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REFLECTION PAPER
Paris 2024. A cyclist's reinterpretation of movement at the Olympic Games

Foreword

Similar to the way an athlete trains for a competition, optimizing gradually each aspects of their performance, *A cyclist's reinterpretation of movement at the Olympic Games* aims at a gradual optimization of the design process when confronted with the architectural program, through continuous feedback loops. The final configuration with its specific formal language is the result of trainings, or iterations in computational design terms.

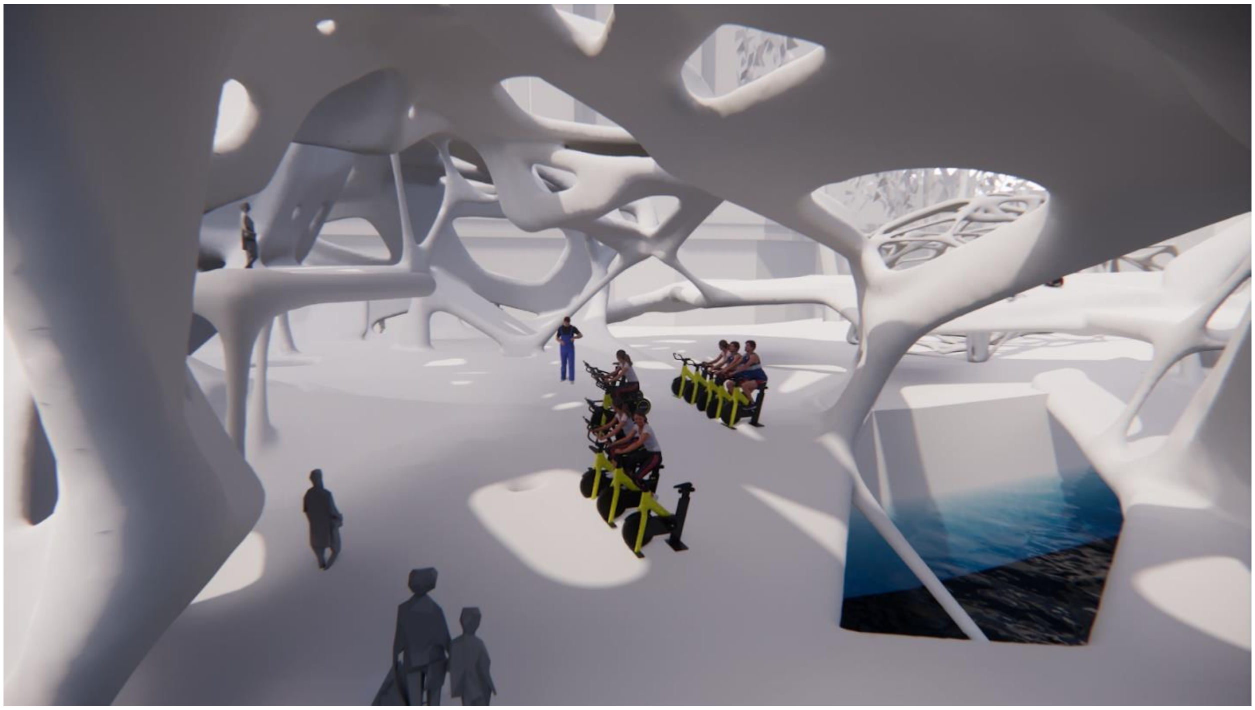

fig. 01. Render of the interior virtual cycling space

I. How research and design coexist

The architectural program addressed regards a global event occurring with temporal regularity, but relatively unpredictable location, since the host country is required to win the bid for hosting the Olympic Games from a number of competitor countries. The building's program is as demanding as a permanent function (in this case comparable to that of a gym and a stadium), but in reality is used as a temporary venue, like a circus. Because of this, I carefully tackled the topics of materiality and temporality, trying to step away from the architectural "white elephants", structures that remain derelict, generated during previous Olympics. The proposal had to correct precedents such as poor

integration within the existing urban fabric, difficulty to re-dimension the structure to the local needs for such venues, difficulty of re-purposing, traffic densification and pollution.
In terms of the theme of *reinterpretation of movement,* I got inspired by the relatively recent advancements in the technology for home-trainers, where the cyclist is able to perform trainings on her/his own fitting level, sitting on his bike in the home garage. These events have infiltrated recently also the pro-racing setting, most recently at the beginning of the Corona lockdown. Creating new paradigms of performing activities will be instrumental to tackle global environmental issues by reducing the need for transport and for very large structures.
The project proposes a venue that integrates both aspects: a dynamic landscape-like architecture to be explored by any visitor (local or tourist) by bike or by foot, as well as integrating virtual racing areas for different sports performance levels.

Reflection on urban heritage
The site chosen for the Cycling Venue in Paris follows the Olympic Games Masterplan in Paris. The understanding I gained about the local context through analysis and site visit allowed me to weigh in the urban dynamics and their impact on site selection. I chose a neighboring site on the Seine river, which would contribute to the enhancement of the local leisure and sports activities.

