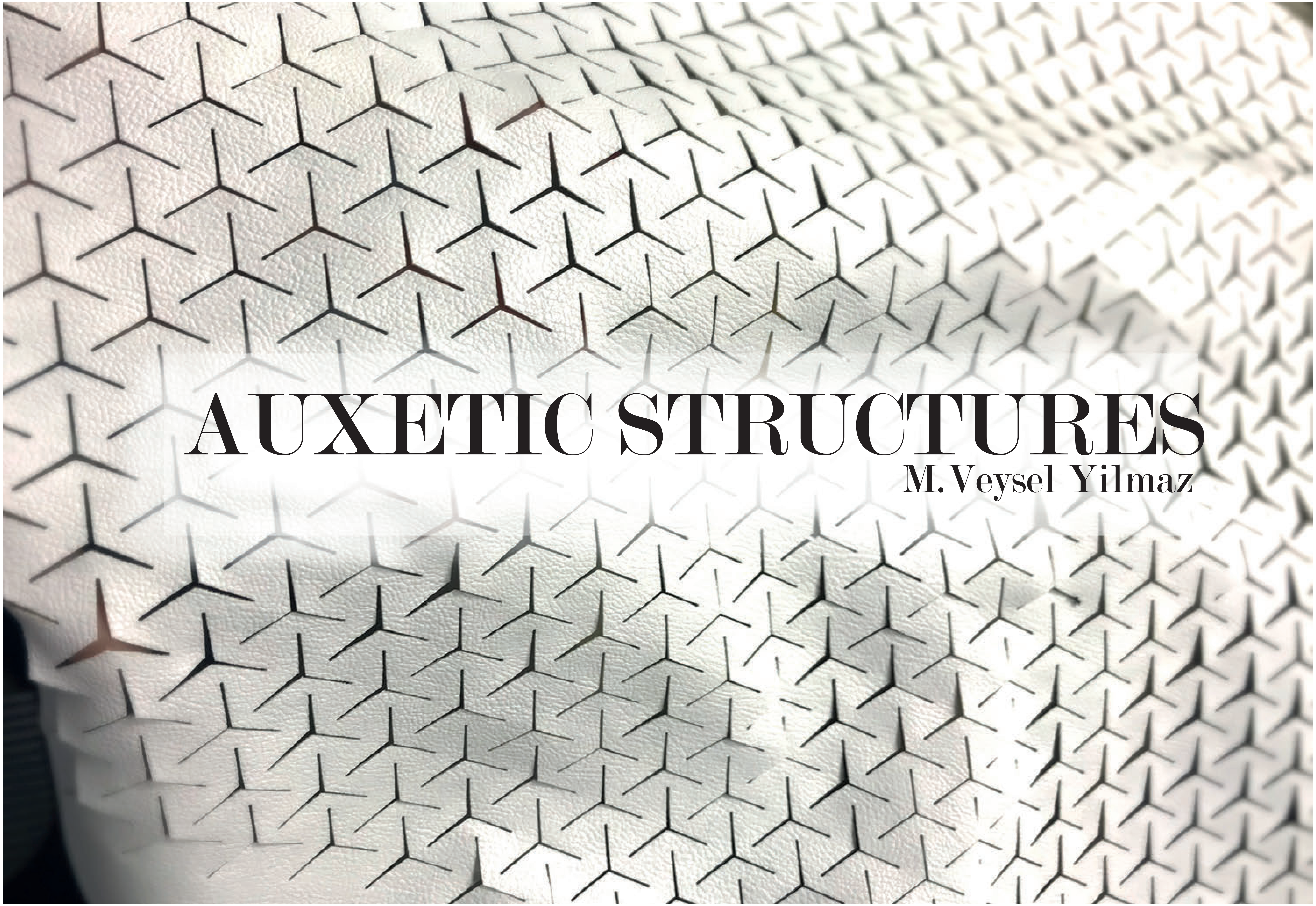


AUXETIC STRUCTURES

M.Veysel Yilmaz

1.INTRODUCTION

An auxetic pattern is a special type of pattern that displays a negative Poisson's ratio, meaning that when stretched in one direction, it expands in perpendicular directions instead of contracting. This is in contrast to most materials, which have a positive Poisson's ratio and contract in perpendicular directions when stretched.

Auxetic patterns can be found in various natural and synthetic materials, such as bone, wood, and some textiles. They are also used in engineering and design applications, such as in fabrics that can stretch in multiple directions, and in structures that can withstand impact and deformation. The unique properties of auxetic materials make them useful in a variety of fields, from aerospace and sports to medicine and fashion.

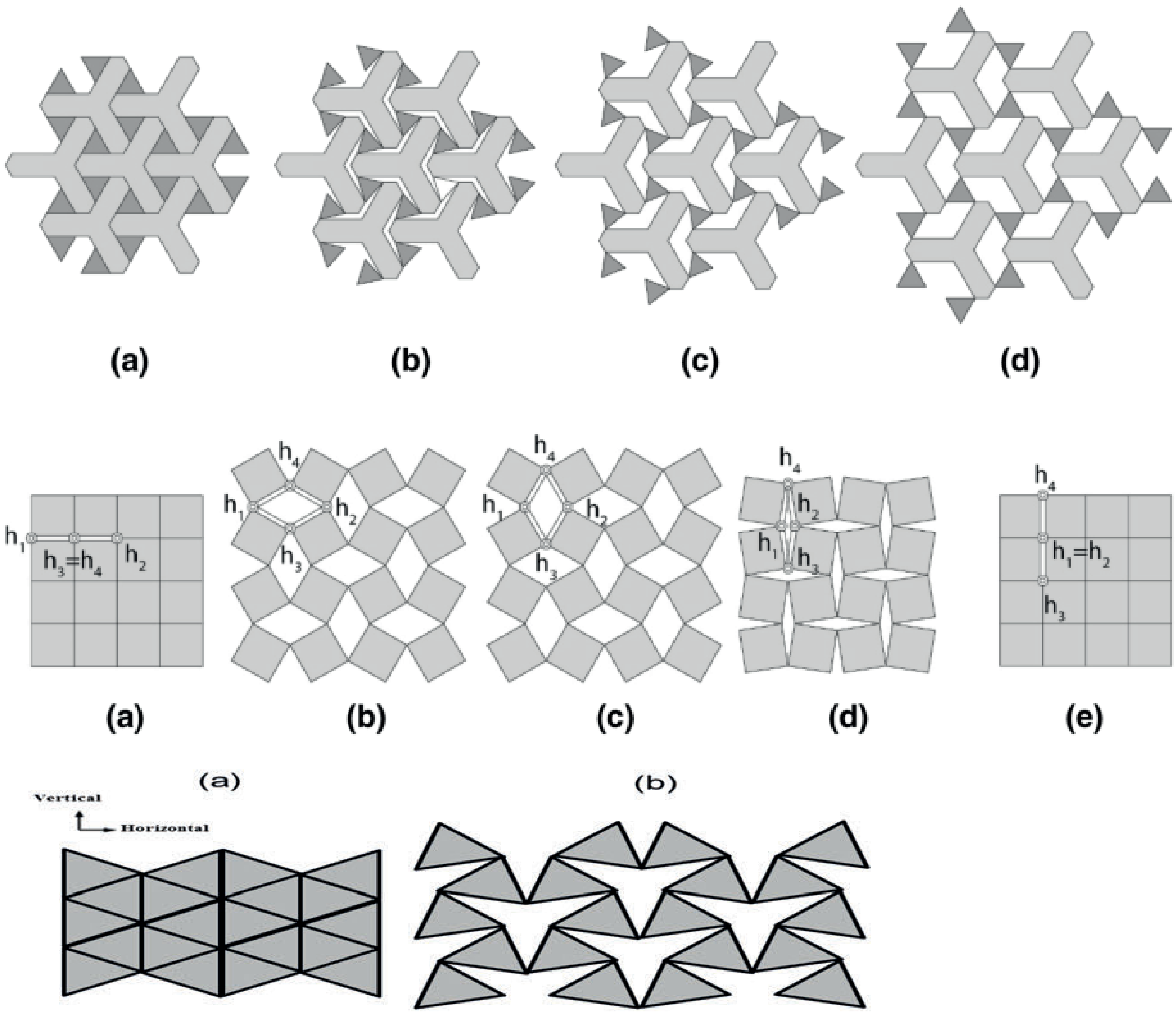


Figure 1. Different Auxetic Patterns

The key concept is a spatially graded auxetic pattern, where individual triangular elements are scaled to program the maximal local expansion factor required to achieve the global target shape.

In this study, I'm going to explore different approaches for free form structure by using auxetic triangles linkage pattern. The use of computational design systems and form-finding methods, such as Kangaroo in Grasshopper software, offers a powerful toolset for creating innovative and complex deployable structures. In this case, the focus is on using an auxetic triangle linkage pattern for a 3D deployable structure.

By investigating different approaches for freeform structures using auxetic structures, designers can explore new possibilities for adaptable and dynamic designs. This might involve experimenting with different configurations of auxetic triangles or combining them with other structural components to create more complex forms. Ultimately, the goal is to create a deployable structure that is not only functional and efficient, but also aesthetically compelling and responsive to its environment.

The key concept is a spatially graded auxetic pattern, where individual triangular elements are scaled to program the maximal local expansion factor required to achieve the 3d target shape. The expansion factor of triangles wil be already embaded in digital form and fabricated as a opened.

1.1 RELATED STUDIES

The desired target shape in the deployed state can be programmed into the auxetic structure by optimizing for suitable maximal expansion factors across the linkage, which in turn determine the spatial layout and sizing of linkage triangles.

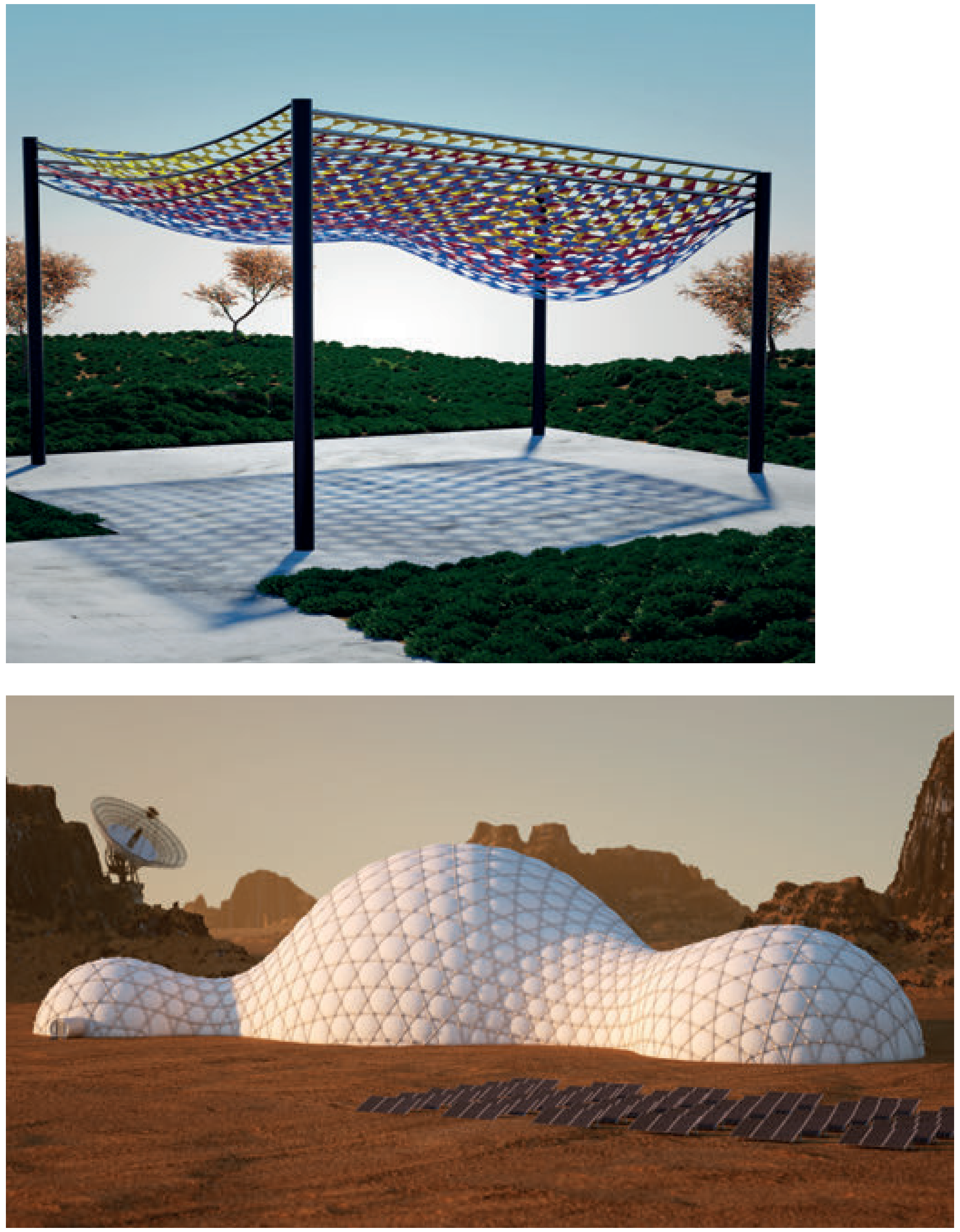


Figure 2. Computational Design of Deployable Auxetic Shells Mina Konakovic-Lukovic, Pavle Konakovic, Mark Pauly

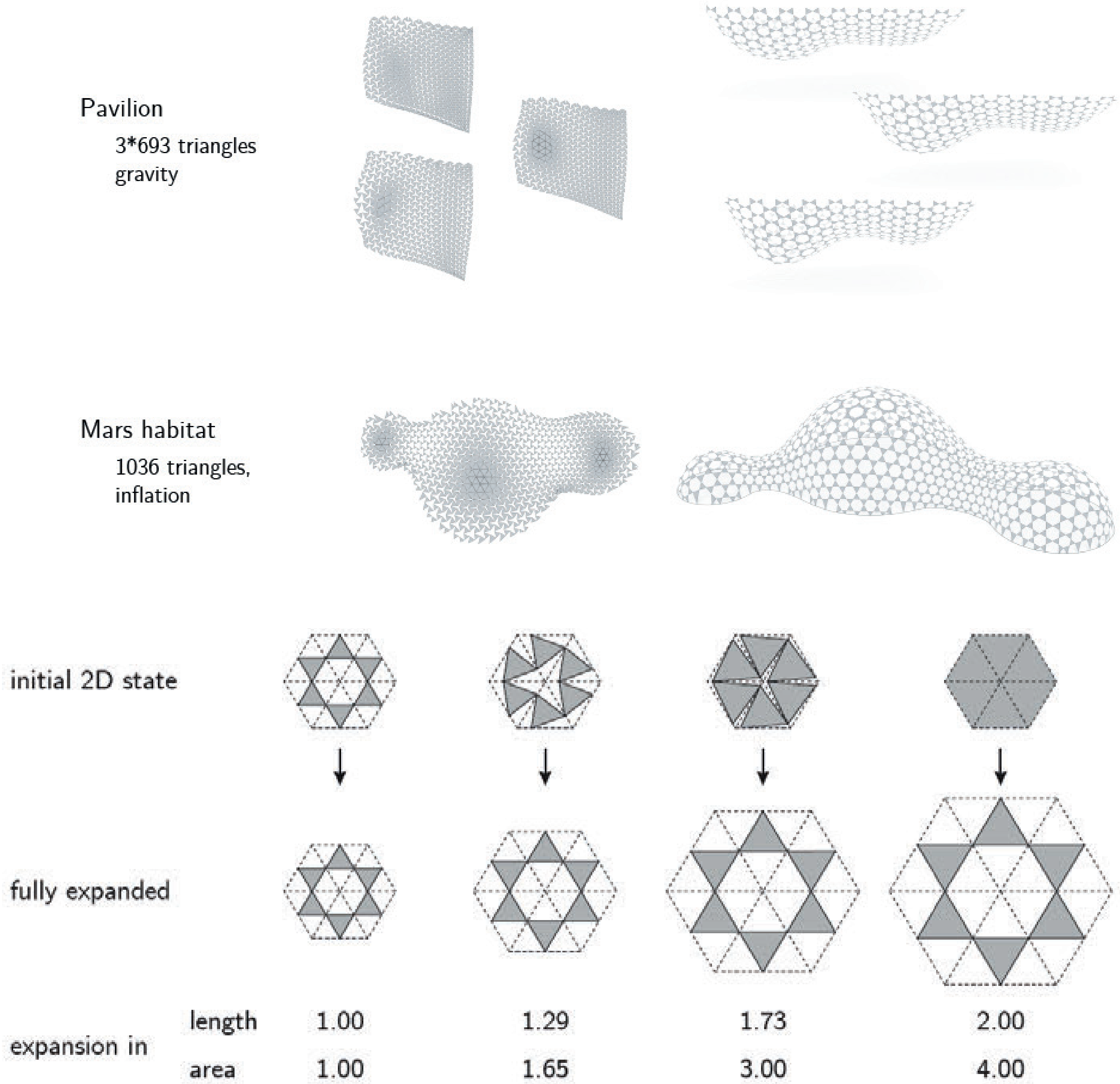


Figure 3. Computational Design of Deployable Auxetic Shells Mina Konakovic-Lukovic, Pavle Konakovic, Mark Pauly

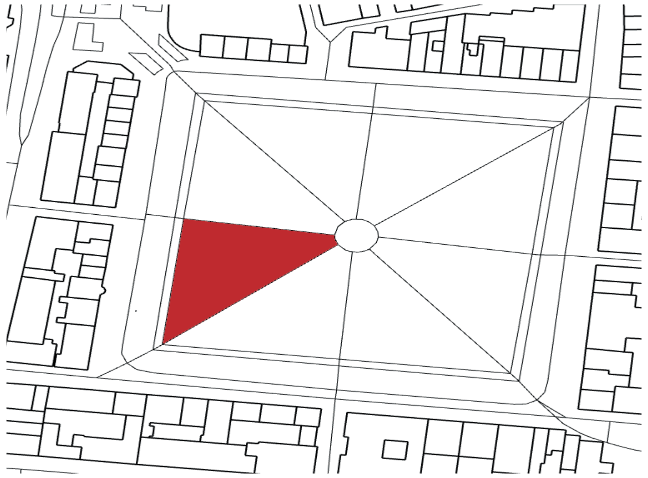
2.Study Topic

The aim of this study is to explore the use of auxetic structures in the design of shelters for people. This property is particularly useful in the design of shelters, as it allows for greater flexibility and adaptability in the structure.
To create the desired 3D shape for the shelter, computational form finding methods will be used. This involves using computer algorithms to generate and optimize different forms for the structure, based on specific design parameters and constraints. This process allows for the creation of complex shapes that may be difficult or impossible to achieve using traditional design methods.

