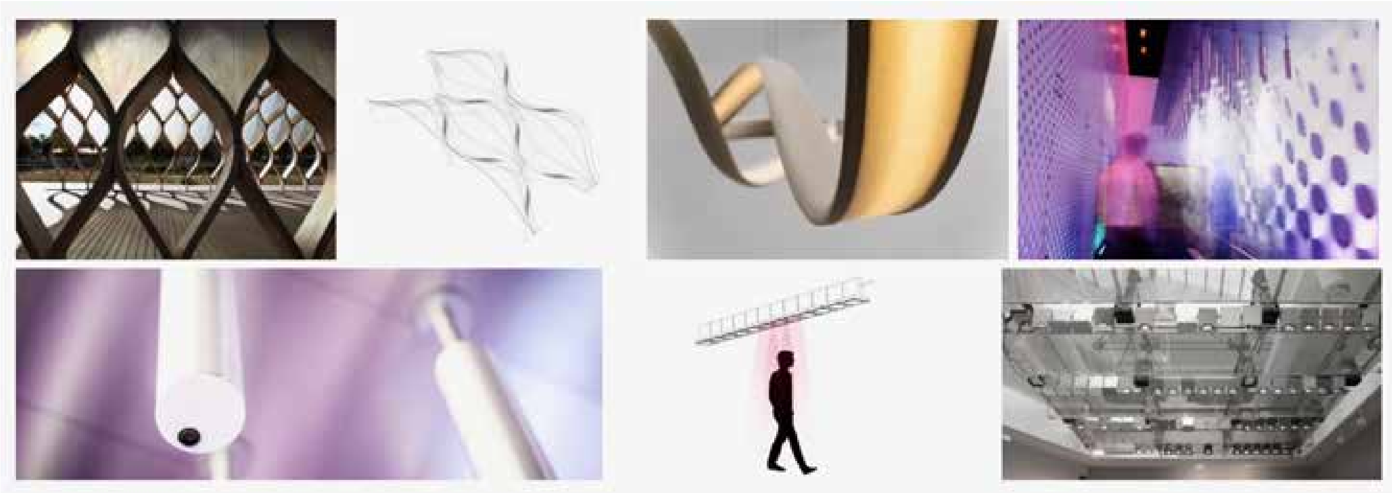




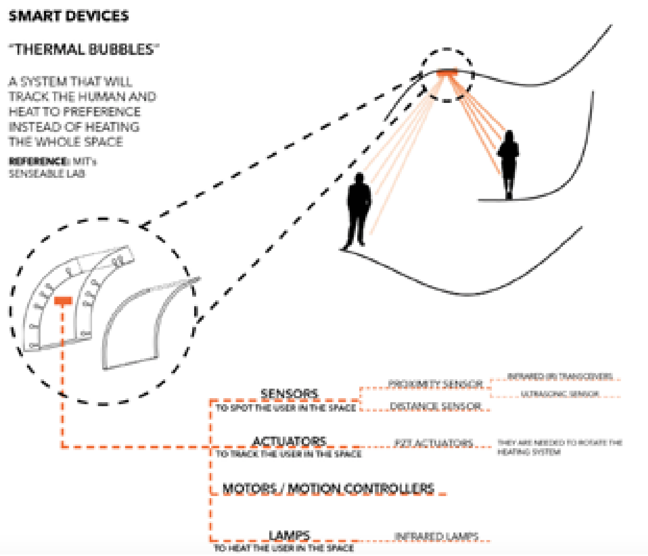
After creating this system based on the porosity the next step was to add the devices that were chosen to achieve each comfort criterion.

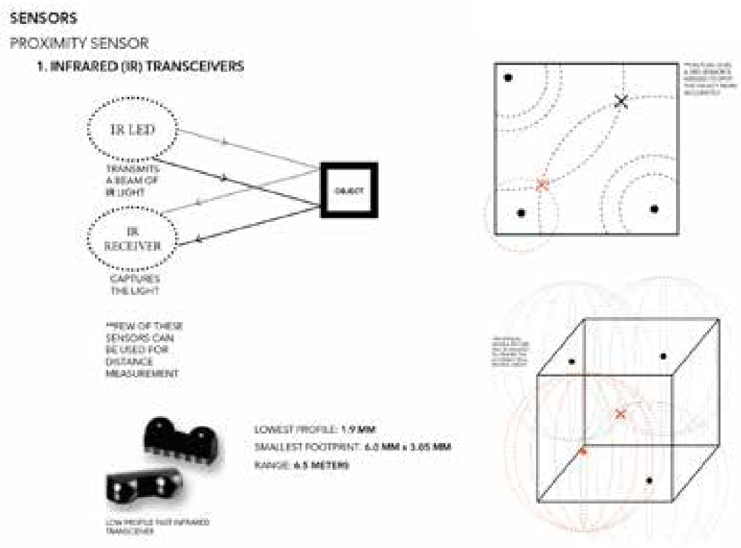


MICRO SCALE - DEVICES



At the micro scale, the local heating and cooling is addressed by means of devices such as those developed by Carlo Ratti and the MIT Senseable City Lab. Both use movement and proximity sensors to understand the position of the person in space and therefore activate the proper device. The placement of these sensors needs to be correctly mapped in the building since three sensors are needed at the time to locate a person.