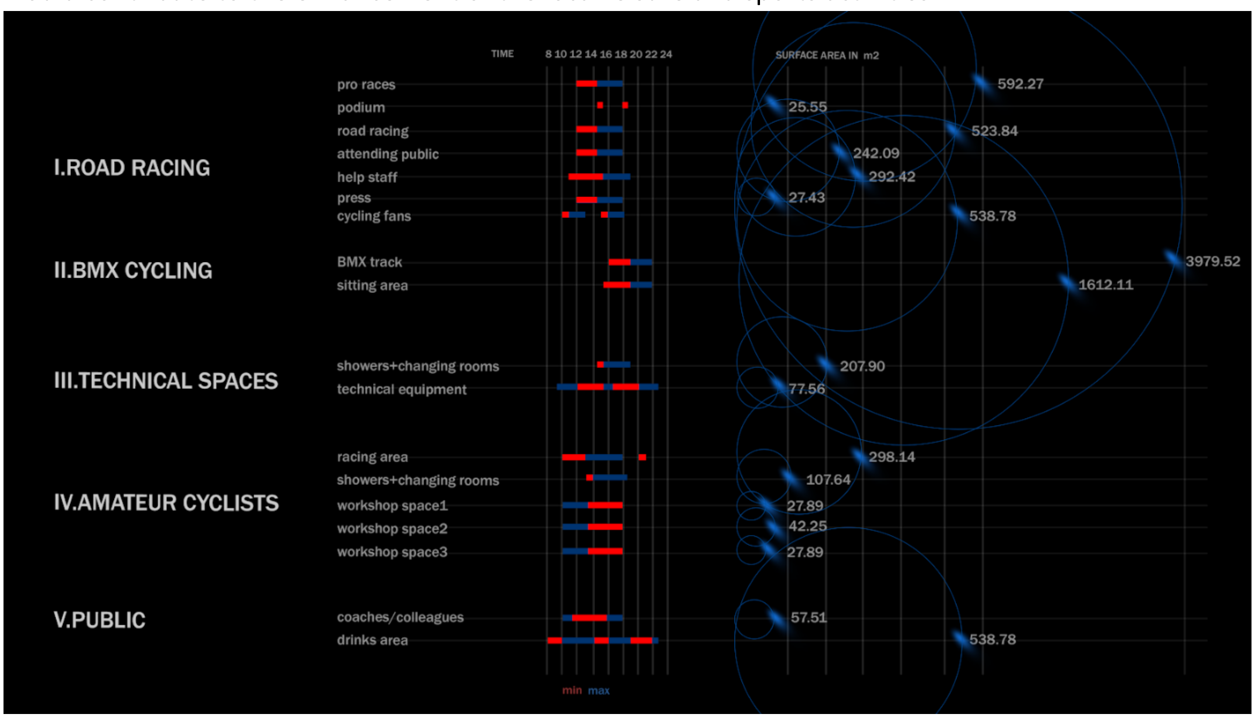

fig. 02. Parameters definition

Methods: Scientific relevance and applicability of research
A cyclist's reinterpretation of the Olympic Games is a valuable opportunity for the integration of computational design for different reasons. Having a data-based approach means that the algorithmic logic could be applied for similar projects in different global settings.
I performed an analysis of the functional and user requirements and defined the following parameters: surface area, number of users per function, pattern of use, height of space, visibility, intensity of use.

Based on these parameters and on my previous experiences, I chose Voronoi as mathematical model and geometrical tool to be applied across scales. I considered three dimensional Voronoi graphs, though not lacking in complexity, to be an apt tool for the distribution of spaces, structural loads, degrees of visual porosity, sunlight admission. The parameters were translated into point cloud configurations and the relationships and interactions between them determined the output. The design itself was the result of a bottom up approach of data translation as well as a top-down design approach. The result is a continuous structure that establishes a relationship to the quay, the river Seine and the city of Paris, as well as providing a dynamic venue for the development of cycling races.

Algorithmic approach and data-driven design

Utilizing the collected data, I designed scripts following the evolution of the process, in Grasshopper. During the preliminary site design phase, I used SpaceSyntax to generate configurations of the functional distribution, based on the size of the specific function and the connection.