In the fabrication stage, a combination of 3D printing and laser cutting will be used to create the physical structure. By combining these fabrication methods with the use of auxetic structures and computational form finding, it is hoped that the resulting shelter design will be both innovative and functional.

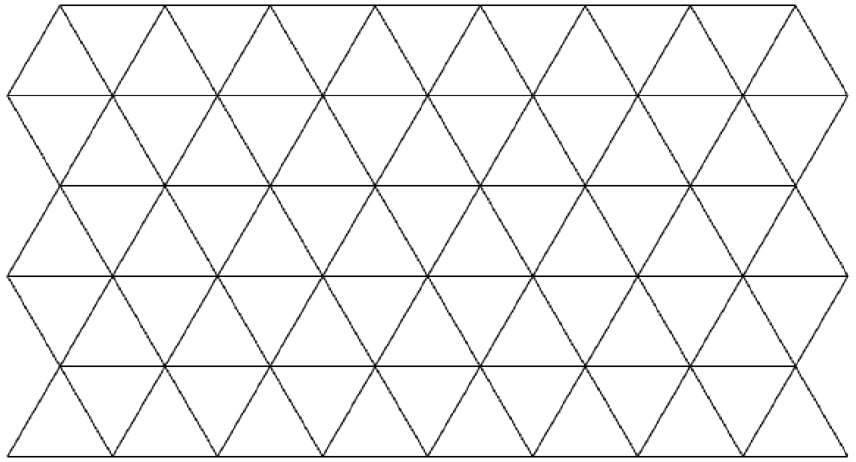
LOCATION: QUEEN SQUARE, BRISTOL

Figure 4. Queen Square, Bristol

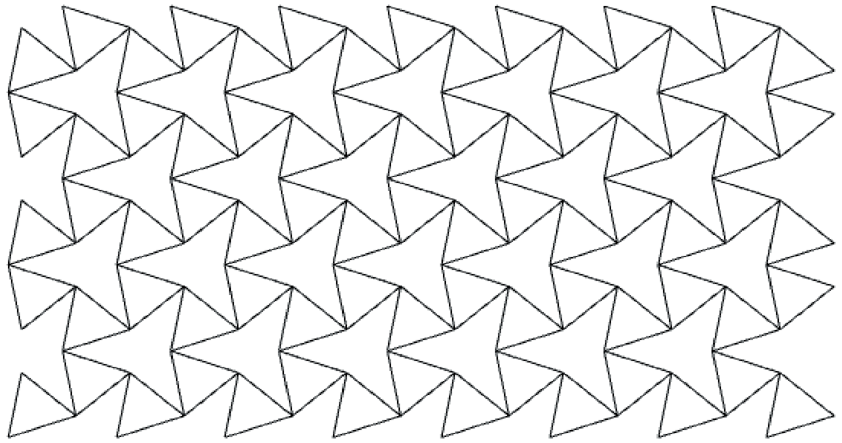


According to location, I selected triangular initial boundary for shelter

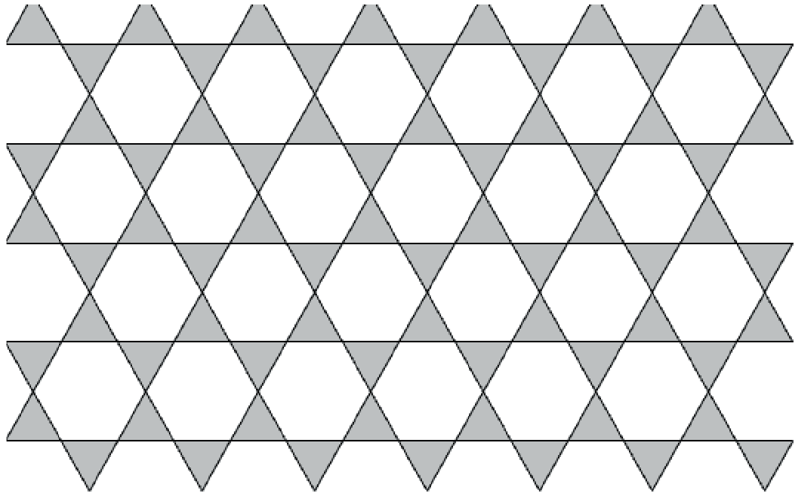
For this study, Triangular auxetic linkage is selected.



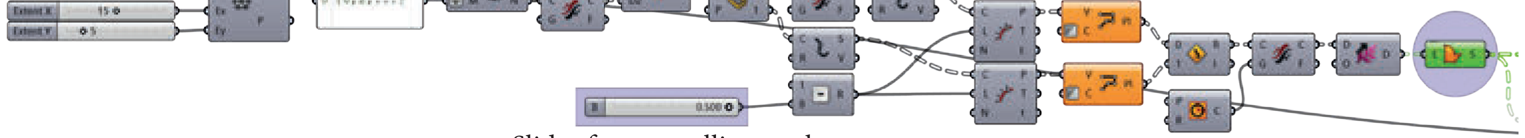
FULLY CLOSED



PARTIALLY OPENED

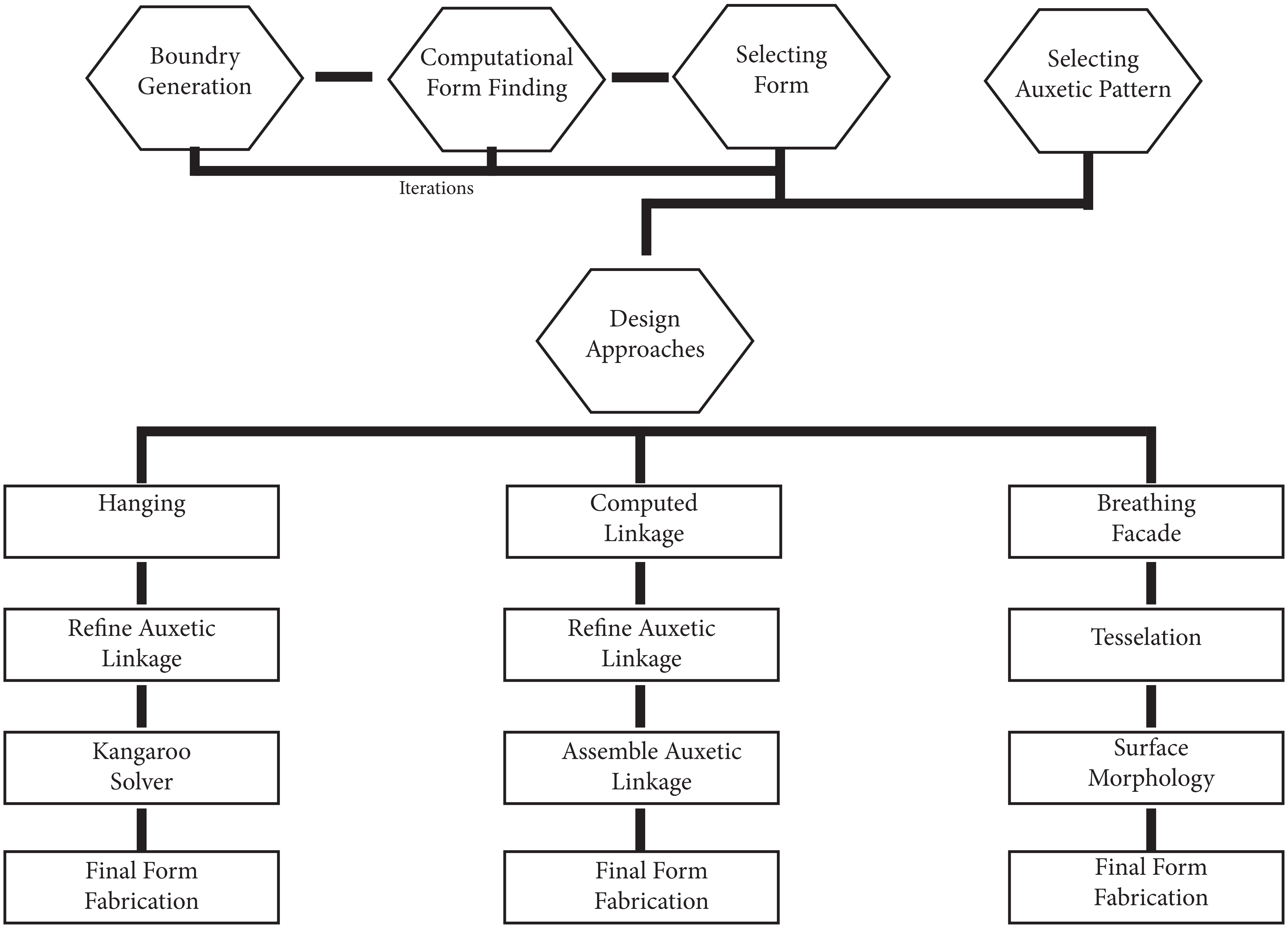


FULLY OPENED



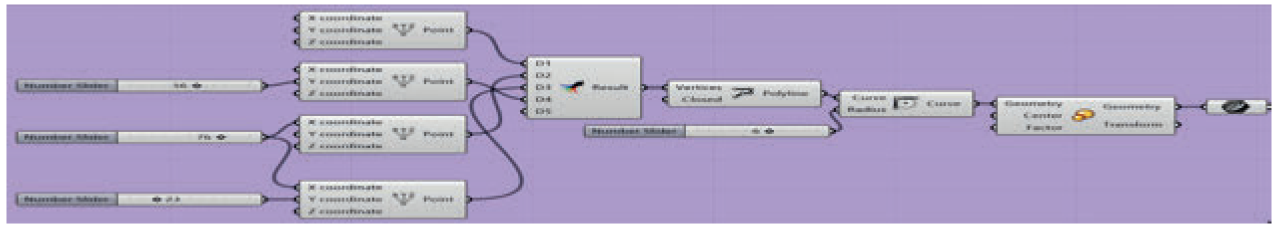
Slider for controlling angle

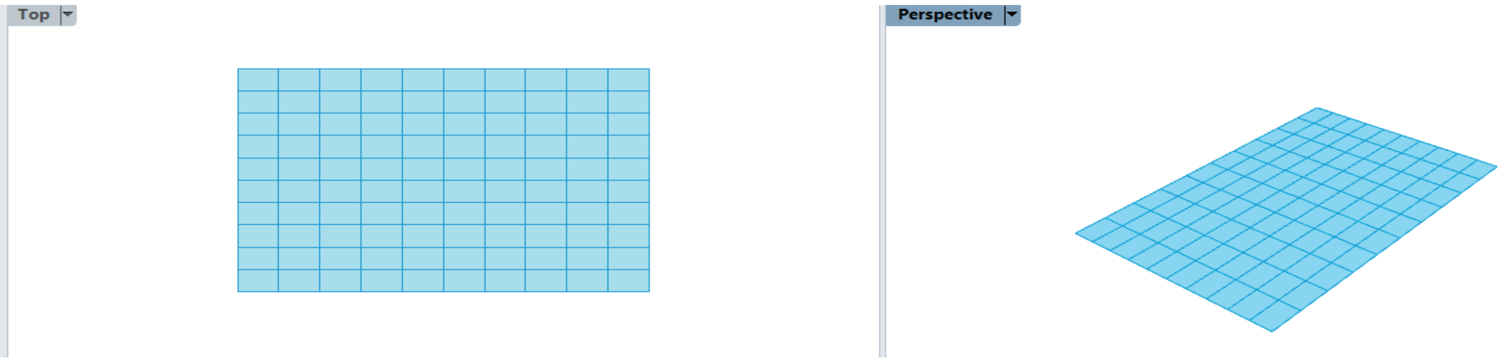
2.1 Methodology

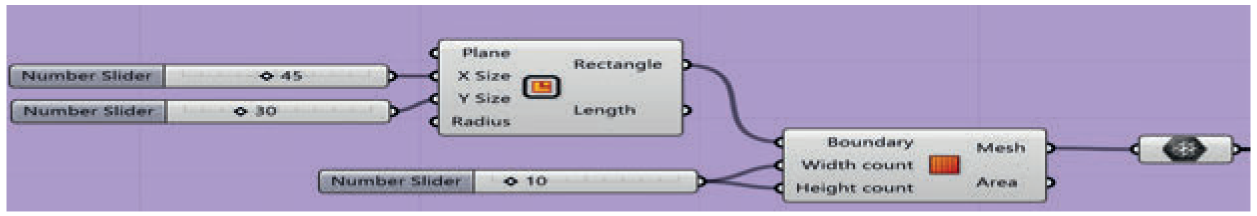


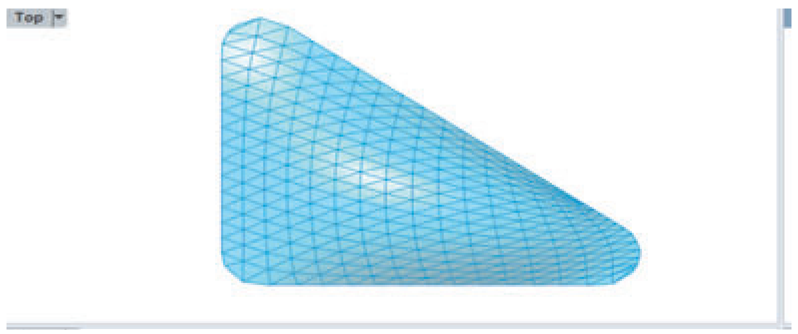
3. Form Finding

I started with rectangular planer mesh and created target planer surface accoding to location and bended that rectangular mesh to desired planer surface