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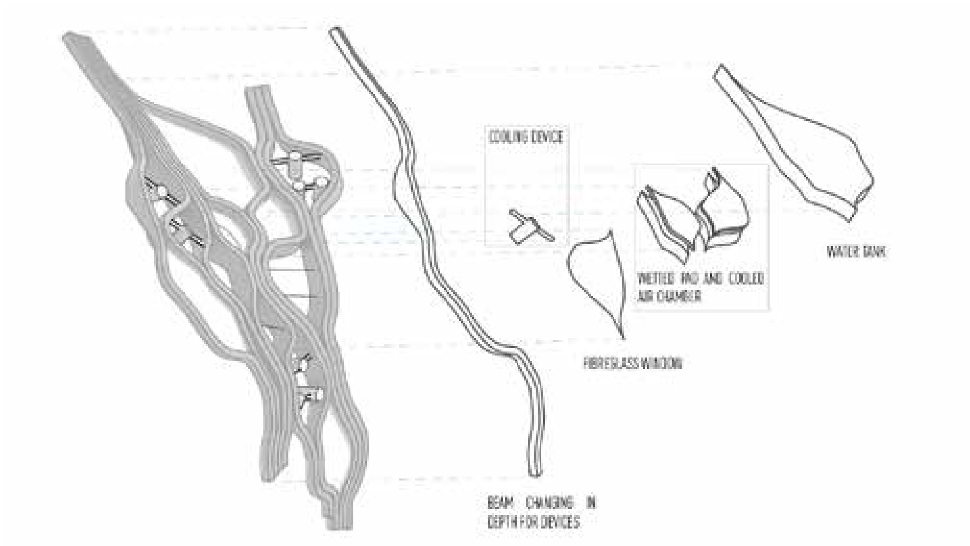
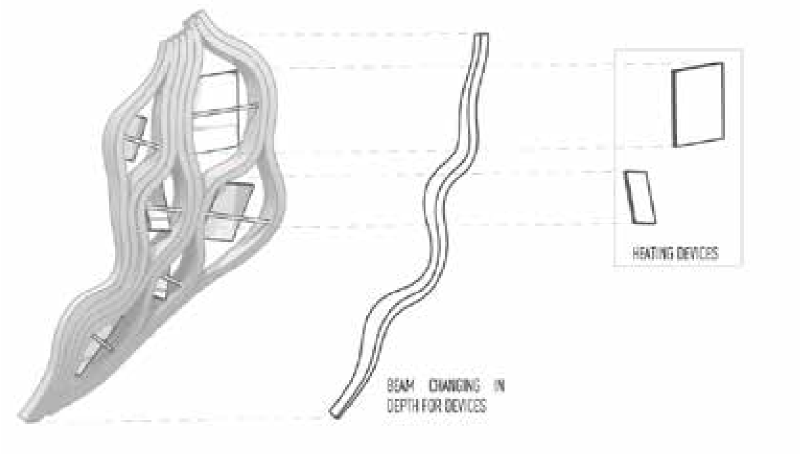


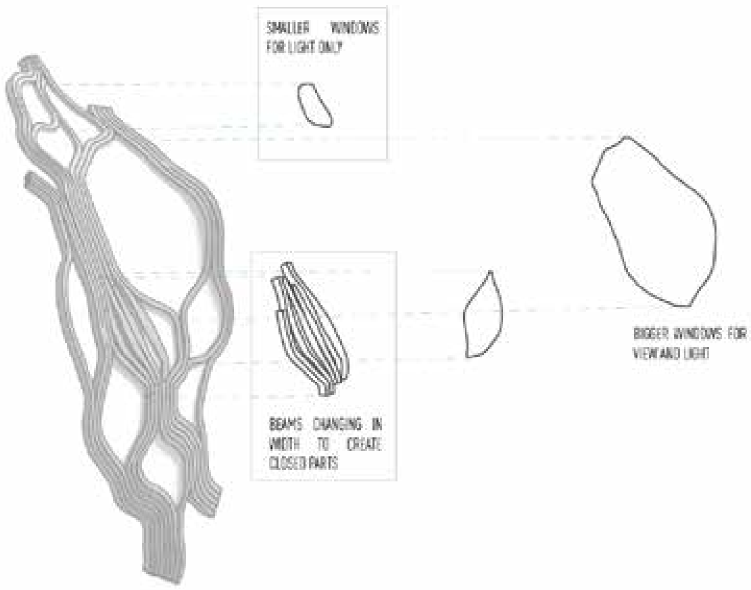
Local cooling is achieved by using evaporative cooling. This system requires a tank where to collect rainwater which is then sprinkled on a pad. By means of a fan air is then drawn through the pad and cooled air is created, which is then stored in a chamber. From this chamber a system of pipes brings to each outlet, which is free to rotate in multiple directions. In addition, electrical cables are required in order to power their movement.