fig. 03. SpaceSyntax for program configuration on site

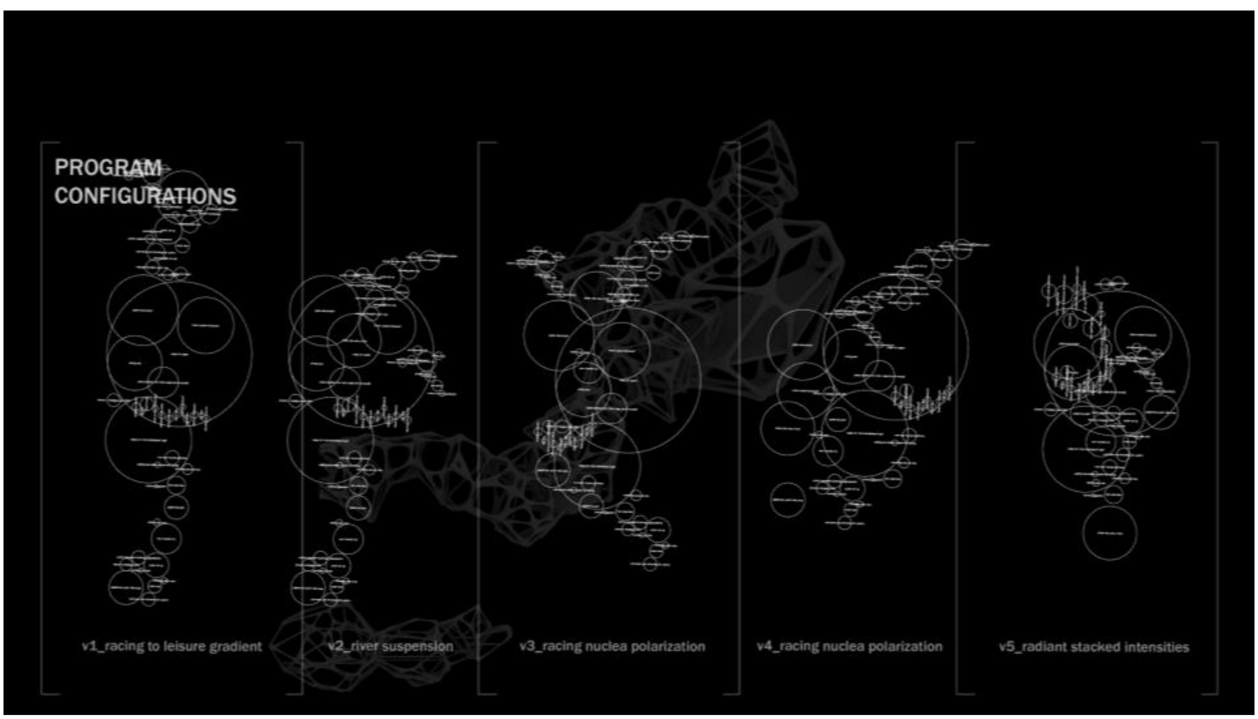

fig. 04.Iterations of program configuration according to functions size and location

This constituted the base for the spatial configuration of the project, which was not fixed, but evolved through time, according to changes in the program, urban context limitations, design decisions. The first attempt at materializing the configuration spatially was by using the iterations created with SpaceSyntax to create a three dimensional point cloud, that represented the base of a Voronoi diagram.

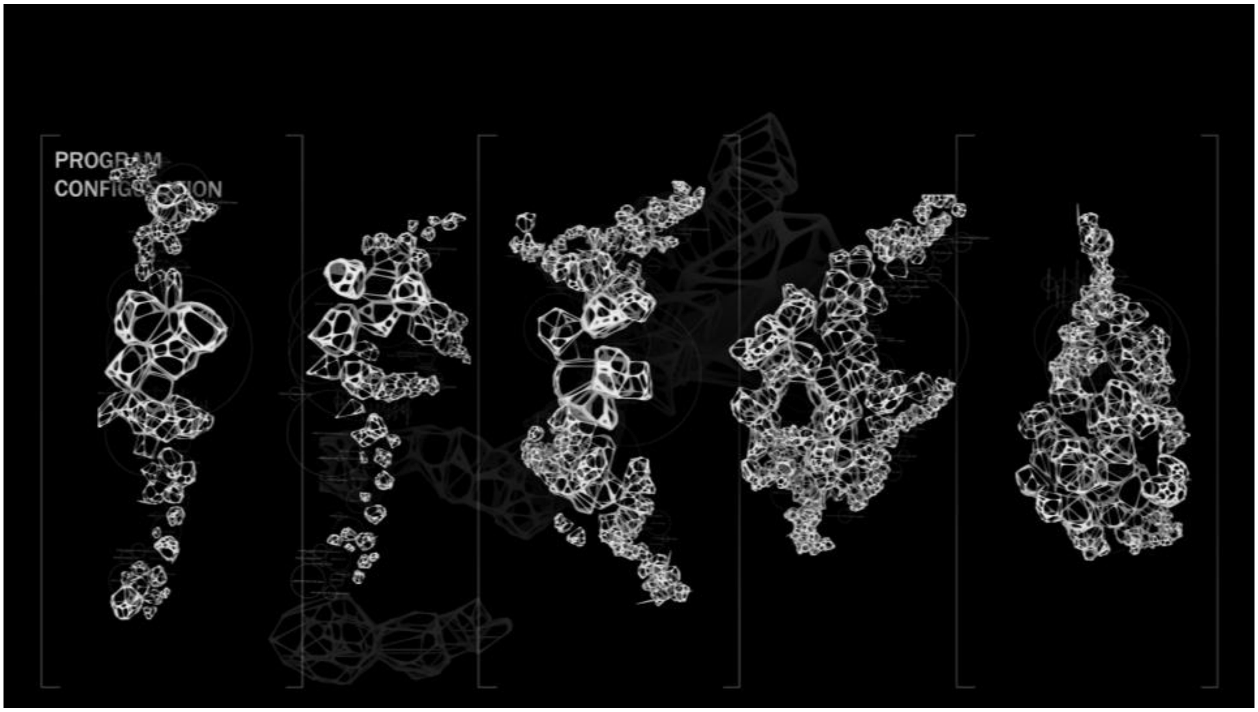

fig. 05. Iterations of program configuration as 3-dimensional Voronoi clusters

However, one important aspect of the Cycling venue and the activities that would take place there is its dynamism. This quality needed to be both present in terms of the space being a formal, stylistic expression of movement, as well as a functional enabler of dynamic movement. People of all ages would be able to cycle through the park, watch the races, interact with people who share the same passion and gain different perspectives of the pro-athletes and what performance entails.

During the workshop we created together at the beginning, I explored the idea of dynamism through 3d models. We then utilized Millipede to calculate the compressive and tensile stresses spreading through the structure and materialized these as a network of beams. This sustained the idea of material economy, where material would only be used where necessary for load support.