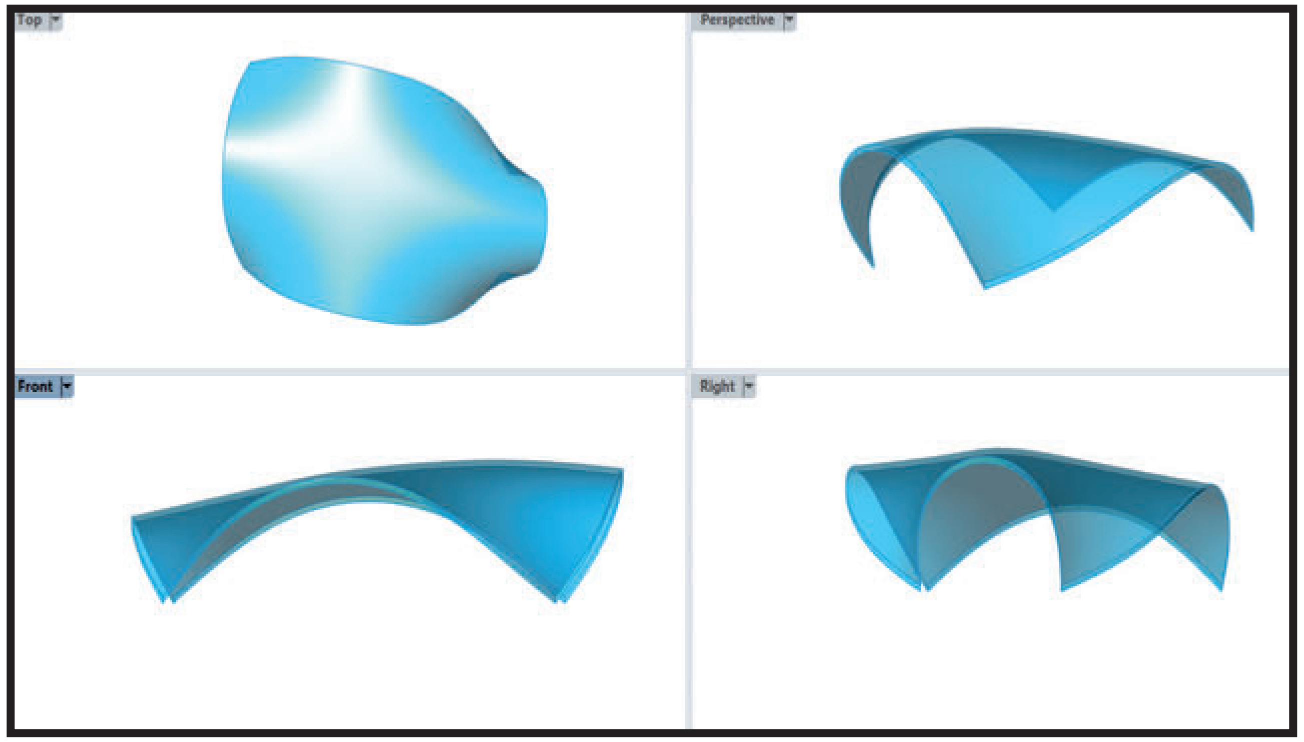




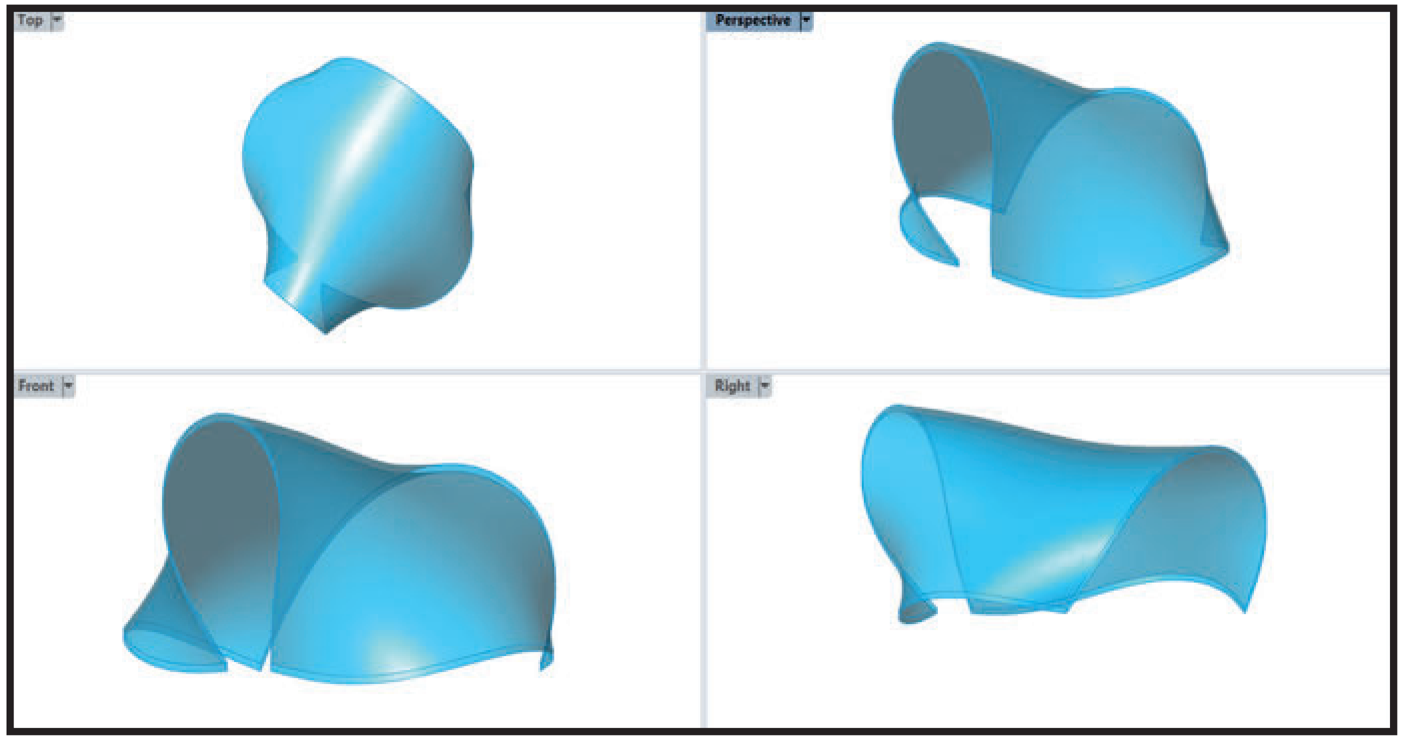


3.1 Form Finding Iterations

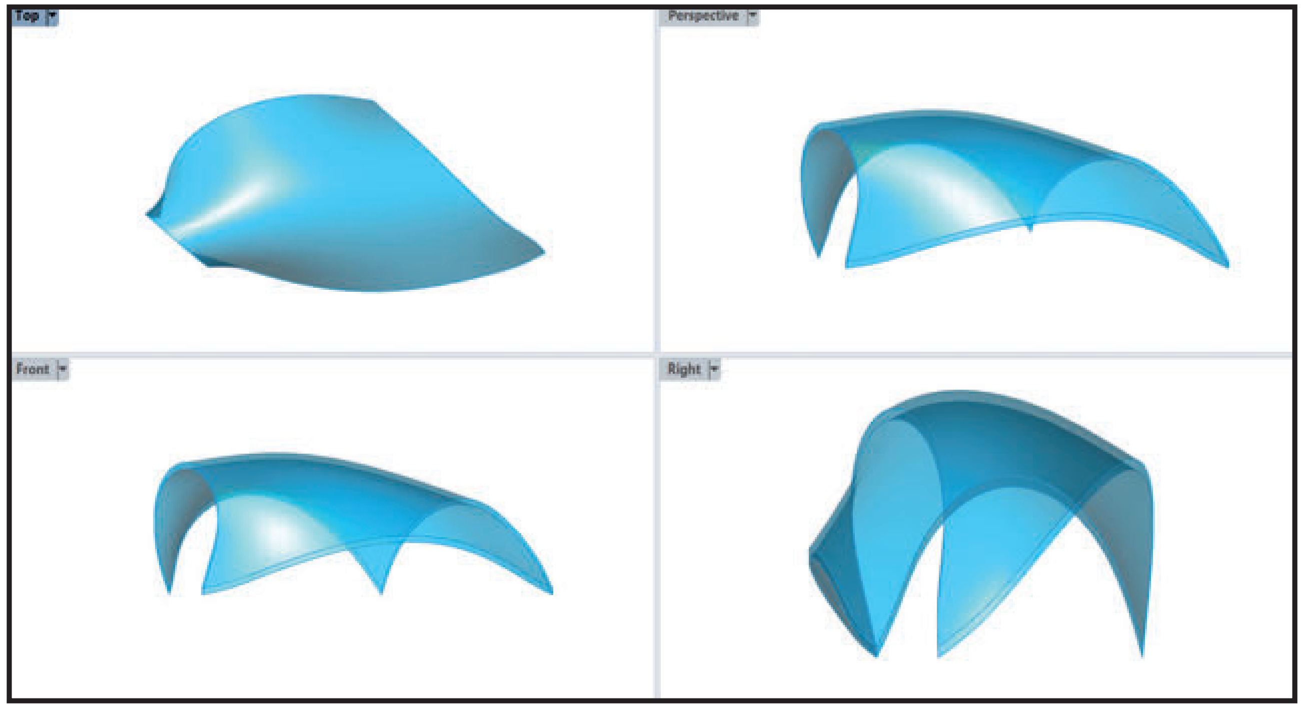
By changing anchor points, loads and parameters I got different form iterations.