In order to create niches in the wall where to place the devices, the beams are thickened in correspondence of the devices.



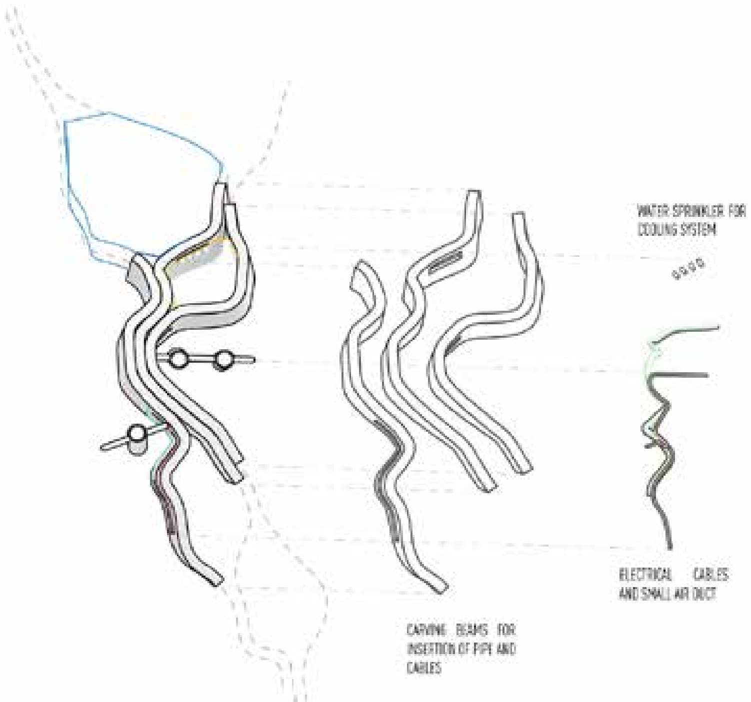
Local warming is achieved by using a system of infrared lamps that, similarly to the local cooling system, are free to rotate in multiple directions.

In order to create niches in the wall where to place the devices, the beams are thickened in correspondence of the devices.



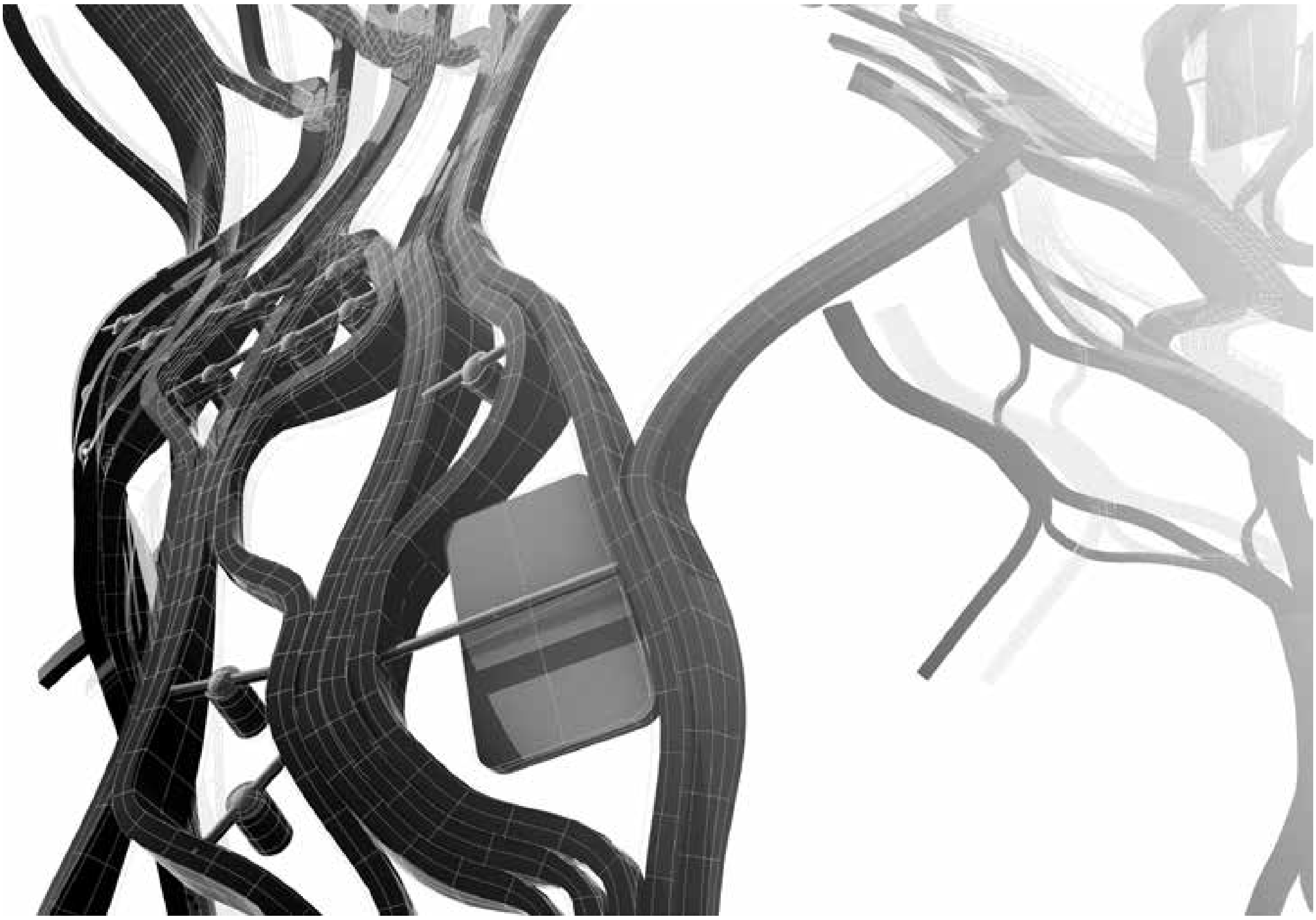
Openings are differentiated between those solely for light and those that allow sight to the exterior. The former are smaller in size and more densely packed, while the latter are larger and more sparse. Enclosed surfaces are instead created by widening the beams.