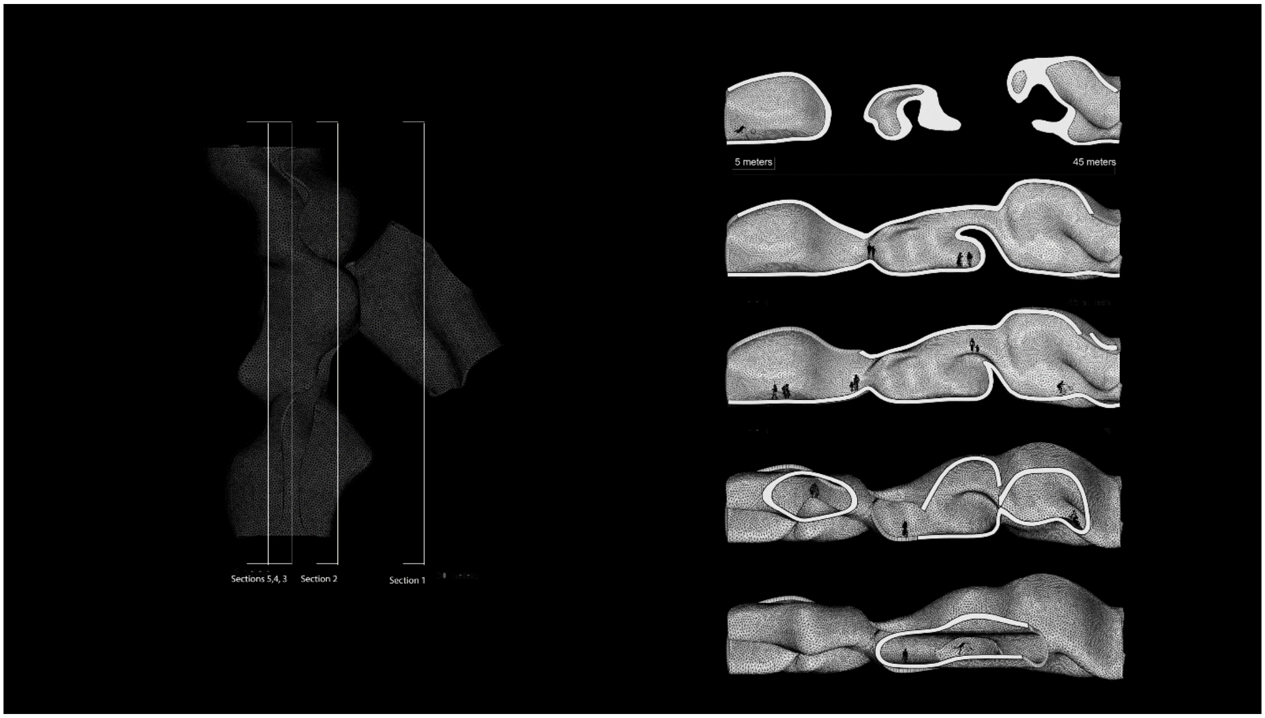

fig. 06. Cross Sections through dynamic environment conceptual model

During this workshop, we also developed robotic manufacturing toolpaths, which resulted in the subtractive manufacturing of a wooden beam of curved geometry, as selected from our proposed structure. This process was informative of the capabilities of robotic manufacturing for obtaining a customized fragment, as well as regarding the by-products and challenges of such a process. For instance, as preparation for the robotic milling, the beams had to be glued and held in place for drying. Furthermore, due to the size and reach capabilities of the robotic arm, the beam was milled first across half the cross-section, and consequently turned 90 degrees on the bed and milling the other half. The material that is removed through this process is a coarse wooden powder, which I intended to be utilized for 3d printing of urban furniture.

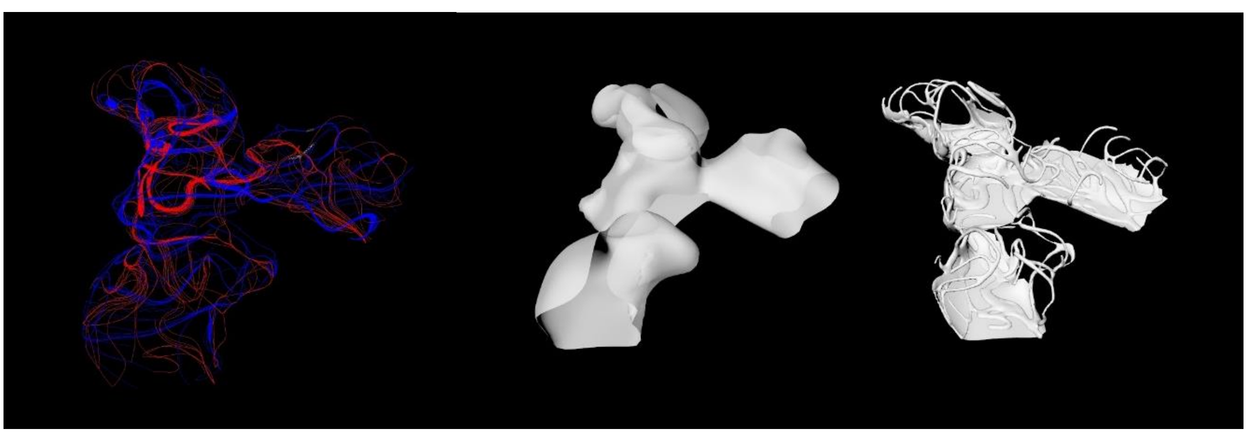
fig. 07. 3d model concept of a dynamic environment. Structural analysis and beam network