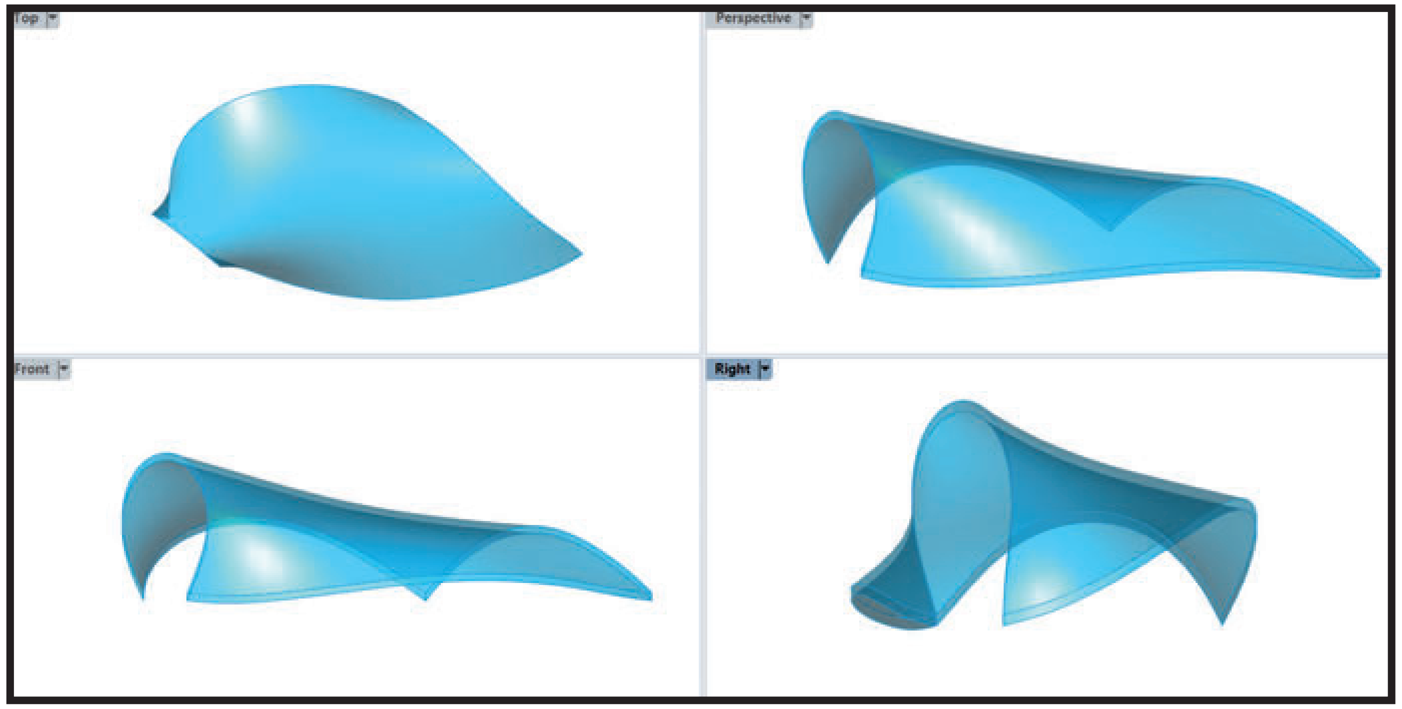
Iteration 1



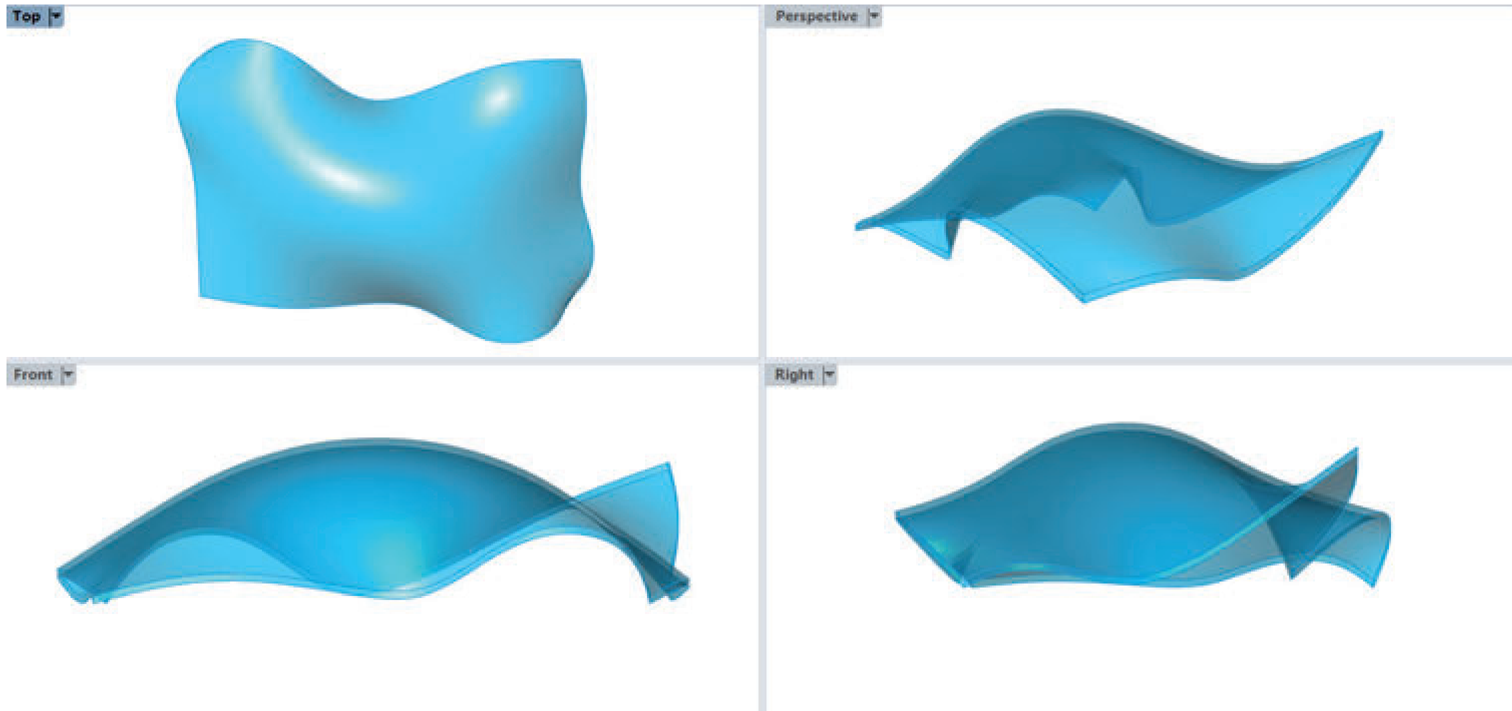
Iteration 2



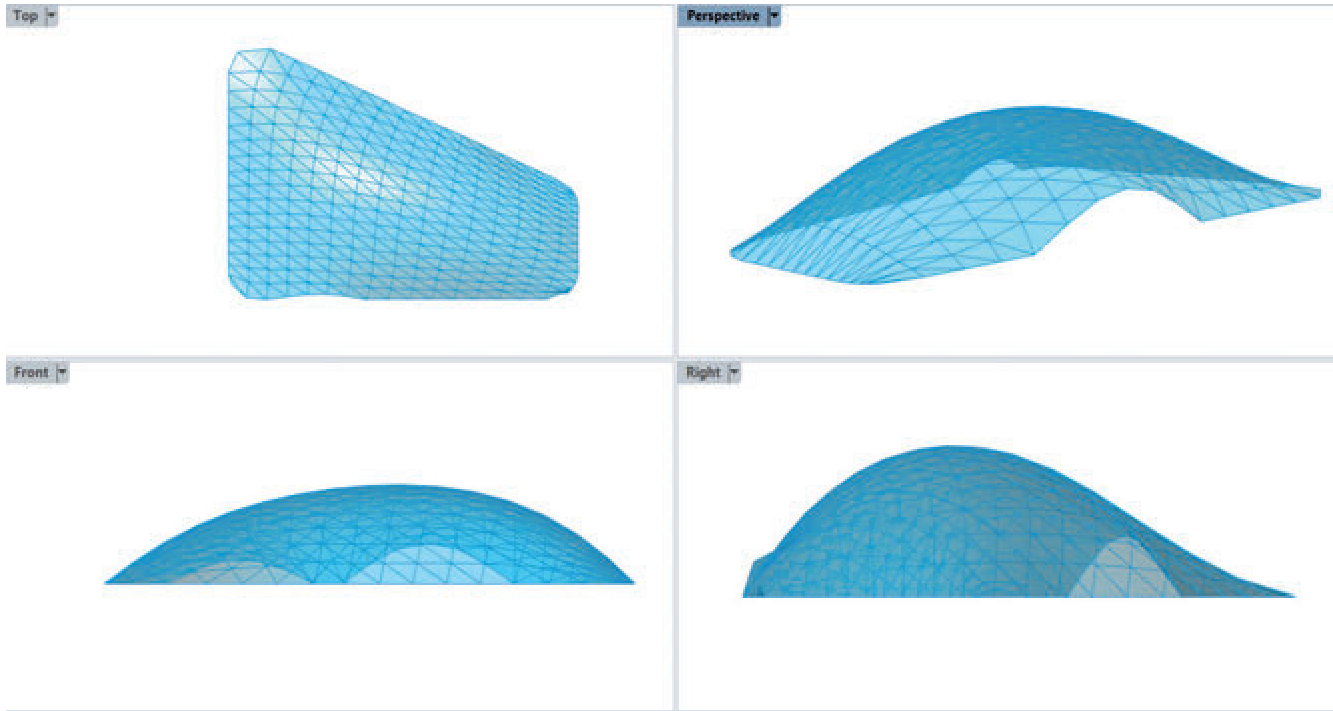
Iteration 3



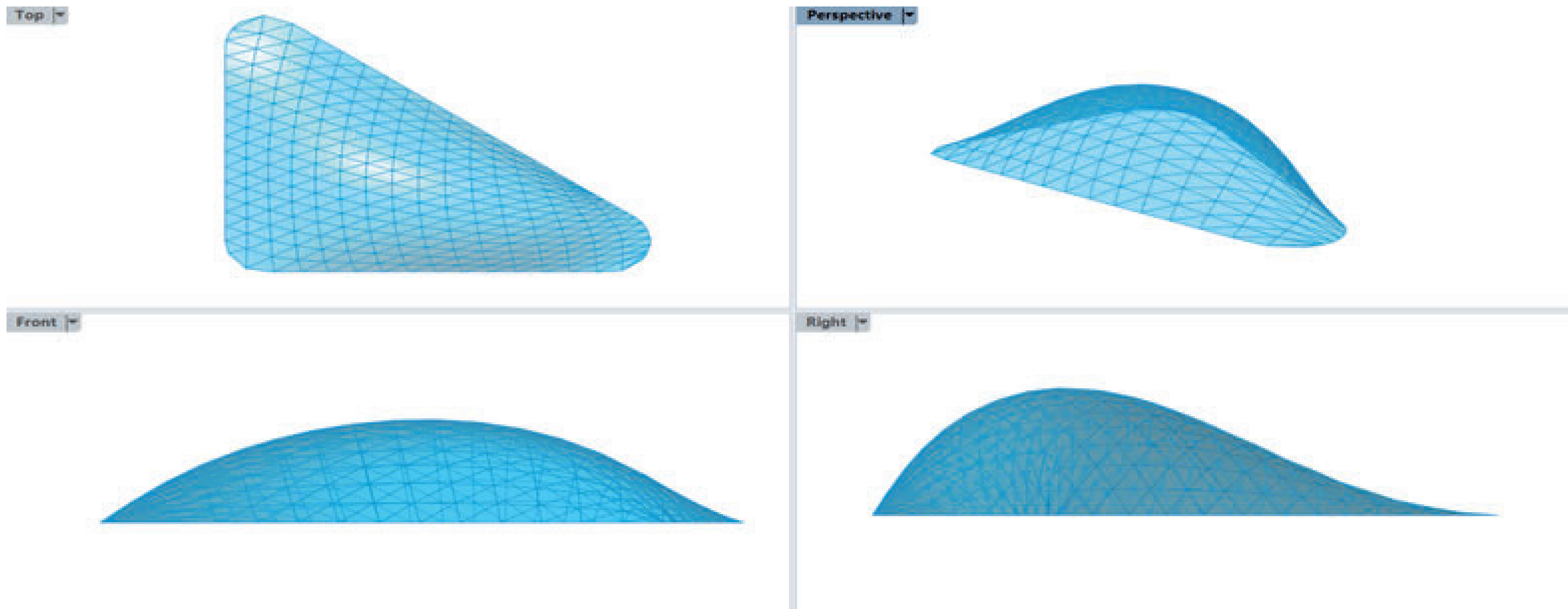
Iteration 4



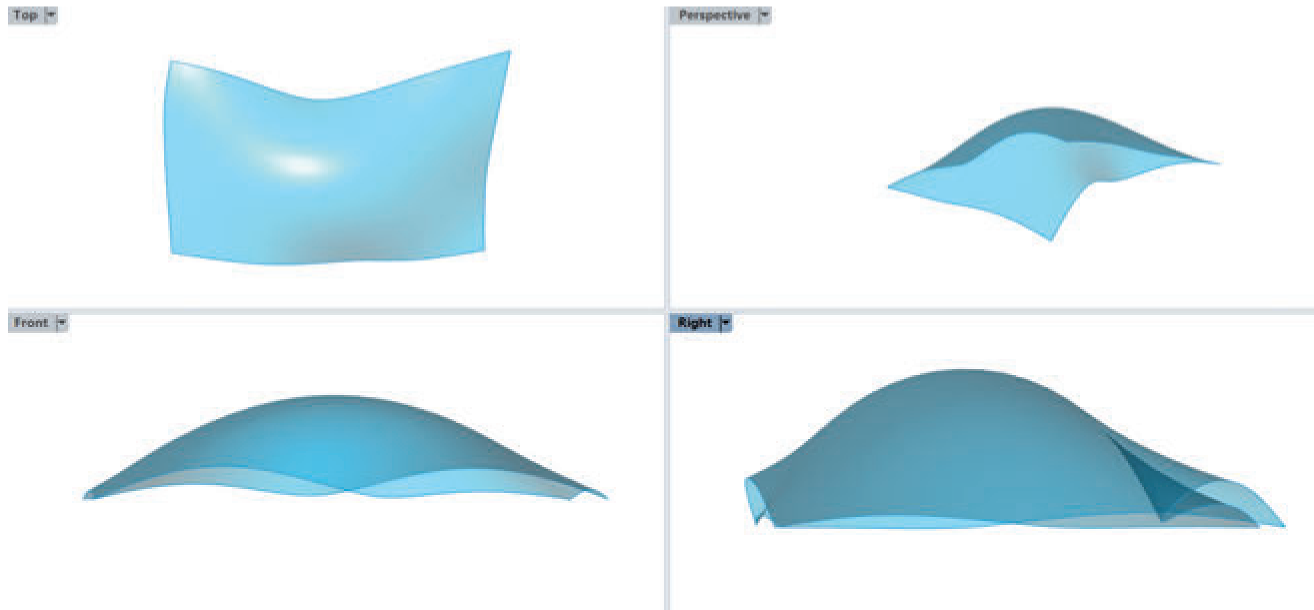
Iteration 5



Iteration 6



Iteration 7



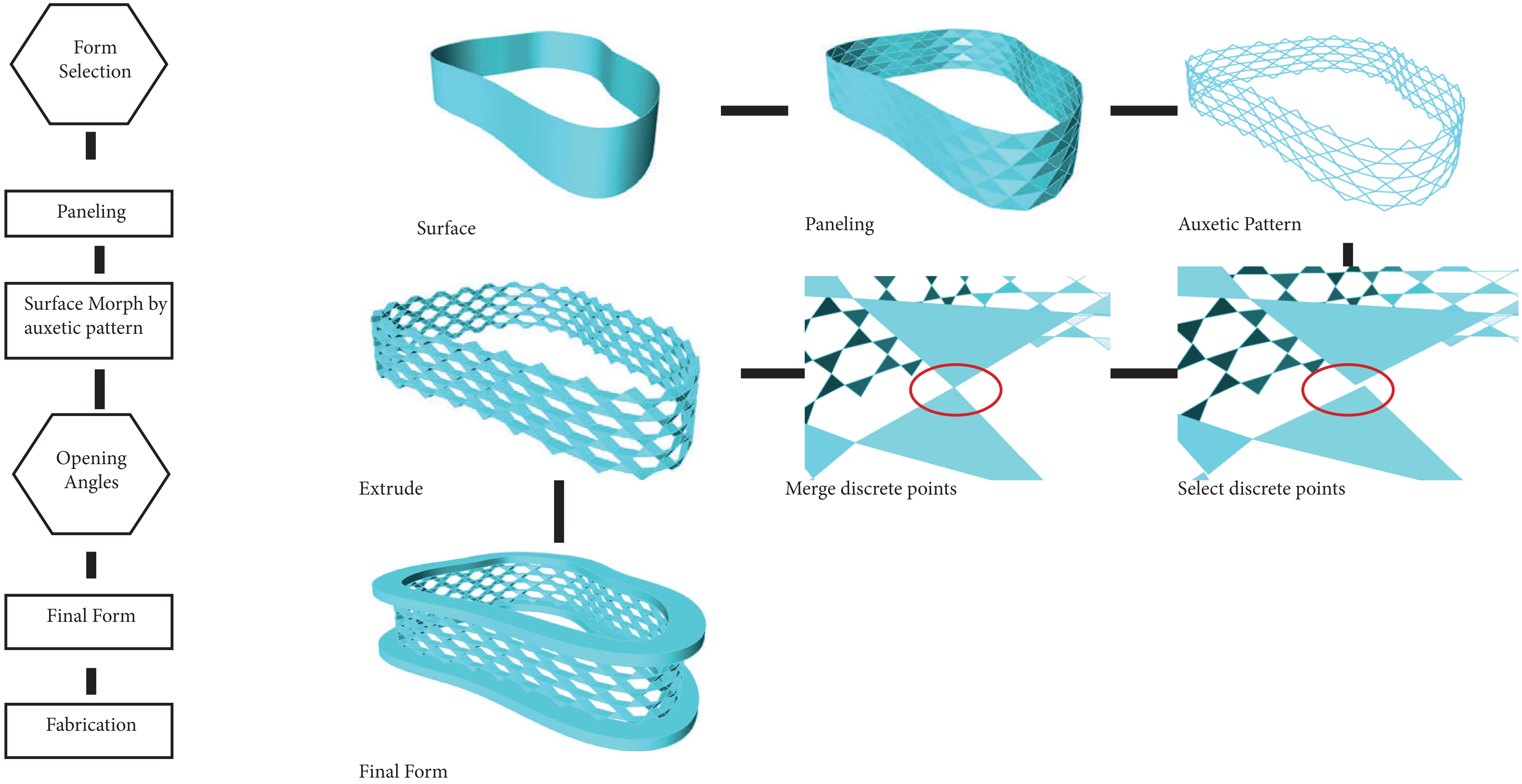
Iteration 8

After form iteration, auxetic pattern will be applied to selected forms in each approach.

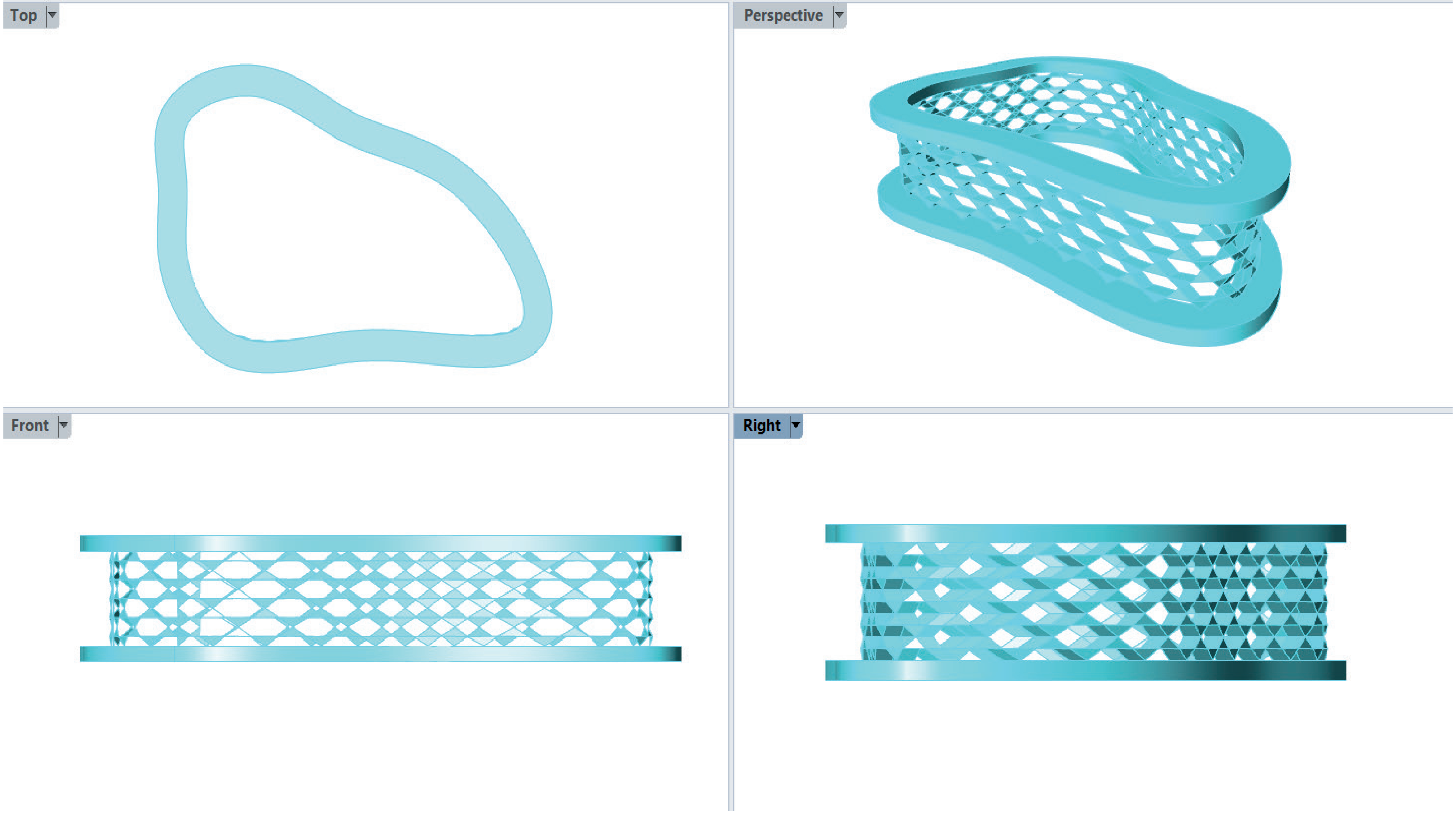
4. Design Process

4.1 Breathing Facade

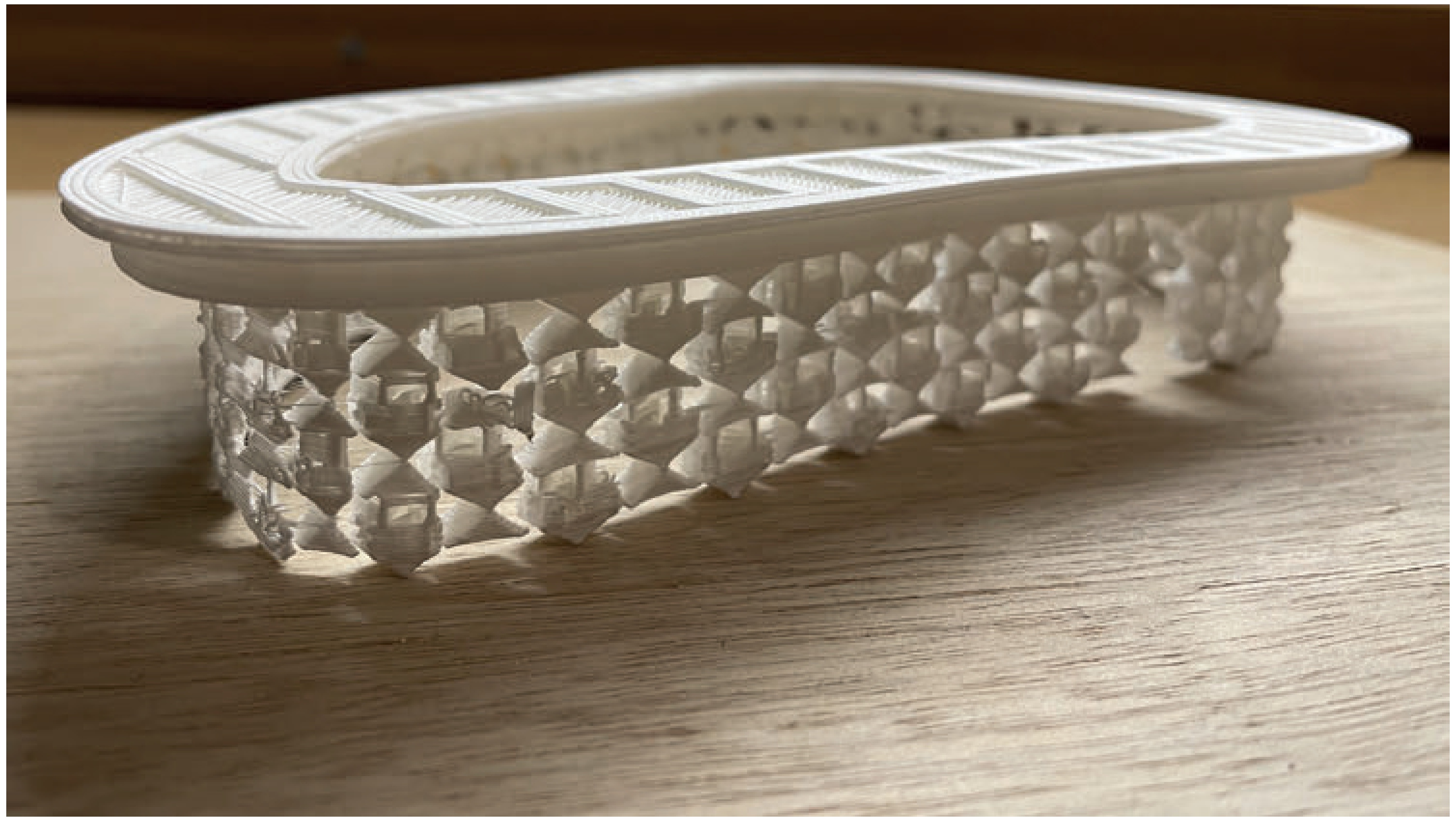
By applying an auxetic pattern to the target facades, the surface of the material can expand and contract in response to changes in wind. This can help to improve indoor air quality by allowing for increased airflow. In addition, the use of auxetic structures on facades can help to reduce the need for mechanical ventilation systems, which can be expensive to operate and maintain.



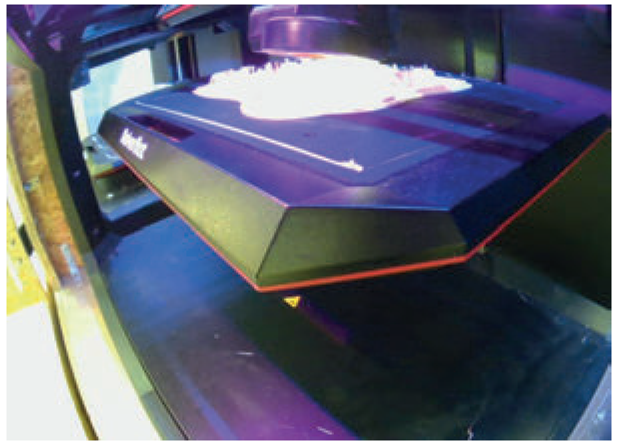
4.1.2 Breathing Facade Final Form

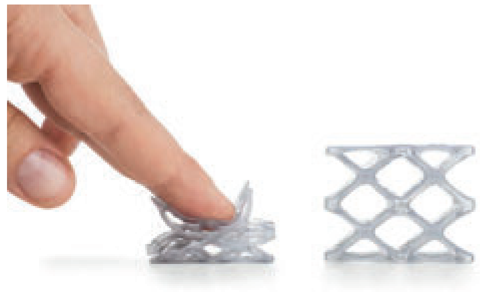


4.1.2 Breathing Facade Fabrication

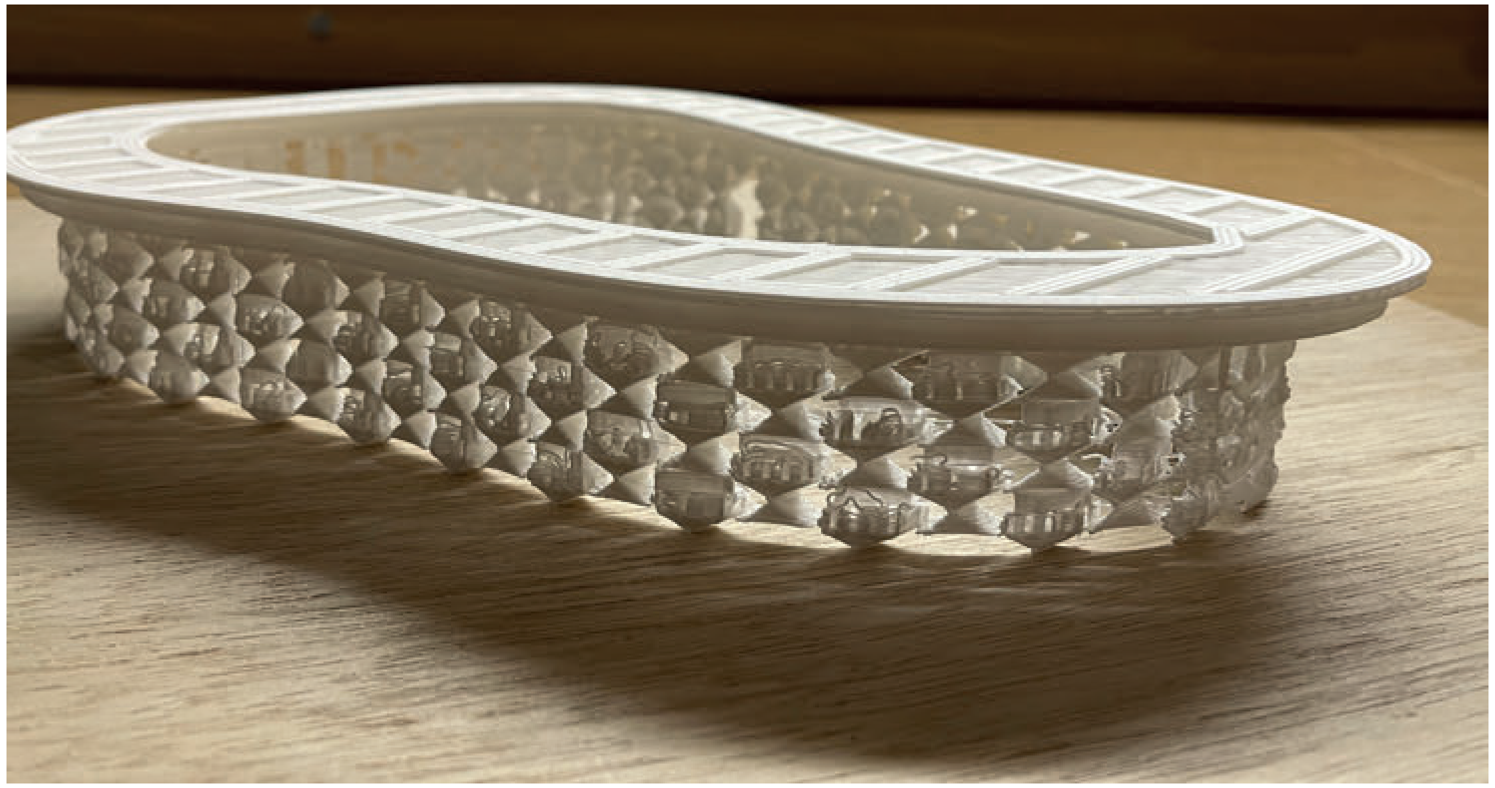


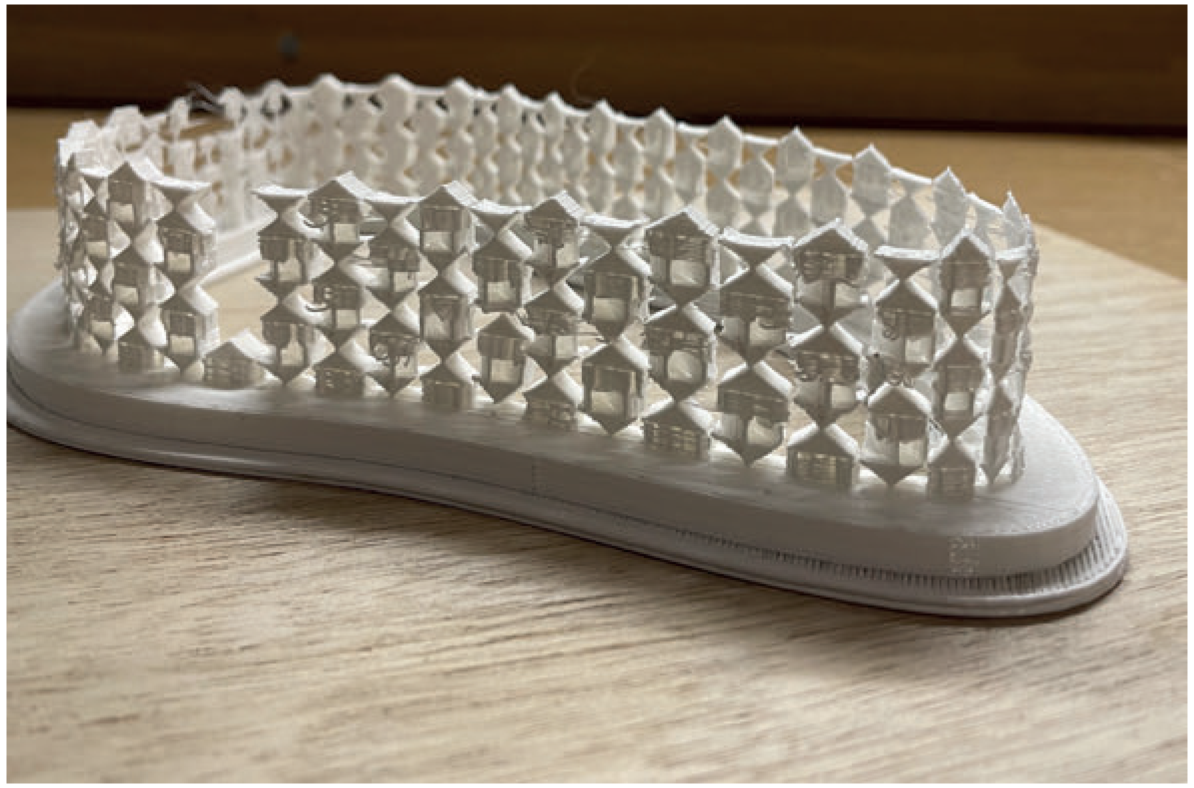
I used 3d printer by using PLA flament for fabrication. But TPU or TPE filamnets are can be used, because this materials have elastic behaviour and we can test expansion with this material.