In order to create an external surface, in particular in the case of windows, openings would be covered by a fibreglass skin. In order to minimise the use of moulds the preferred method of production would be to use the beams as a mould on which the glass-fibre composite plastic is produced and then robotically cut.



These devices require pipes and tubes, whose location differs according to the production method. In the case of laser cut they would be hidden inside the beams, whereas in the case of milling grooves would be cut on the sides of the beams. The latter is here showed.

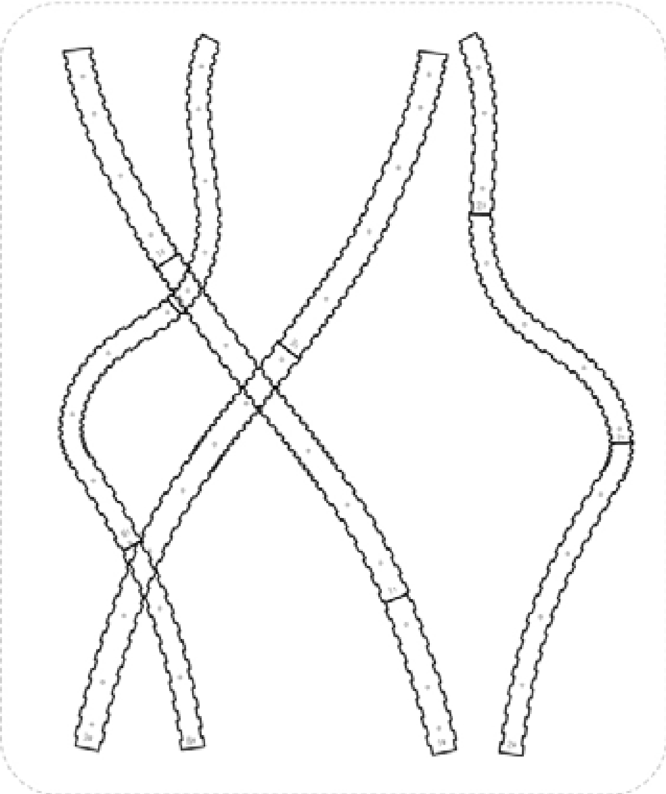
The same method would be used to create artificial lighting, with LEDs strips hidden in the sides of the beams.



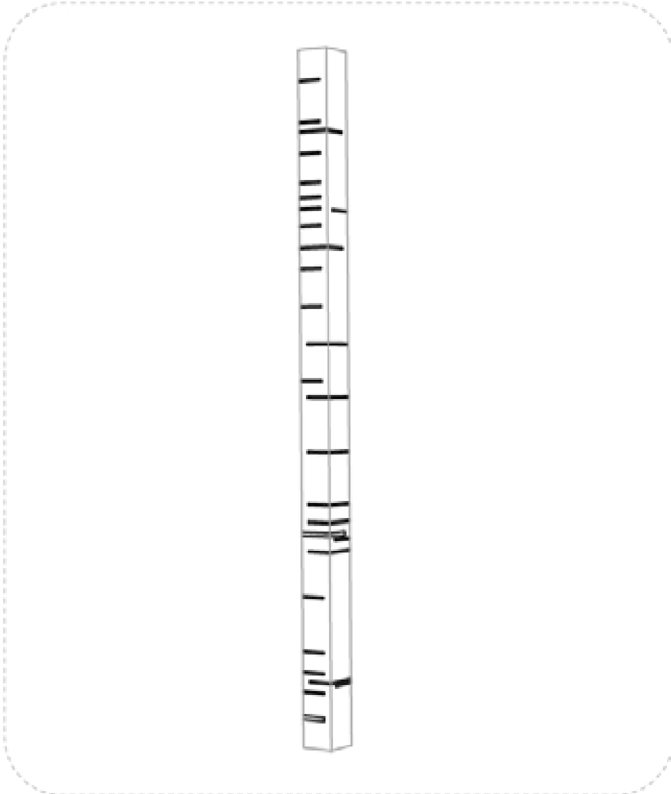
Above shown is a section of the result in which it is visible the variation of thickness of the beams depending on the presence of the devices.