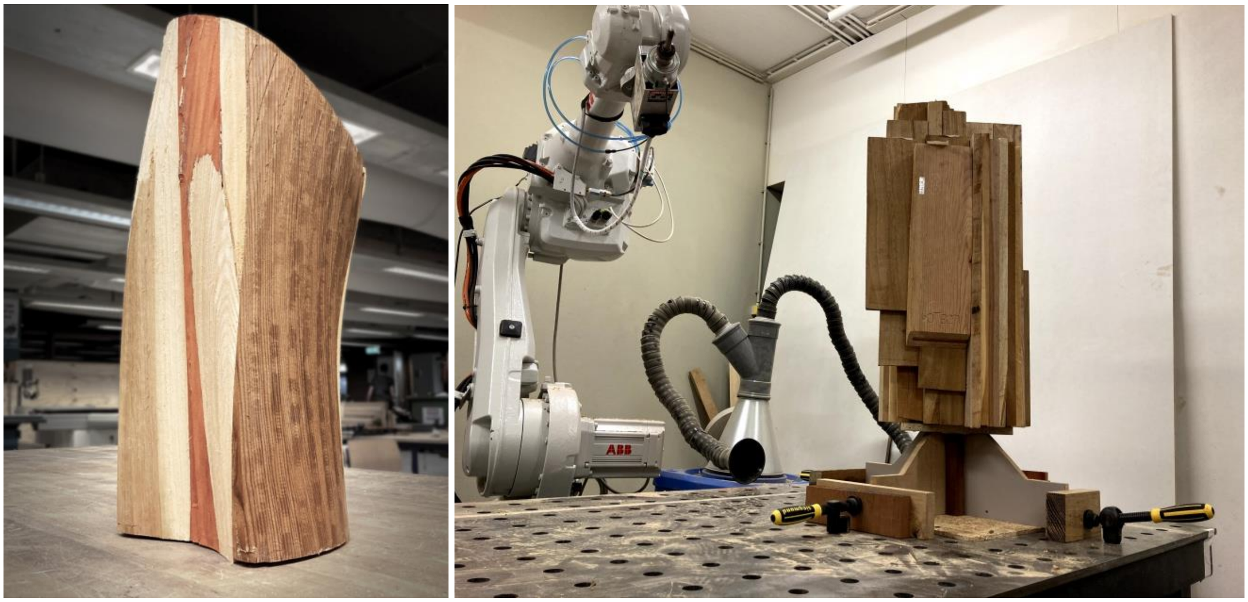

fig. 08. Subtractive manufacturing of a wooden beam obtained from wood from left-over industrial processes

Researchers from RMIT University have developed a series of “design tectonics” obtained through additive manufacturing with a polymer containing wood powder (Alima et al., 2022). Subsequent to the 3d printing, these porous structures were infused with mycellium, a living organism that grows and consumes the wood. In the framework of a post-Olympics material circularity, my initial idea was to similarly apply this research and gradually transform these “scaffolds”, benches, tables, chairs, into compost that would be used for growing plants, by controlled decay.

fig. 09. “Bio Scafoolds” – prototypes of 3d printed wood structures infused by mycellium, RMIT, Natalie Alima

However, at an architectural level such an intervention might pose a couple of challenges:

1. Although such infusion with mycellium has been done also previously, all applications are at small prototype scale. Thus, more research is necessary to understand the structural aspect (structural failure) of such a process.
2. Health hazards may be associated with any type of fungi growing extensively on an urban structure, especially when accessible to children. Further research would clarify possible alternatives with similar effect, but representing no health risk.

The three-dimensional Voronoi logic was applied at both macro and meso scale. At macro scale it enabled an organic distribution of the functions on site and continuity between the various spaces within a dynamic environment. At meso scale it allowed for a customized distribution of material,

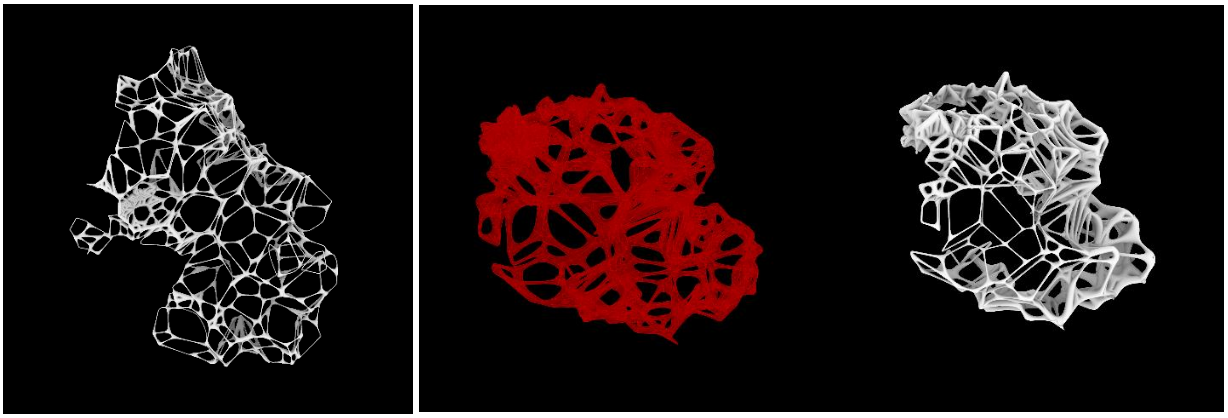

fig. 10. Three dimensional Voronoi shell lattice.

according to the structural analysis previously performed in Millipede. From this analysis, which was done on the macro level Voronoi shells representing the function-spaces, I extracted the compressive loads and created an algorithm for a meso-structure.
This design has a denser structure of cells corresponding to higher compressive strain and it was created by mapping the compression lines with a higher density point cloud. The design goal is to achieve an increased stiffness in the structure where compression strain would be higher. Instead of projecting a two-dimensional Voronoi lattice onto a curved surface like it is commonly done by computational designers, I create a shell that preserves the three-dimensionality of the spatial Voronoi lattice. The quality of such an approach is that the loads of the structure are distributed.