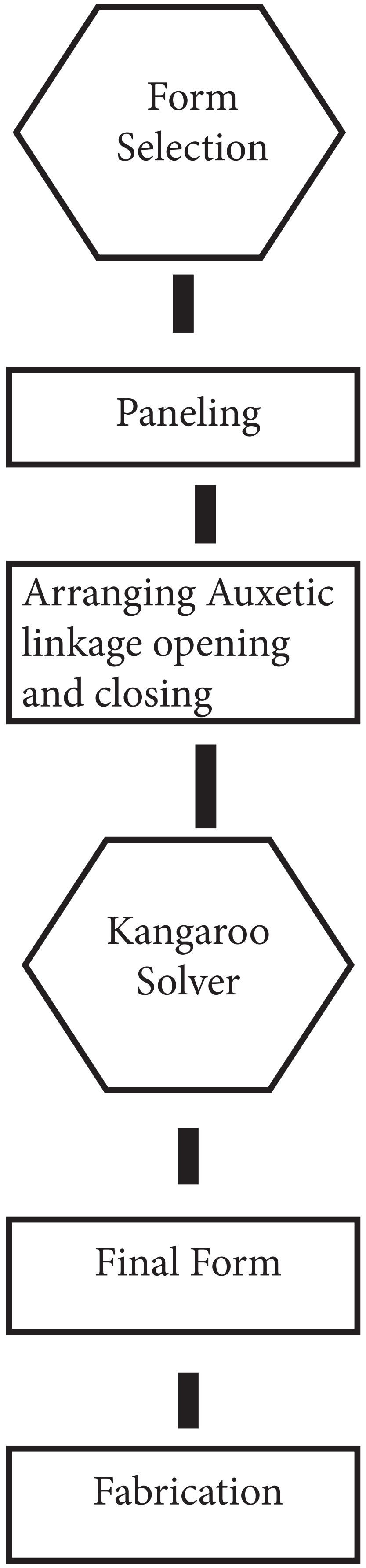


TPU FILAMENT





4.2 Computed Auxetic Structure

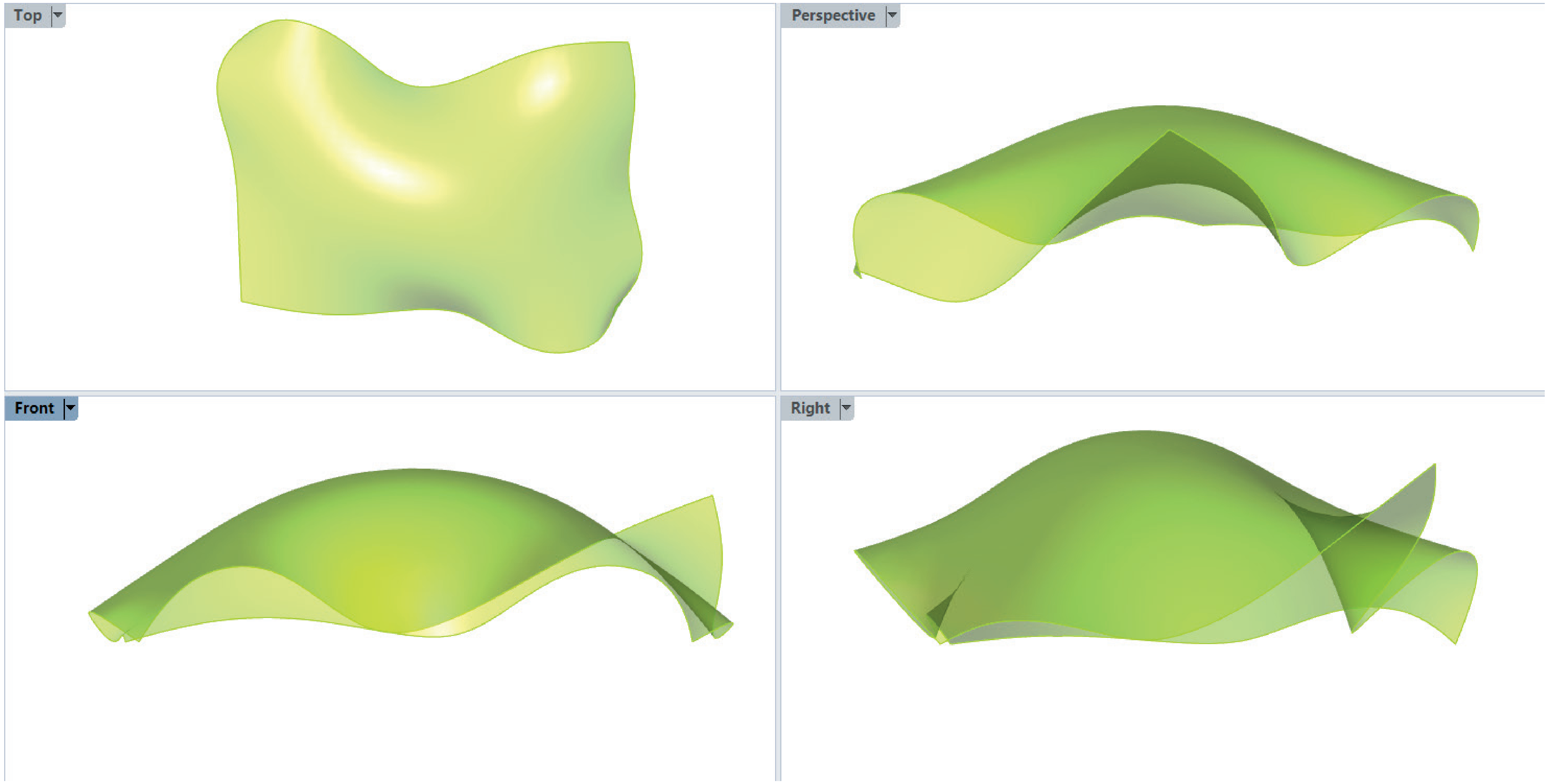


One approach to achieving varying openings and closing angles on an auxetic pattern involves the use of attractor points. This technique can yield diverse shapes and shadows that are aesthetically pleasing. To apply this pattern to a 3D target shape, the Kangaroo solver was utilized.

Kangaroo solver is a physics engine used for simulating physical interactions between objects. The solver was used to deform the auxetic pattern onto the target shape, resulting in a modified geometry. This approach demonstrates a practical method for creating complex and dynamic structures that can be customized to specific design objectives.

First I"m gonaa apply previous approach which we used for surface. After that, computed auxetic structure wiil be used.

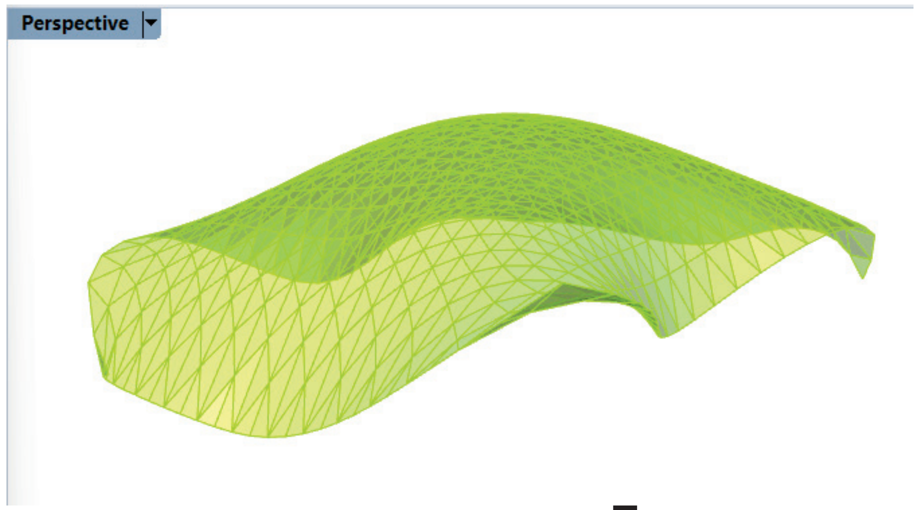
Selected form for applications



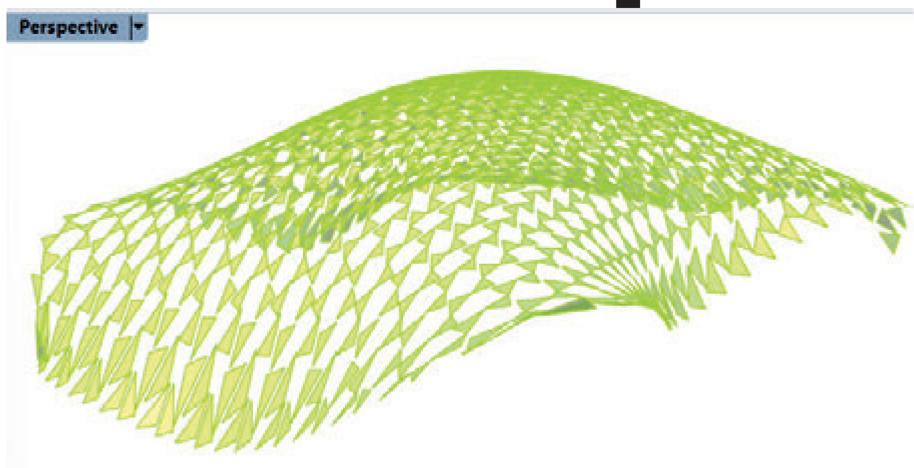
4.2.1 Previous Script

An initial attempt was made to apply the auxetic pattern to a freeform surface using a previously employed script. However, this approach resulted in inaccurate outcomes, as the triangles were deformed and the desired auxetic shape was not achieved. Additionally, the size of the triangles was altered, which deviated from the intended outcome.

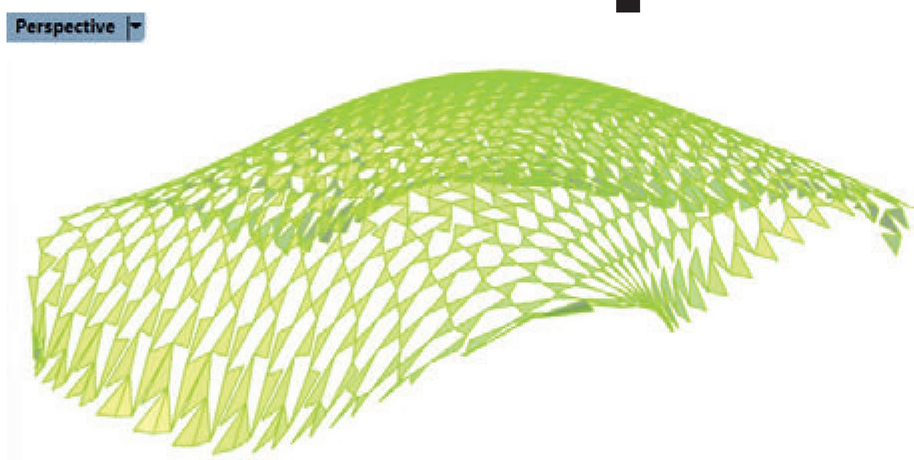
Therefore, an alternative approach will be implemented to deform the auxetic pattern onto the 3D target shape. This may involve utilizing a more sophisticated deformation algorithm which can accurately map the pattern onto the surface without distorting its properties. Through this improved approach, it is anticipated that more accurate and reliable results can be obtained, enabling the creation of complex and dynamic structures that can be tailored to specific design objectives.