MICRO SCALE - RESEARCH & PROTOTYPES

METHOD A : LASER CUTTING



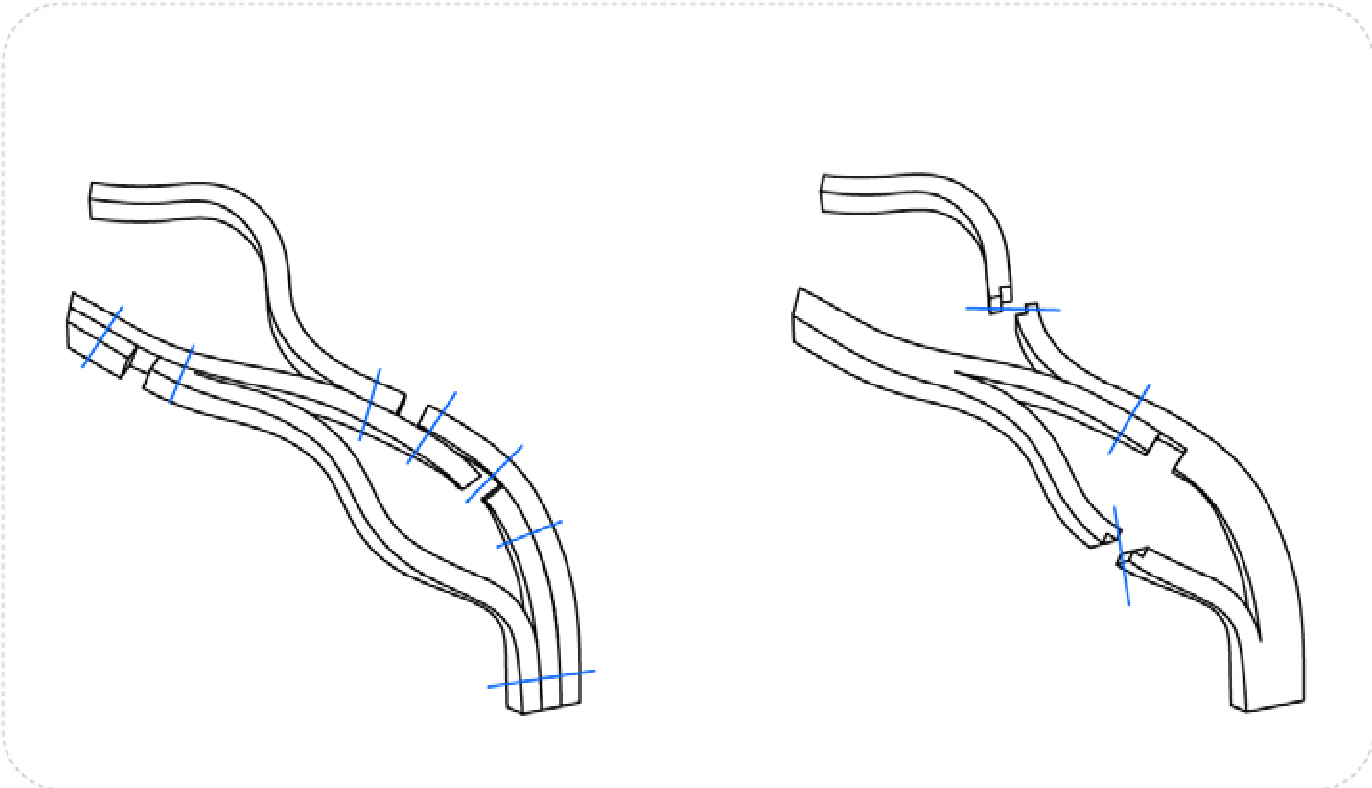
METHOD A : MILLING-



Prototyping was subdivided into two different materialisation systems.

The first one, laser cutting, used plywood sheets of 3 mm. Each beam was deconstructed into its constituent faces and flattened thus creating a hollow beam.

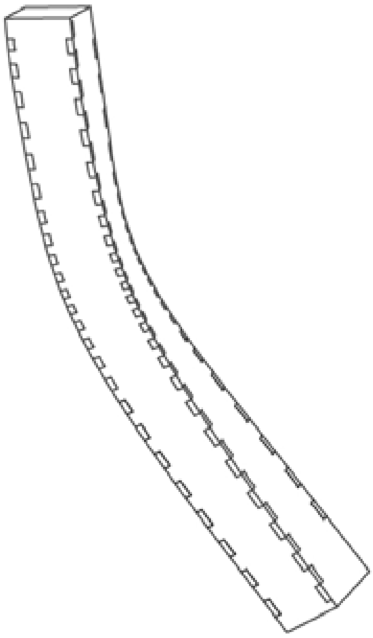
The second one, milling, used fir beams of 27 x 27 mm. In this case the approach was based on the properties of kerf bending, in which removing material would allow bending. By joining again the extremities of the cuts, the beam would regain structural properties.