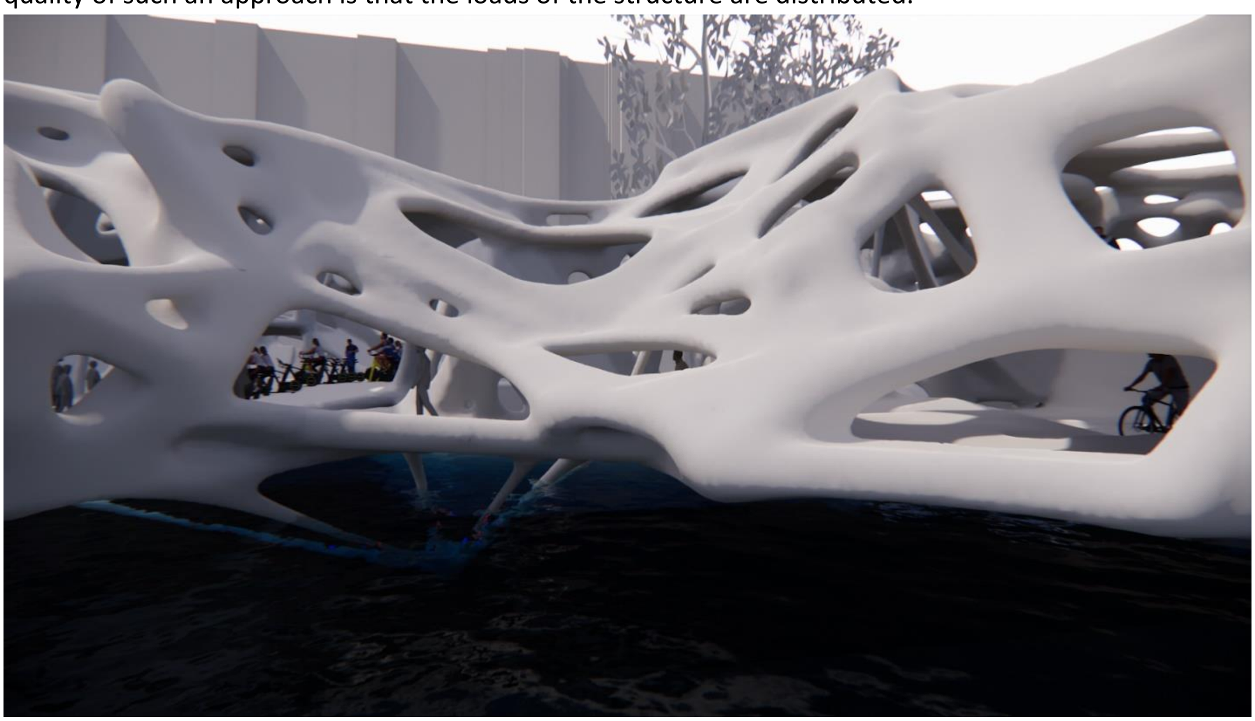

fig. 11 Building shell based on Voronoi lattice

The challenge in this scenario is that the edges of a cell can result spiky, larger than desired and hard to control by simply modifying the point cloud. Thus, I designed an algorithm based on vector forces to “pull” the cell corners closer to the shell of the function-space, while maintaining the shell’s three-dimensionality.

Optimization of the design shell in relation to the desired climate behavior

In the period between P4 and P5, I re-analyzed the relation between the size of the openings in the structure, their location, and the solar analysis of the proposed base geometry for the Paris climate case. Some design alterations were made, based on two main factors:

1. Large openings corresponding to high radiation are an opportunity for energy generation, through the integration of solar cells. Correspondingly the solar cells provide partial shadow to the indoor spaces.
2. A gradual variation in openings from private/public spaces: private spaces, situated at the west, have smaller openings. Public spaces, corresponding to the restaurant area at the east, have larger openings.