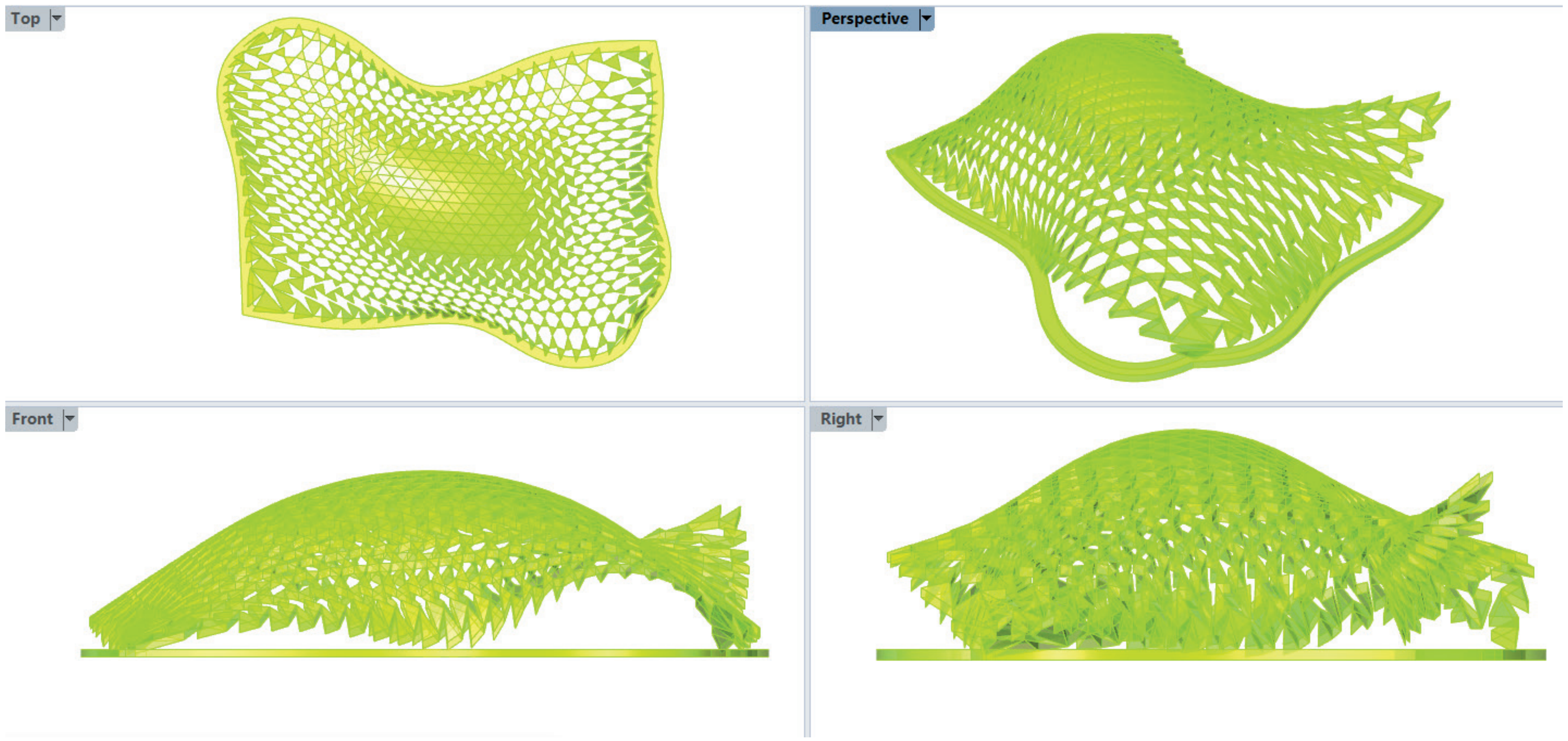
Paneling



Deforming auxetic pattern

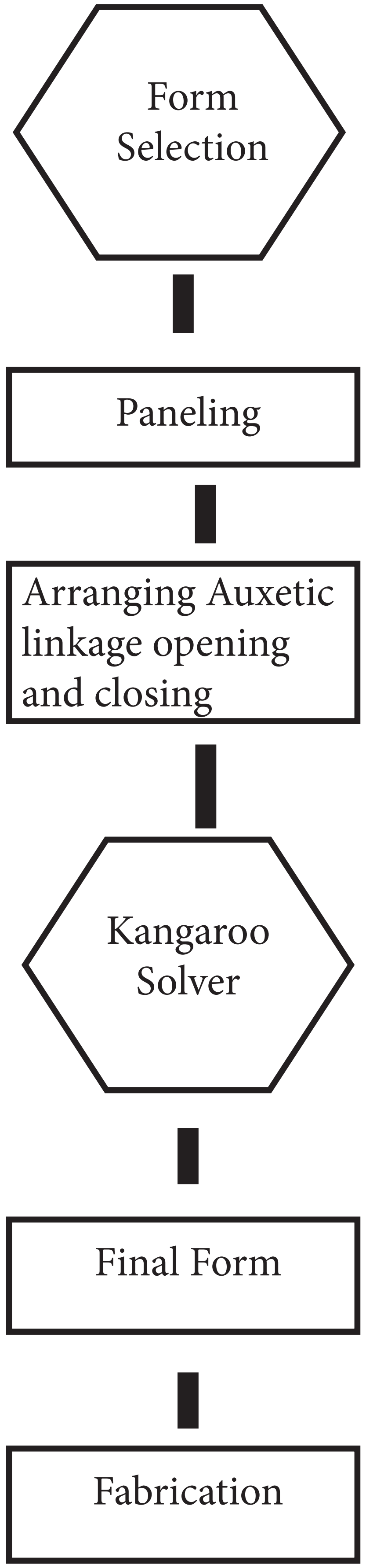


Merging discrete point



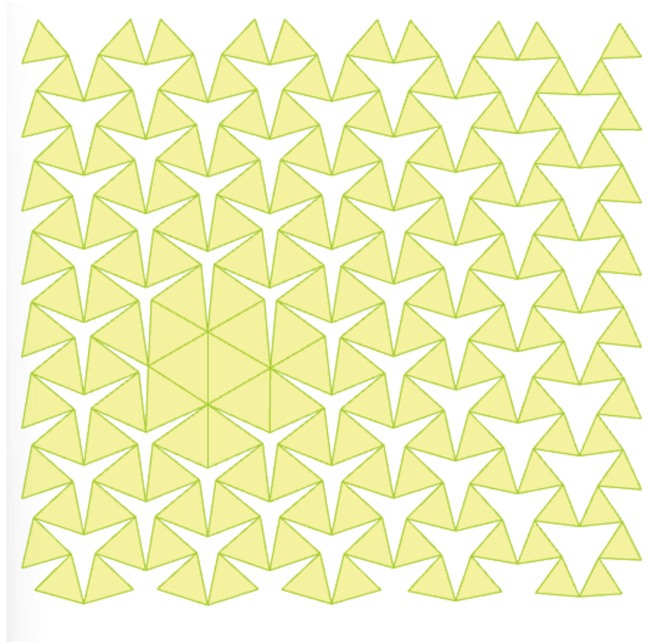
Final Form

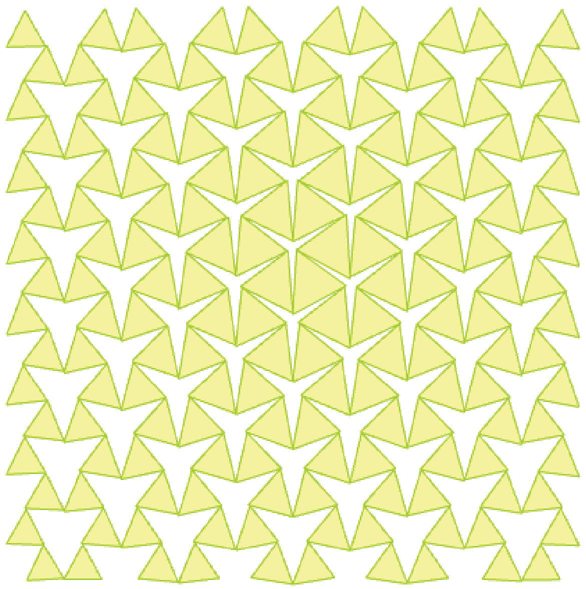
4.2.2 Computed Auxetic Structure Workflow

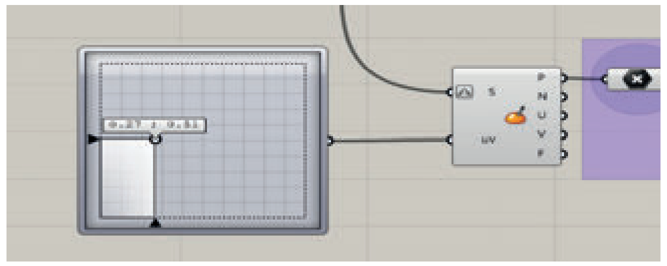


One approach to achieving varying openings and closing angles on an auxetic pattern involves the use of attractor points. This technique can yield diverse shapes and shadows that are aesthetically pleasing. To apply this pattern to a 3D target shape, the Kangaroo solver was utilized.

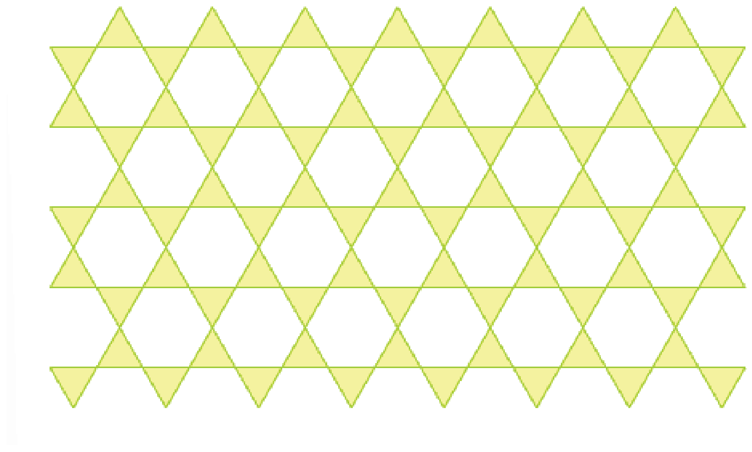
With Attractor Point

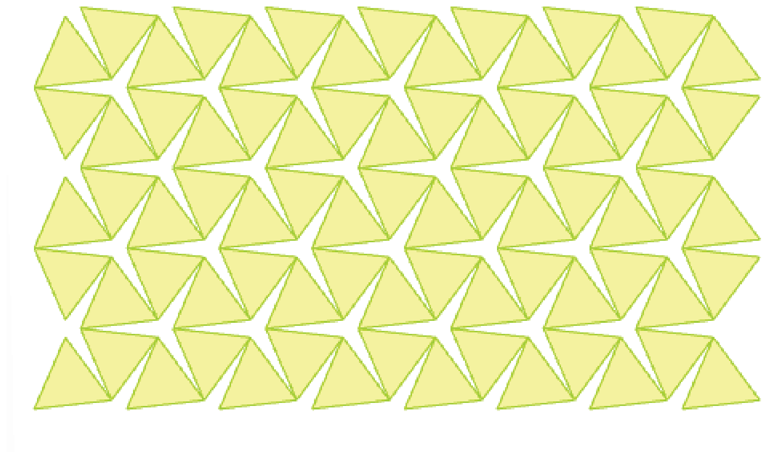


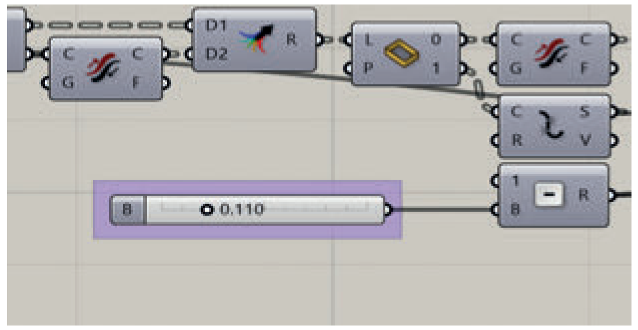




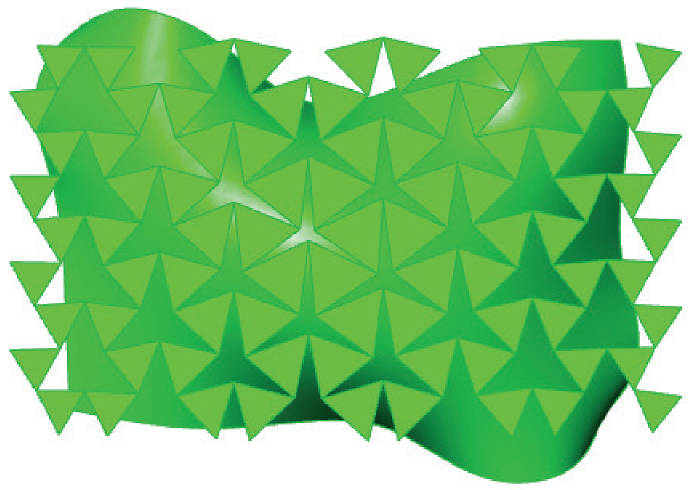
Without Attractor Point

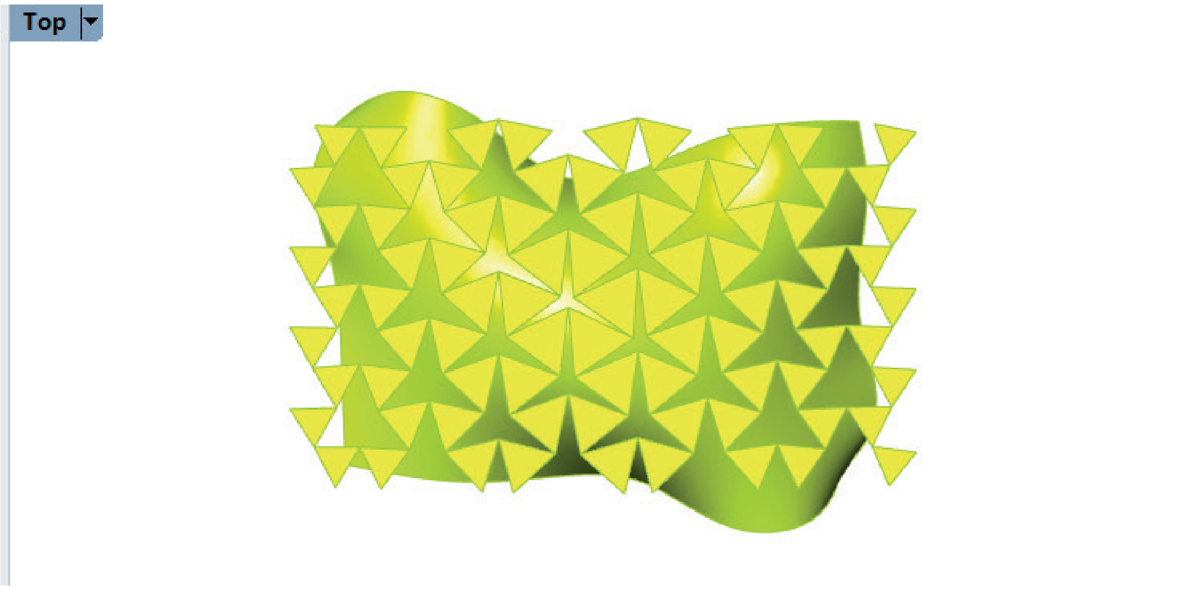


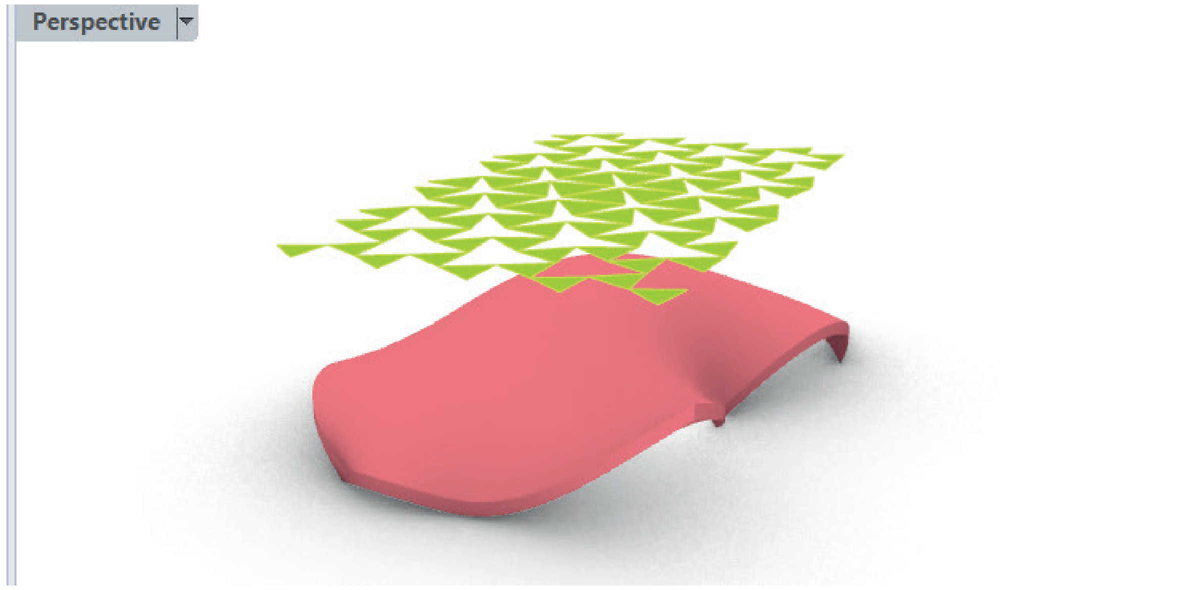


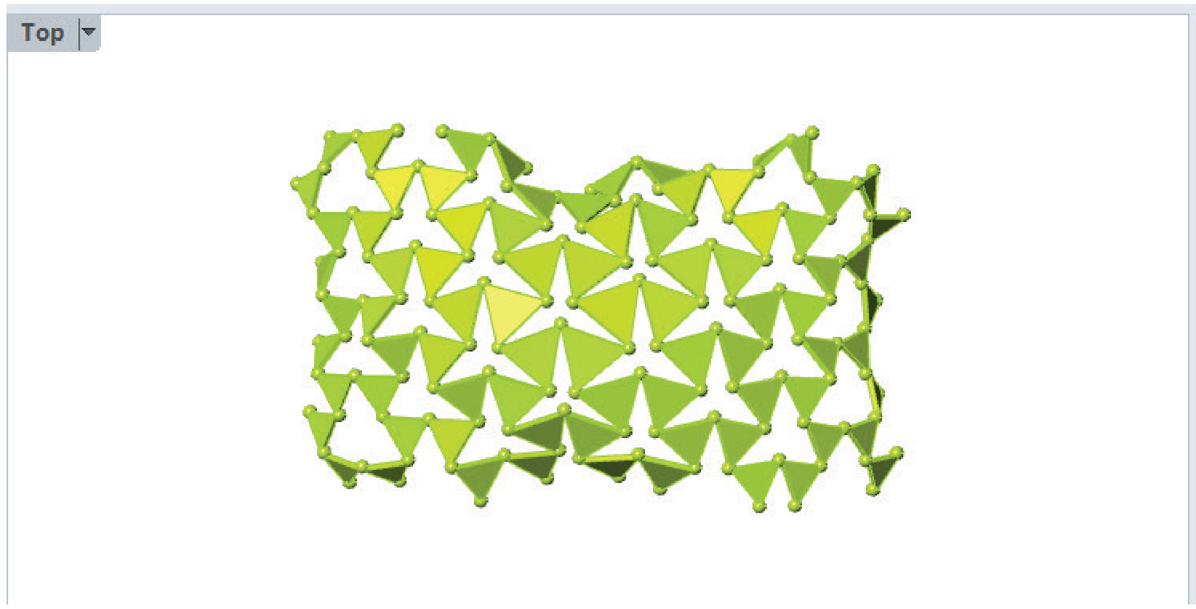


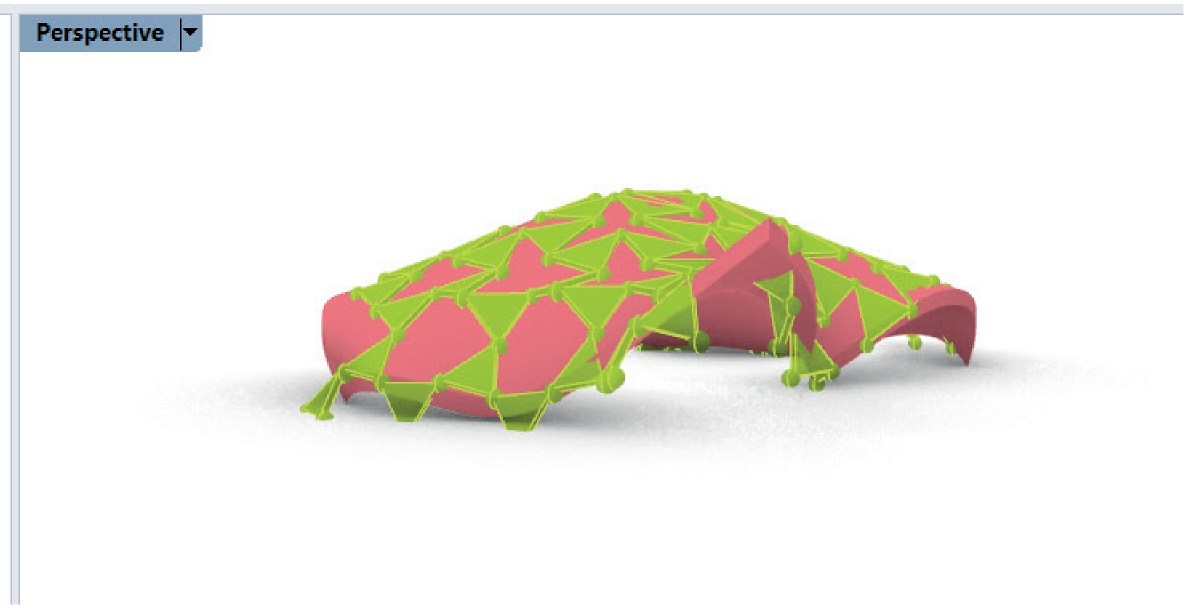
4.2.2 Computed Auxetic Structure Workflow