+ continuous
+ easy division
- fixed number of beams throughout the systems

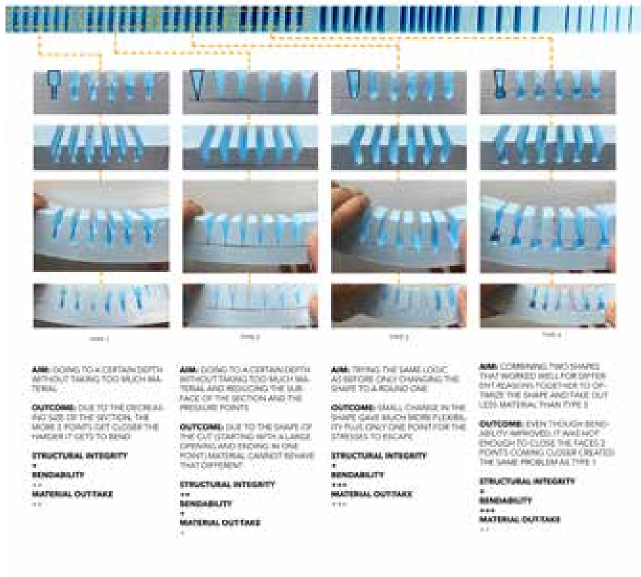
- low strength of some joints
- frequent separations needed
+ variable number of beams

One of the first issues that was faced in the materialisation process was the subdivision. One option was to create continuous separate members, the other to create beams that would branch into smaller elements. While the former would limit the freedom of shape, since the number of beams remained fixed, the latter presented high limitations in the length of the members and the strength of joints. For this reason the first option was chosen.



The laser-cutting method was characterised by joints that depended on the bending of beams: the bigger then bending, the smaller the joints. In this way the joining of the faces of the beams was facilitated.

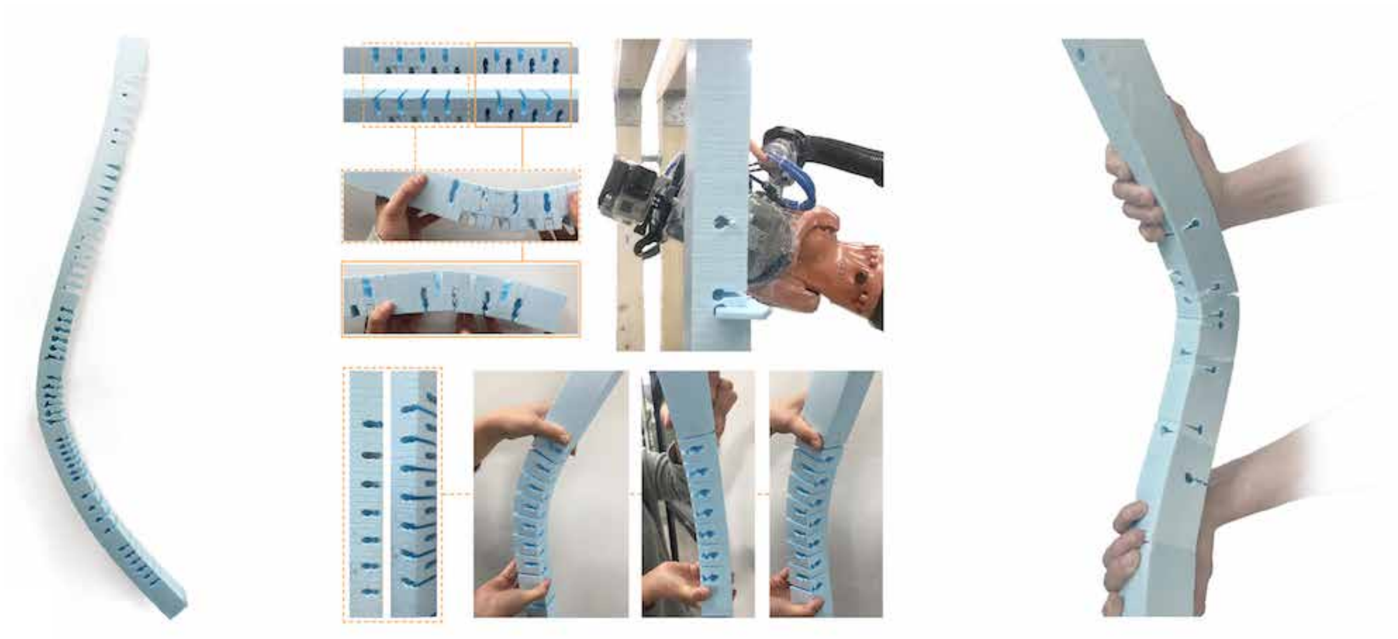
A second issue was the division on each face of the beams, given by limitations of the machinery. It was determined that interruptions should happen in different points for each face so not to disrupt the structural integrity of the final beam.