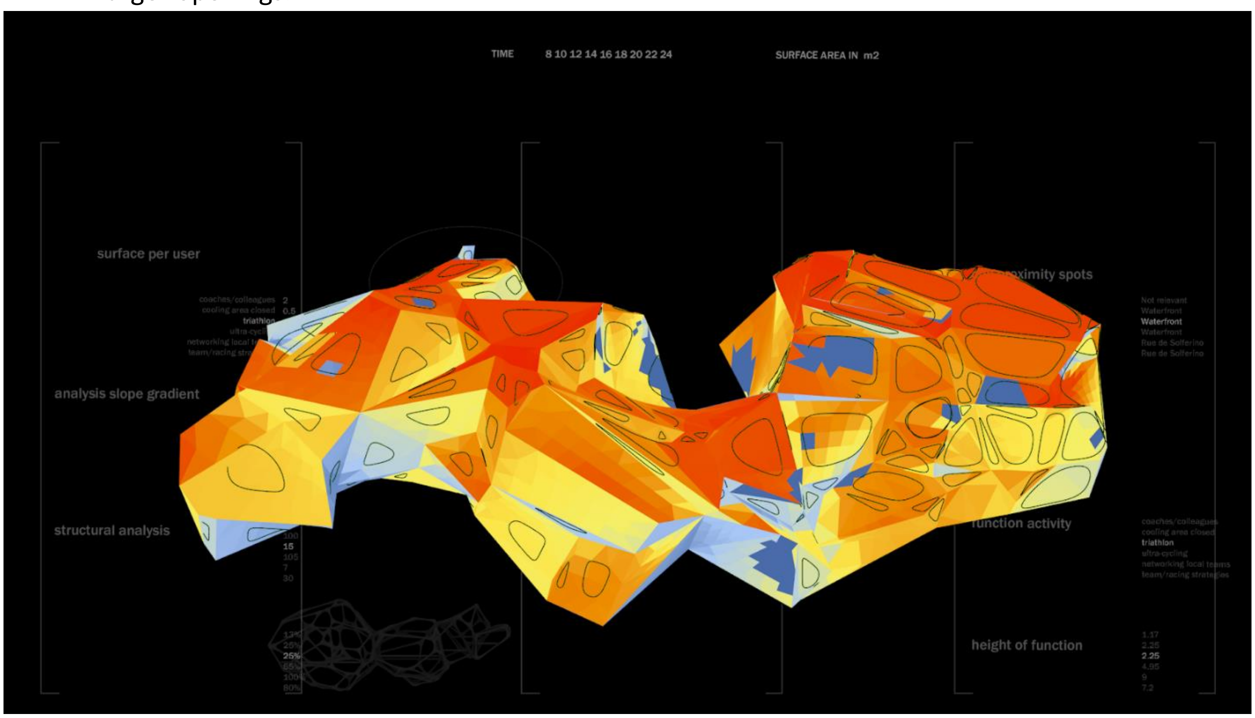

Fig. 12 Radiation analysis in relation to panelization

Reflection on materiality

Of particular relevance for the Olympic Venue was the optimal use of material, and its circularity, which justifies my choice of working with residue wood pieces resulting from industrial activities. In terms of material optimization, the structure is distributed in a differentiated manner, according to local loads. I believe this symbiosis between computational tools and differentiated materiality was successfully applied, achieving also the spatial and stylistic results I had initially envisioned.

As part of the circularity logic, the resulting wood powder from the robotic milling process would be re-used to 3d print the furniture for the Olympics. Based on existing research, I have considered implementing a a mycellium culture that could be injected in the porous structure of the 3d printed wood and gradually grow to replace it.
However, based on research developed so far, a better understanding regarding the process of growth and deterioration of a structure is necessary. Secondly, the availability of mycellium within arm's reach might constitute a safety hazard.

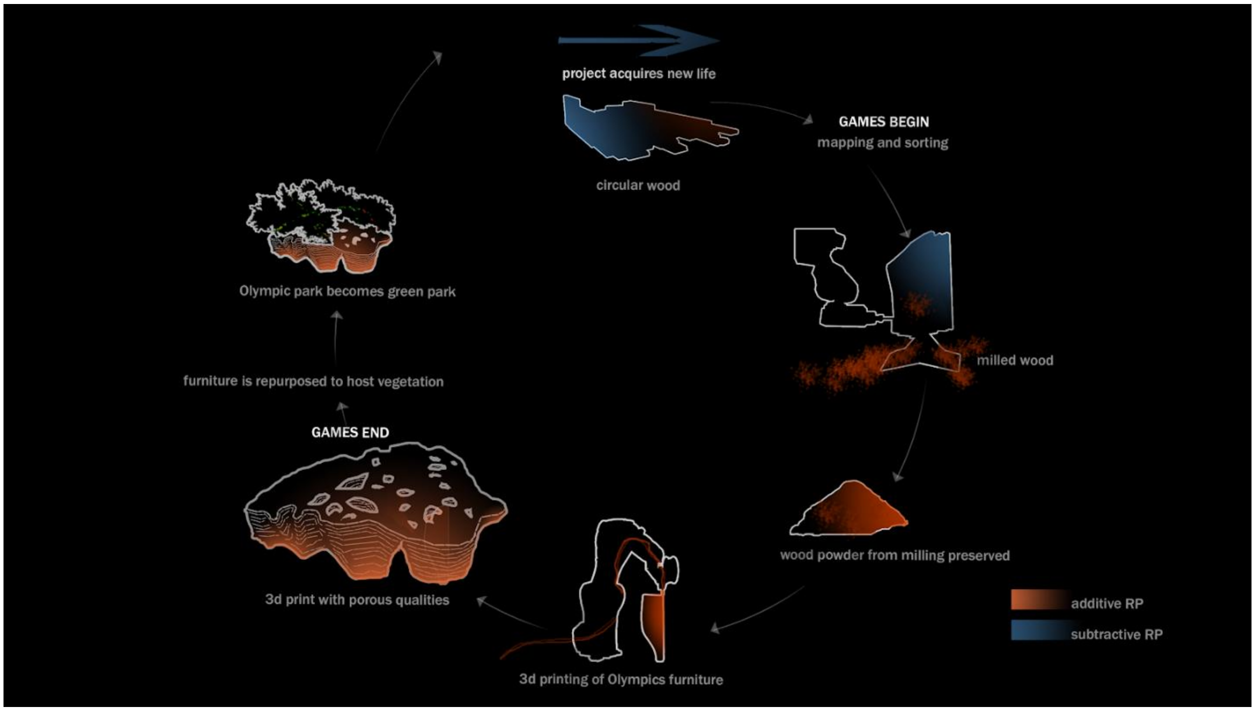

fig. 13 Circularity scheme

The post-Olympic scenario which I chose instead is to preserve the structure on-site for the following four years, an Olympic cycle, including light commercial activities. Consequently, the structure would be transported and re-assembled in a suitable riverside location of an European city.

The Olympic Games and the Robotic Building Lab at TU Delft

The character of the Robotic Building Lab is reflected in the exploration of a wide array of applications of robotics in architecture, ranging from robotic manufacturing techniques to physical re-configuration of habitats and optimization of environmental comfort by manipulation of the information collected through sensing devices.
The design of a project for the Cycling Venue of the Olympic Games within the Robotic Lab represented a specific kind of challenge, due to the different set of tools utilized, which informs the design thinking. Initially I explored the possibility using bio-polymers for the construction. Due to the low structural bearing capabilities of these polymers relative to the large scale of the project, I chose to work with recycled wood robotically manufactured structures, more viable regarding the scale of the venue.
The current project appeals to the Robotic Lab's previous research on robotic manufacturing, in particular robotic milling and additive manufacturing with wood. An area explored mostly at the level of prototyping so far, the exploration of robotically milled wood could offer in practice the possibility to create architectural elements with complex geometries also from recycled material. A workshop at the

beginning of the graduation year, focused on Milling as end result Robotic Production technique, has been the main reference for learning regarding assembly and stacking. It has also showed the limitations of working with circular wood, since this might require pre-processing for tackling irregularities, and the use of glue, with a higher environmental impact.