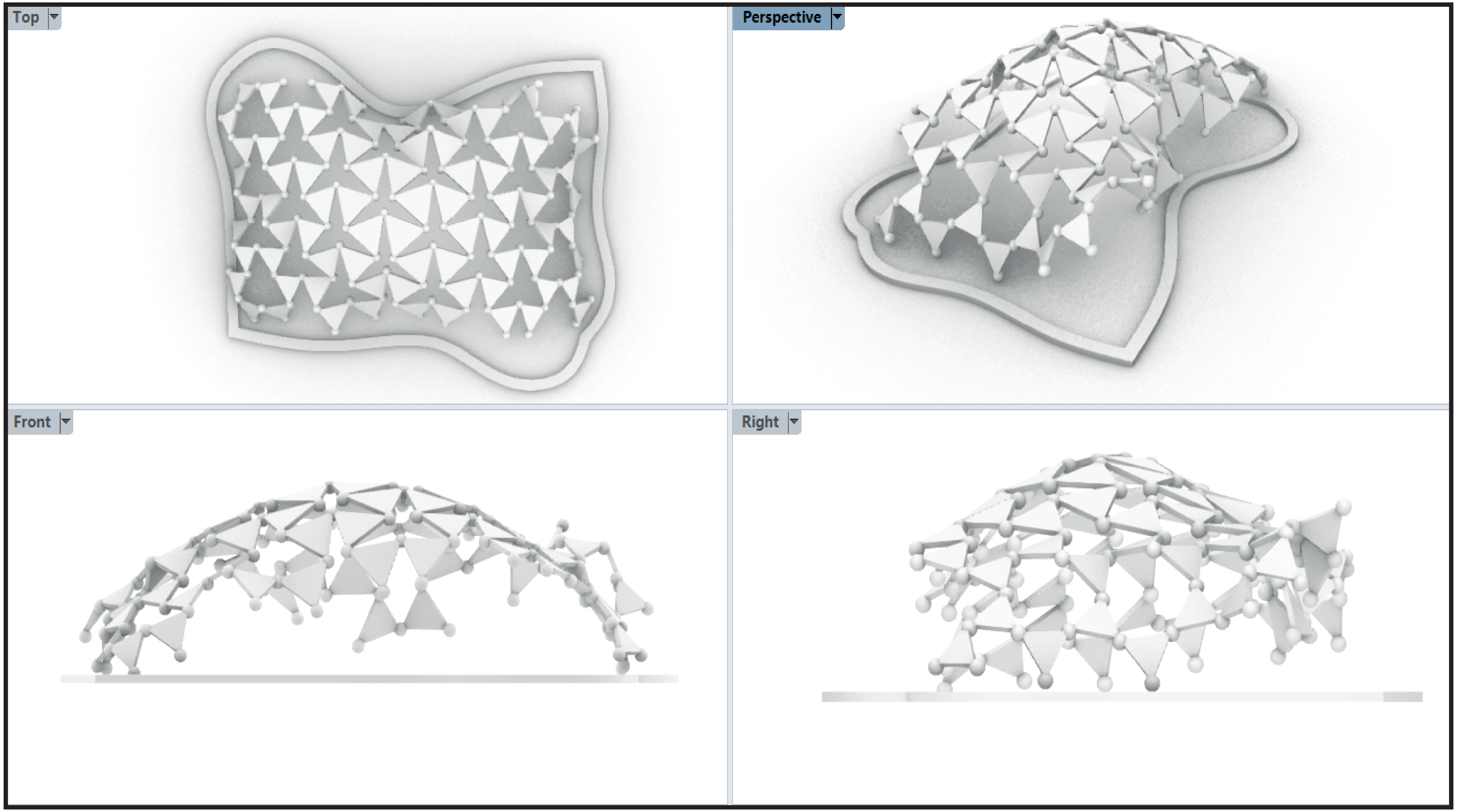




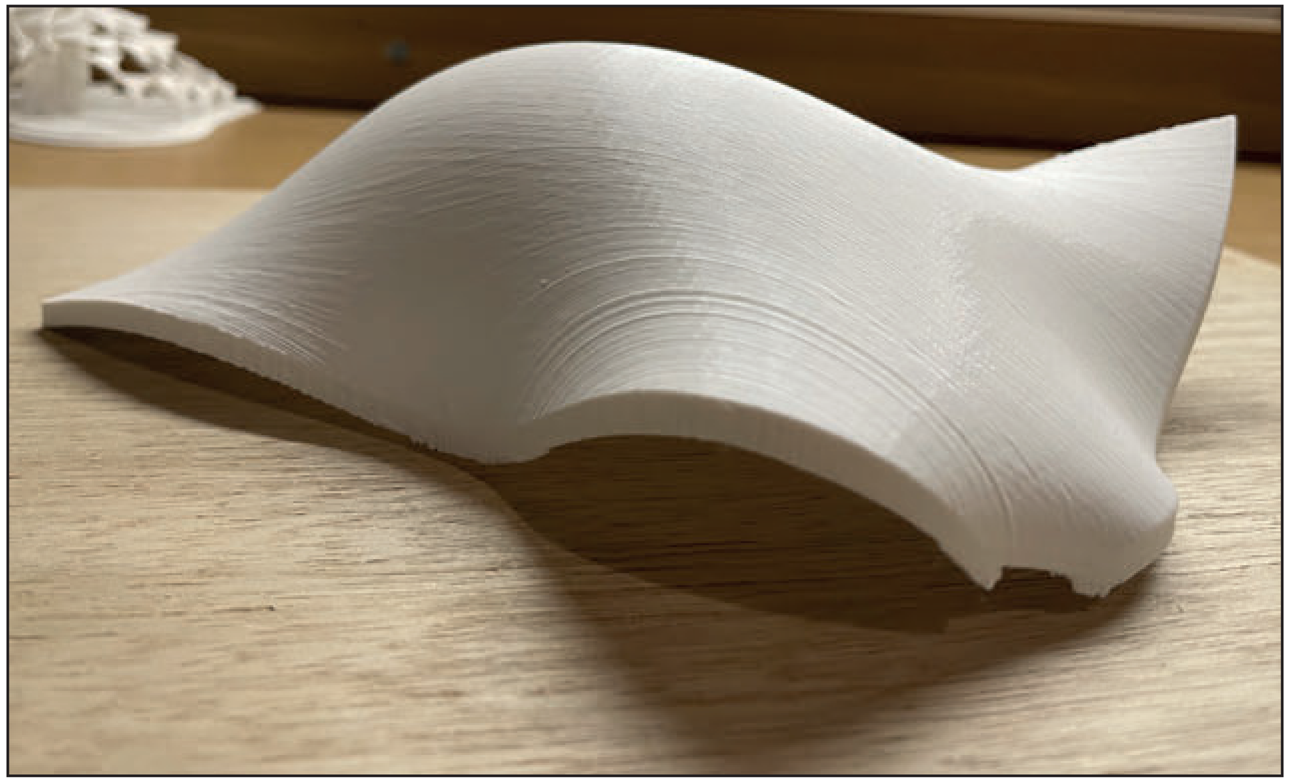


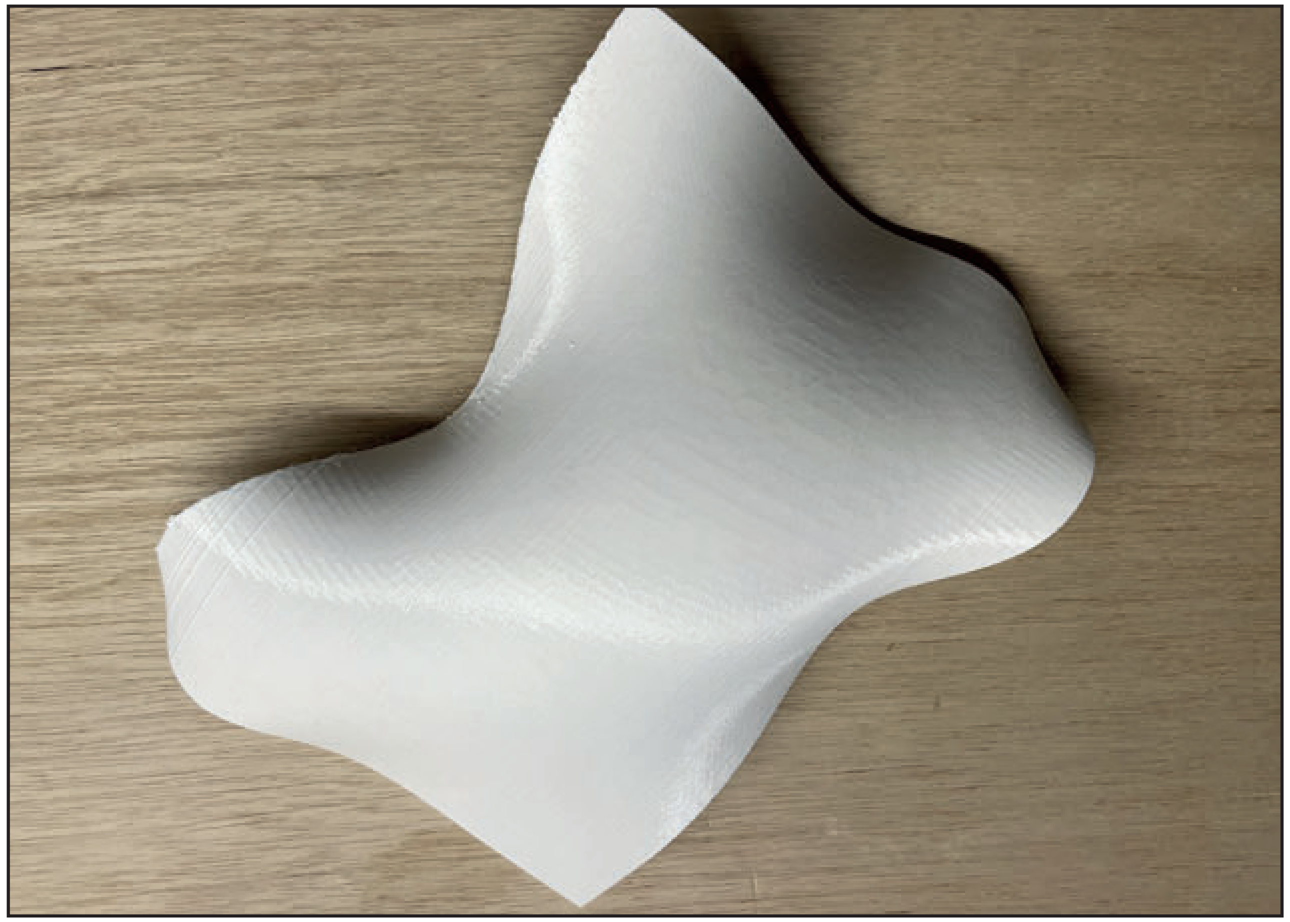


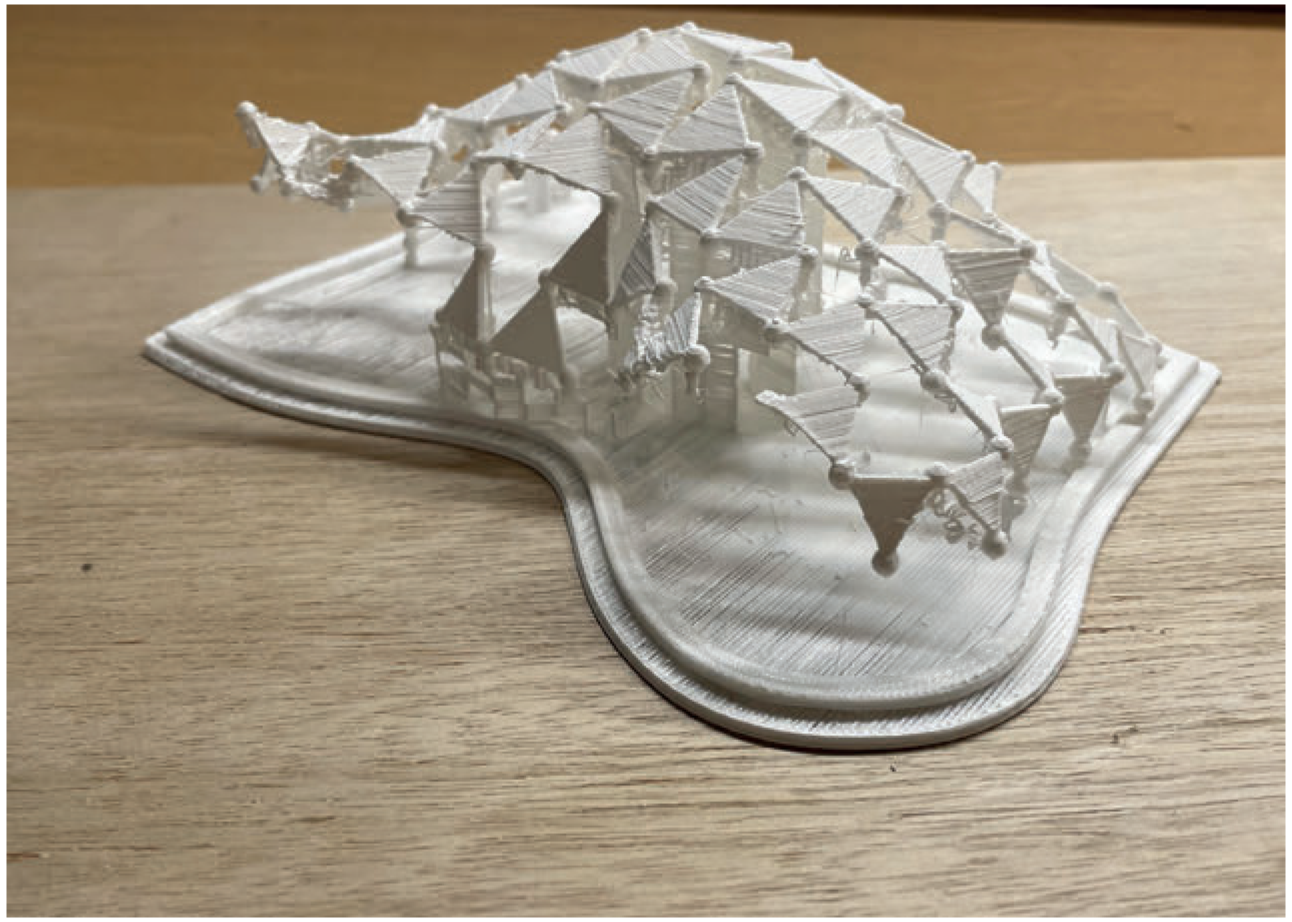
4.2.3 Computed Auxetic Structure Final Model



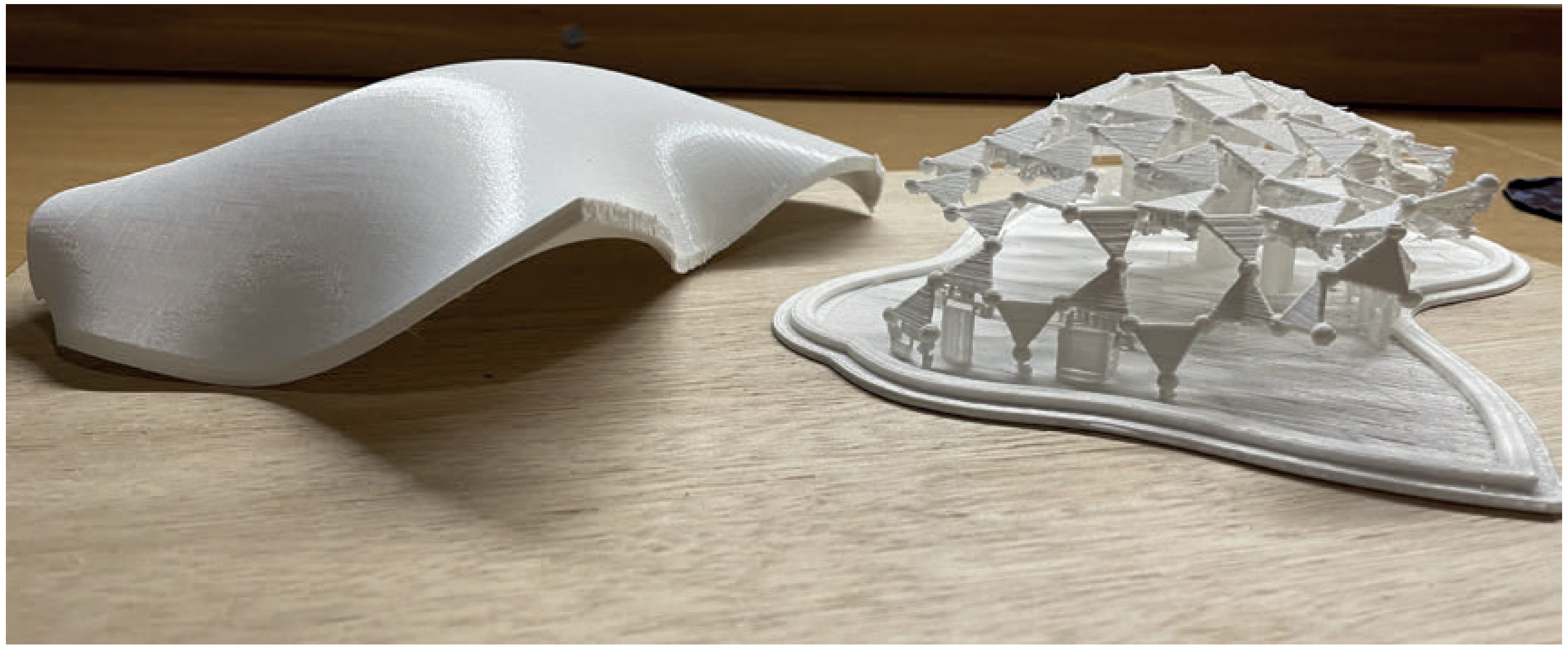
4.2.4 Computed Auxetic Structure Fabrication



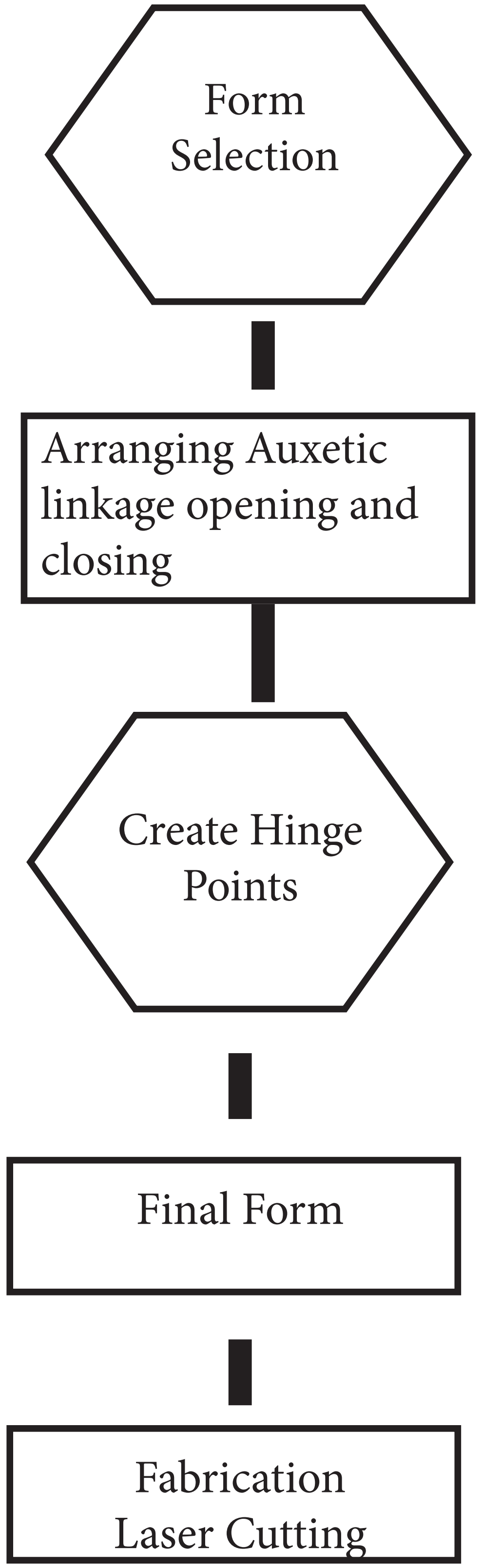




4.2.4 Computed Auxetic Structure Fabrication



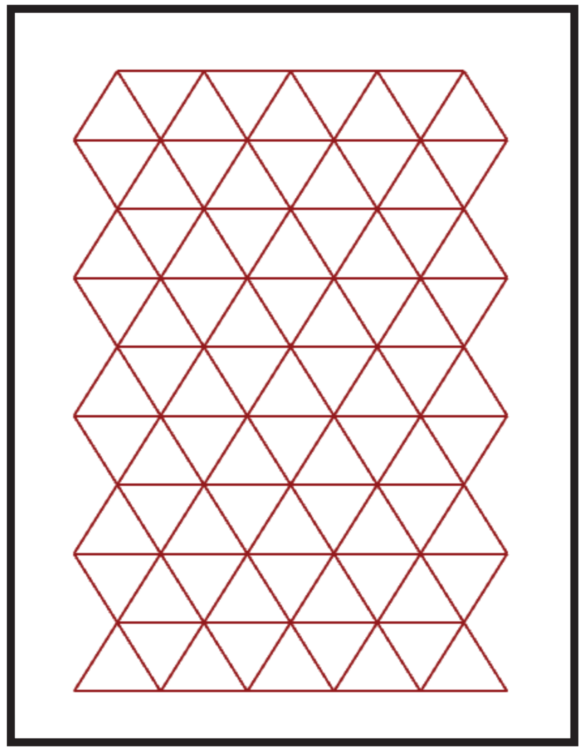
4.3 Hanging



This approach employs an auxetic pattern that exhibits negative Poisson's ratio and is controlled by an attractor point. The pattern is cut out using a laser cutter to achieve precise cuts and a high degree of customization. The triangles cut from the pattern are then connected using ring joints, which serve to form the 3D structure.