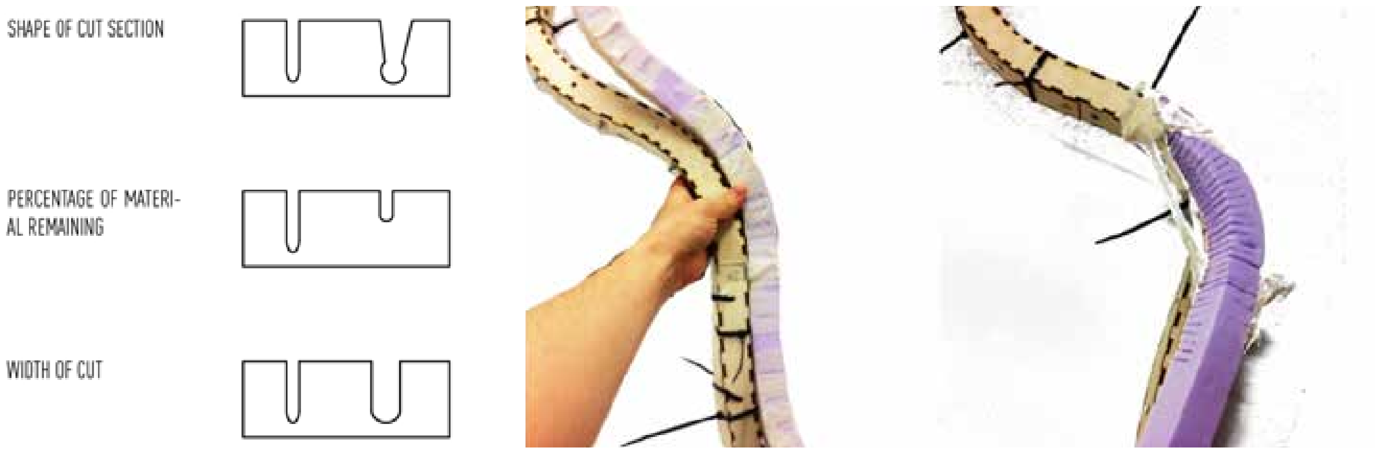
The second method, milling, was first tested on foam materials such as XPS. The main difference between these materials and wood lies in the physical properties, being XPS a homogeneous material.

Moreover, in order to simplify the testing it was decided that the cuts would be kept perpendicular to the faces of the beam, rather than oblique, which was anyway found to give weaker results in bending.

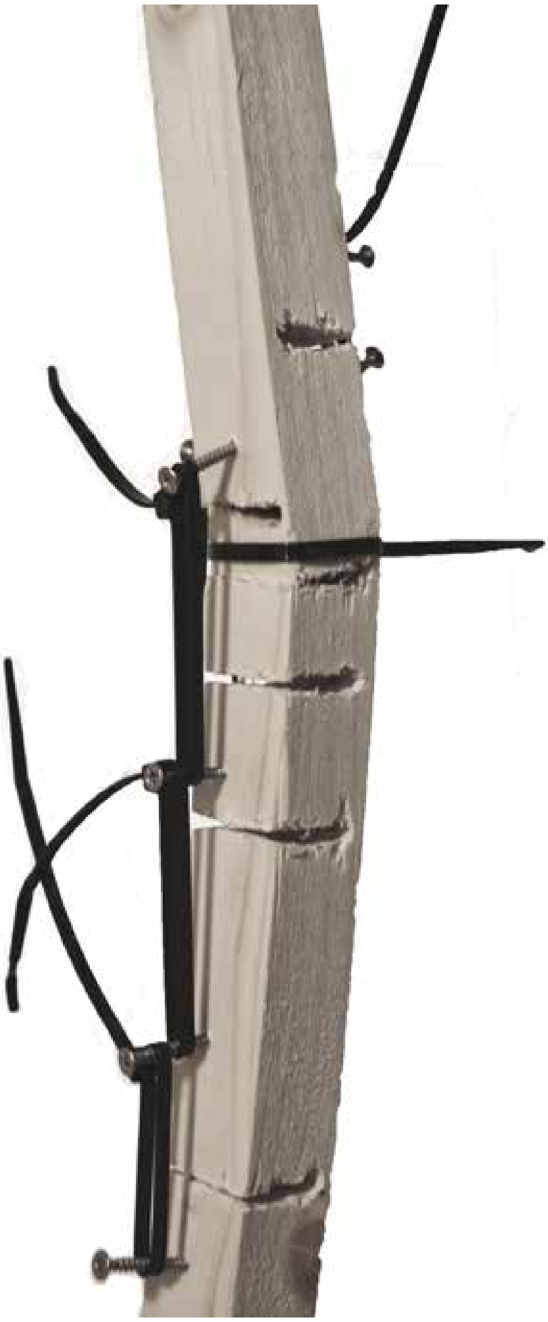
The first testing process regarded the section of the cuts. The ideal was found to be ending in ellipse rather than a circle. While cuts on both sides, both reaching beyond the middle point of the beam, were creating a high level of bendability, they were deemed to excessively reduce the strength of the beams. This was due to the fact that only on one side the cuts could be re-joined. Torsion was one of the main issues that were encountered. In fact different ways of achieving it were tested. The first was by creating cuts that are diagonal to the beam. However, in order to reach the same percentage of removed material, the beam was excessively weak and would break more easily. It was therefore decided to separate the diagonal cuts into two directions, on two adjacent faces of the beams. This proved to give good results in terms of torsion.