Reflection on the Studio's methodological approach

The robotic processes explored in connection to robotic manufacturing are supported by computational design techniques, namely through Grasshopper, a plug-in of the 3d modelling software Rhino. In terms of the technique process, I preferred the 3d Voronoi logic for its capacity to integrate the different functional requirements within a continuous structure. This is applicable from macro, mezzo to micro scale. One of the challenges with using this mathematical model in design is the domino effect it has, making it really challenging to control elements of construction individually without influencing the configuration.

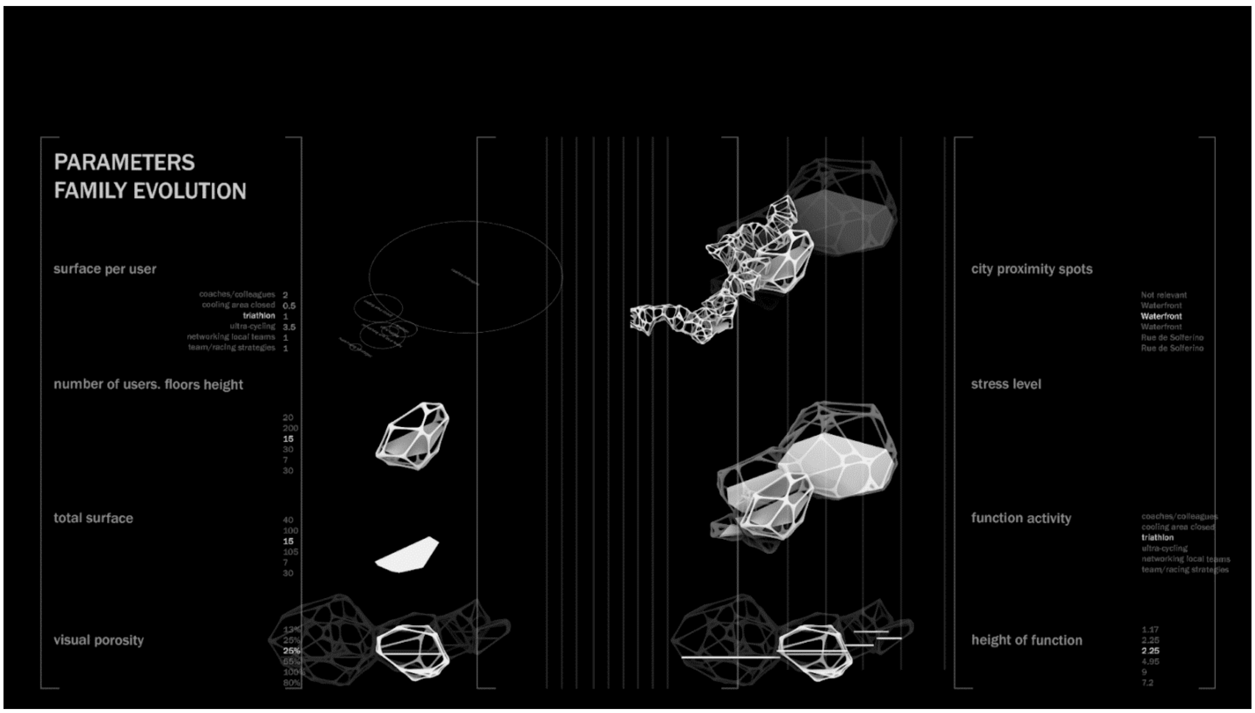

fig. 14 Site design iterations

Relevance and integration in the architect's practice. Potential applications

The exercise of developing a project for the Olympic Games helped me challenge the status quo of materiality as well as of program by having a closer reading of design from the perspective of affordances, and understand behaviors rather than assign pre-defined historical architectural solutions (such as typologies).

As far as the concept's applicability is concerned, our group together with professor Bier and the Hogeschool van Amsterdam has already performed the robotic manufacturing of a number of beams through robotic milling. However, when it comes to the whole building, scaling up the manufacturing

process would require a more concrete paradigm shift in the architectural building industry and the adoption of robotic arms already highly utilized in other industries. Furthermore, although I have developed scripts for a series of optimization scenarios, more research should be invested in rendering the structure optimally efficient from an engineering and material economy perspective.
The computational skills I have developed through this research are applicable at different scales. The reflection on Mathematics and Physics integrated in the computational thinking are not merely a means to an end, but a logical understanding through first principles of the relationship between geometry and structural behavior, where material knowledge is key.

Ethical issues

In its application in practice, the environmental ethical dilemma that remains is if the manufacturing technique adopted will indeed be more optimal than traditional ones in terms of re-use of materials and environmental impact, also considering the level of processing that corresponds to the robotic milling (from pre-processing to final product), particularly regarding up-scaling for mass production. The building industry is becoming more and more aware of the advantages of using industrial robots in producing customizable building elements, so it is viable to assume that more efficient technologies will be available in the near future.

Last word

In the future, I hope to be involved in the engineering of complex materials for Space applications, where robotic manufacturing is a must, in the hope of inspiring the wider adoption of such technologies.

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