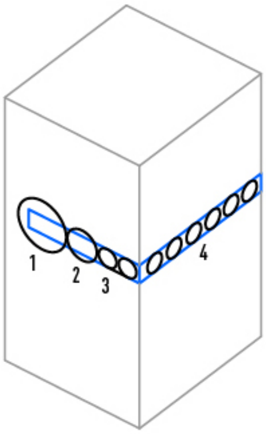


A first robotically-produced beam was also tested. One of the main problems observed was that the beam would be weakened throughout the milling process and would therefore start bending before the process was completed. This could result in the robot breaking the beam or anyway high imprecision due to shaking.



These criteria were then taken into consideration into the computational study for creating the cuts. Further parameters were then introduced which considered the distance of the cuts and the dimension of the milling head used in the production process. This process of rationalisation meant that it was impossible to reproduce exactly the initial shape and instead it was necessary to rethink the shape starting from the limitations found in the production process.





Eventually, wood was also tested. The tests were carried out on rectangular fir beams of 27 x 27 mm, a softwood that proved to be very sensitive to chipping and breaking. It was anyway essential in understanding in how to reduce these detrimental behaviours and in testing the overall process.

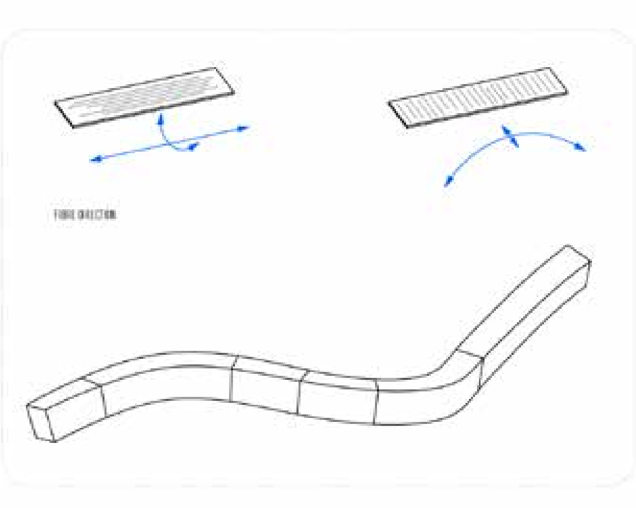
A solution regarding the weakening of the beam during the fabrication process was to create the cuts on only the two edges initially and realising the final cut on the main side of the cut only at a second stage.

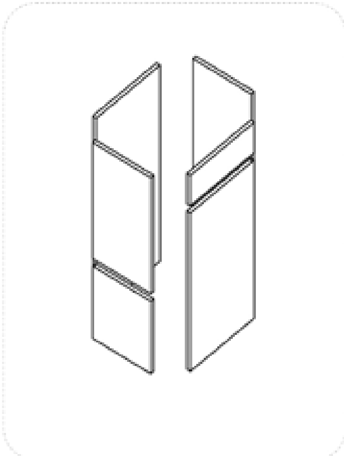
Testing on wood also proved that the dimension of the cuts is not the only factor to be taken into consideration. In fact, the distance between the different cuts, in particular when these are on two different faces of the beam, was crucial because, when they were too close, would cause the beam to weaken and break.

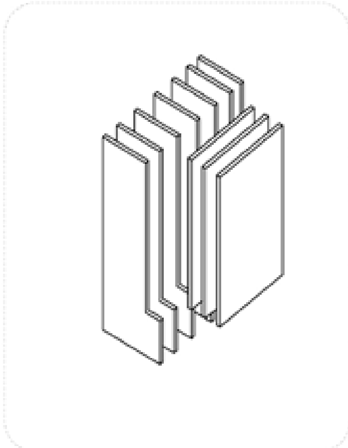
As easily predictable, the bending characteristics of wood were less straightforward and similar cuts required different strength in order to re-join the extremities. In particular, nodes can greatly hinder the bending of wood.

An initial testing of epoxy resin glue was made. While it responded well to compression, tension forces proved to be problematic and further testing of glues would be required to understand how to avoid this issue.

Further research need would involve different types of wood, and possibly delineating the best of wood for different topologies. Better understanding on how to deal with the limitations of wood would also be required.







The direction of fibres proved to be crucial for both systems. In fact, the bending behaviour of wood heavily relies on the direction of the fibres. The highest flexibility is reached when the fibres are in the opposite direction of the bending. While this can easily be introduced in the fabrication process in the case of laser-cutting, it is a substantial limitation in the case of milling. In fact, wooden beams will always have fibres whose direction correspond to that of the desired bending and, therefore, bending is always hindered by it. However one solution could be to engineer the material beforehand, by for instance creating cross-laminated beams in which the direction of fibres can be modified.

Eventually the two systems, laser-cutting and milling, could be integrated and used for different requirements. In fact, the former proved that it can reach higher bending, while the latter higher structural properties.