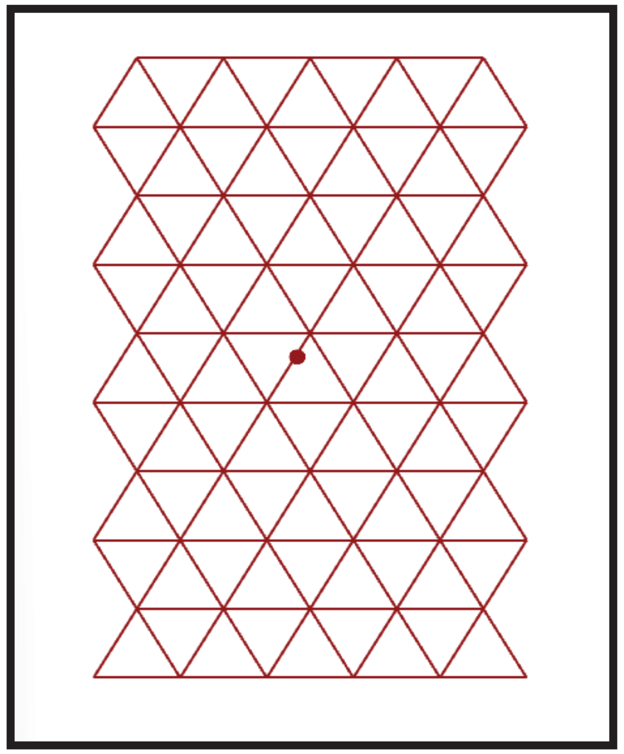
Gravity is utilized to allow the 2D planar auxetic pattern to assume its final form. The attractor point governs the shape and orientation of the pattern, providing a significant degree of flexibility in designing the structure.

STEP 1

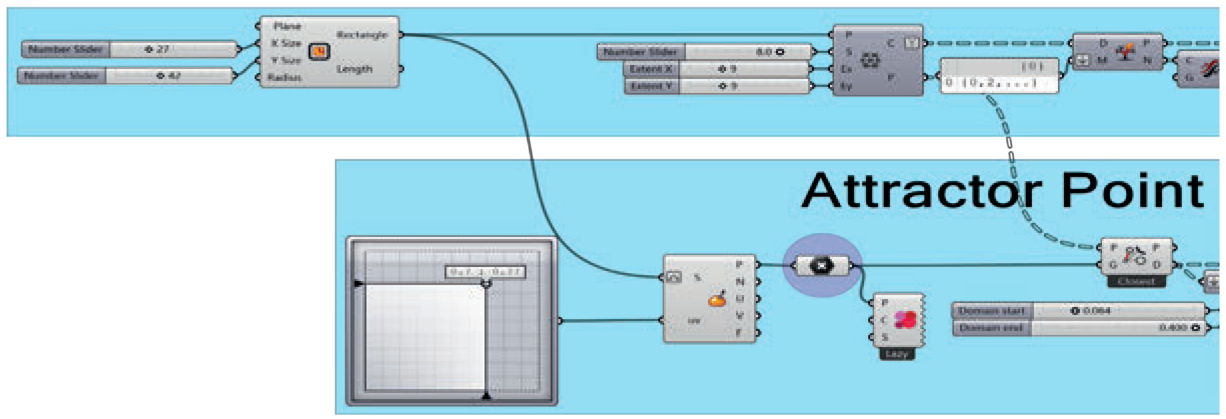


Initial Mesh

STEP 2

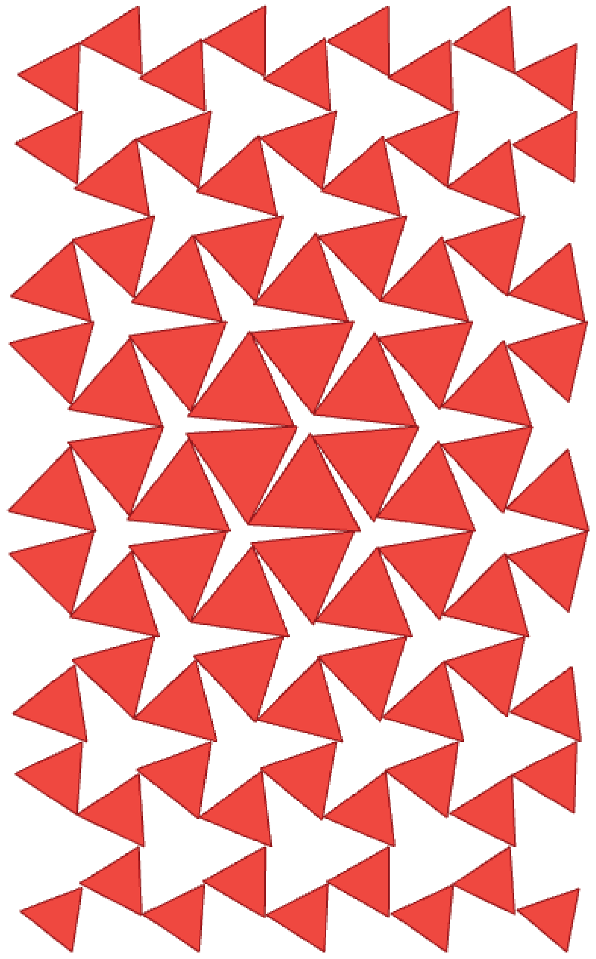


Attractor Point



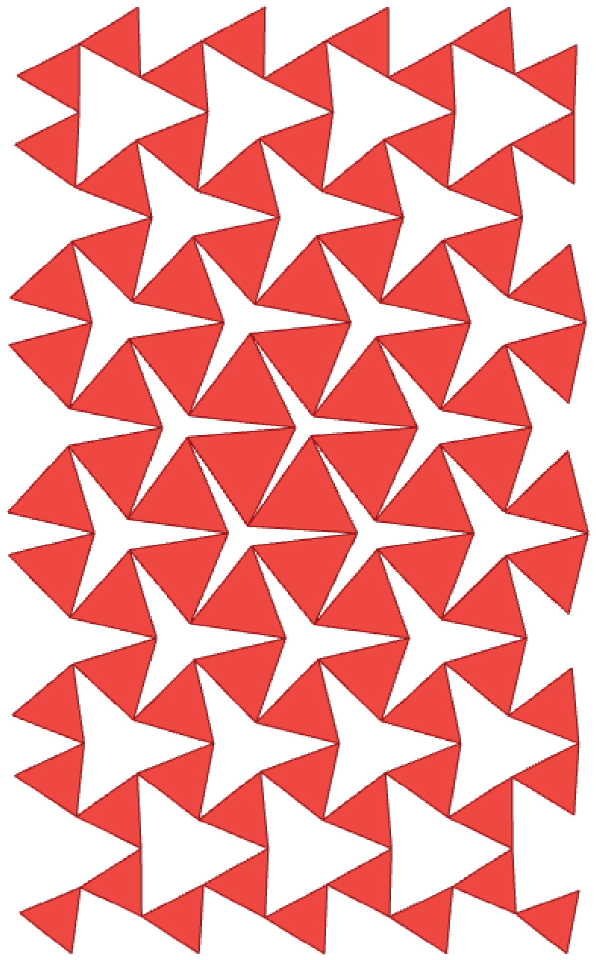
4.3.1 Hanging Workflow

STEP 3



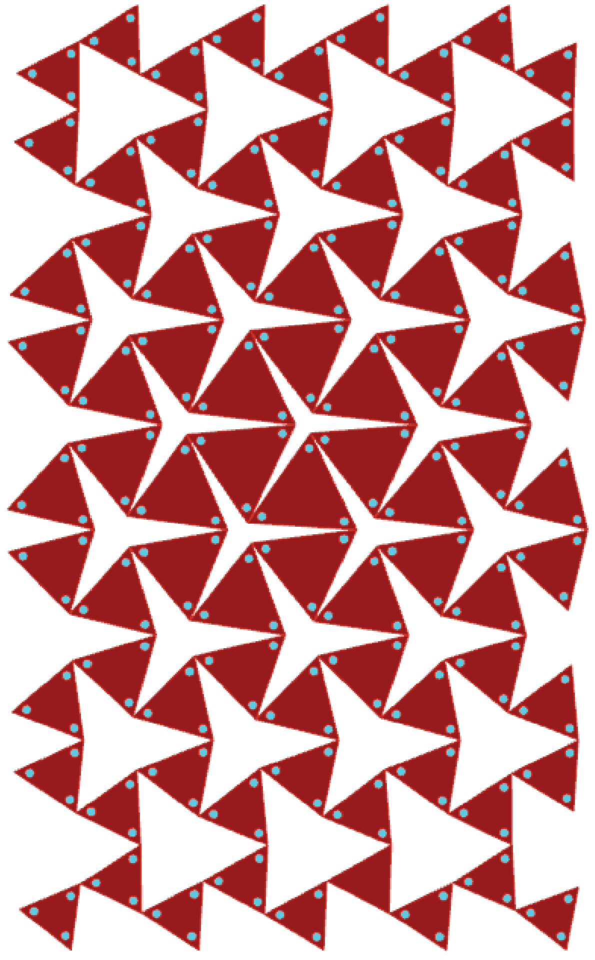
Auxetic Pattern

STEP 4



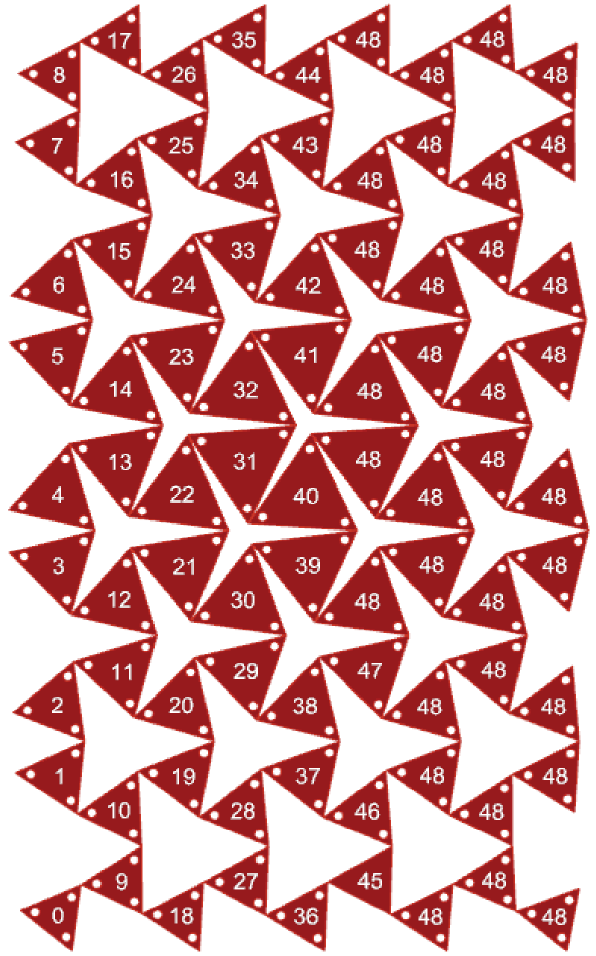
Merge close points

STEP 5

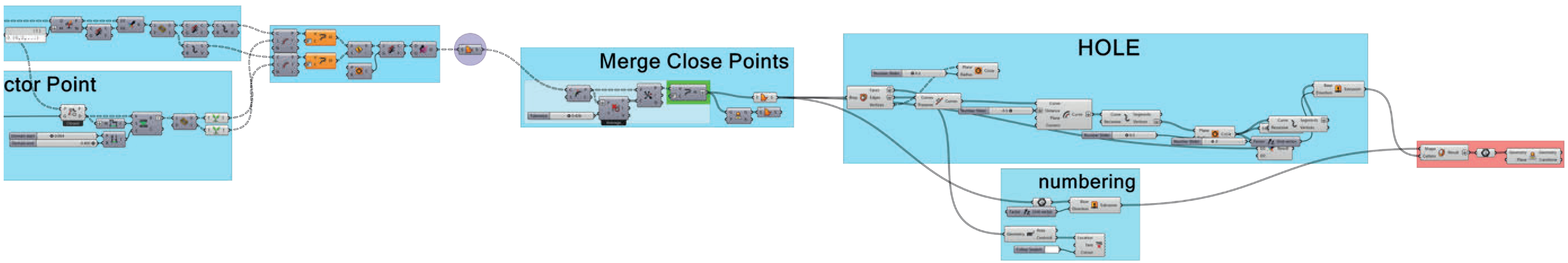


Create hinge points

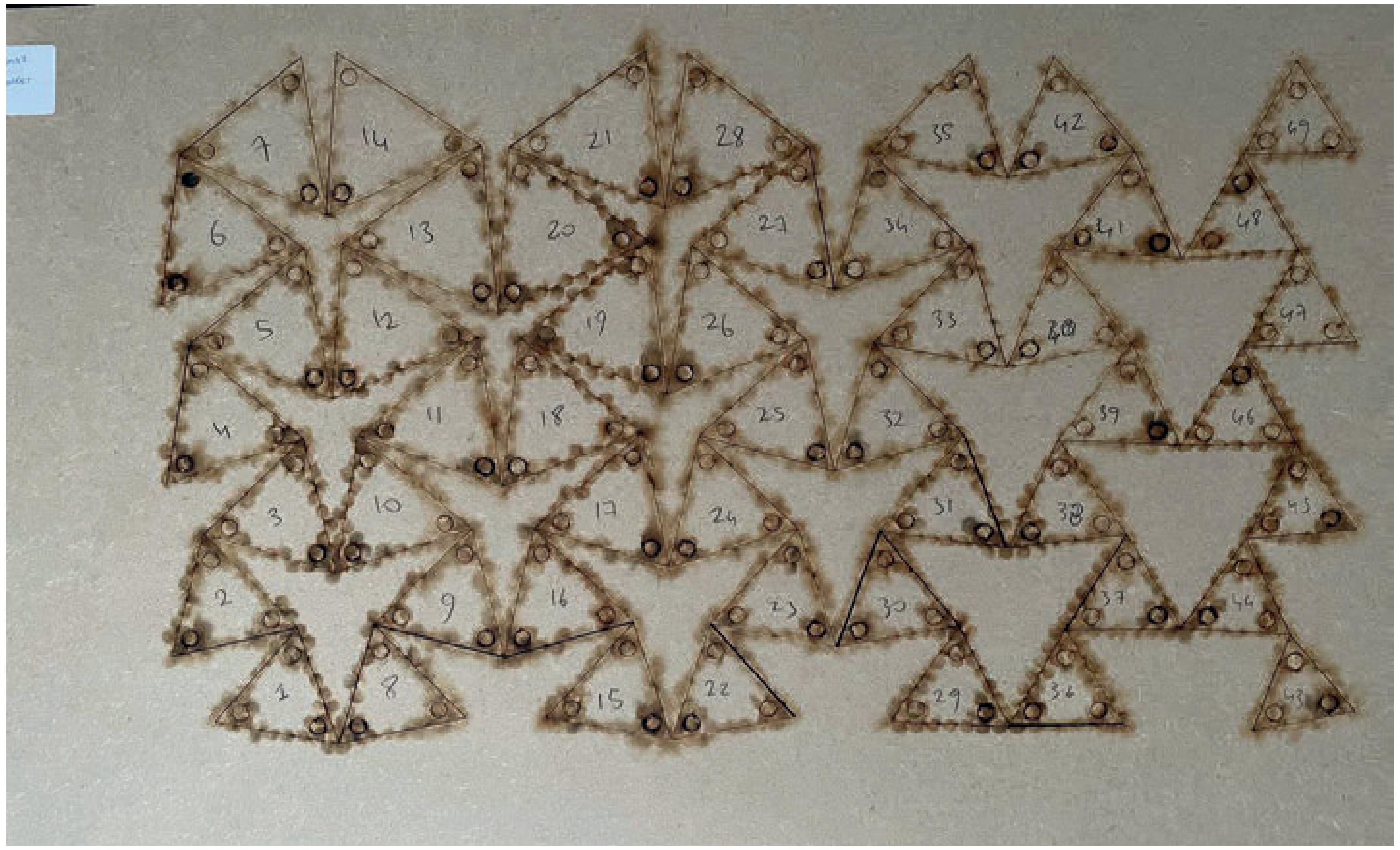
STEP 6

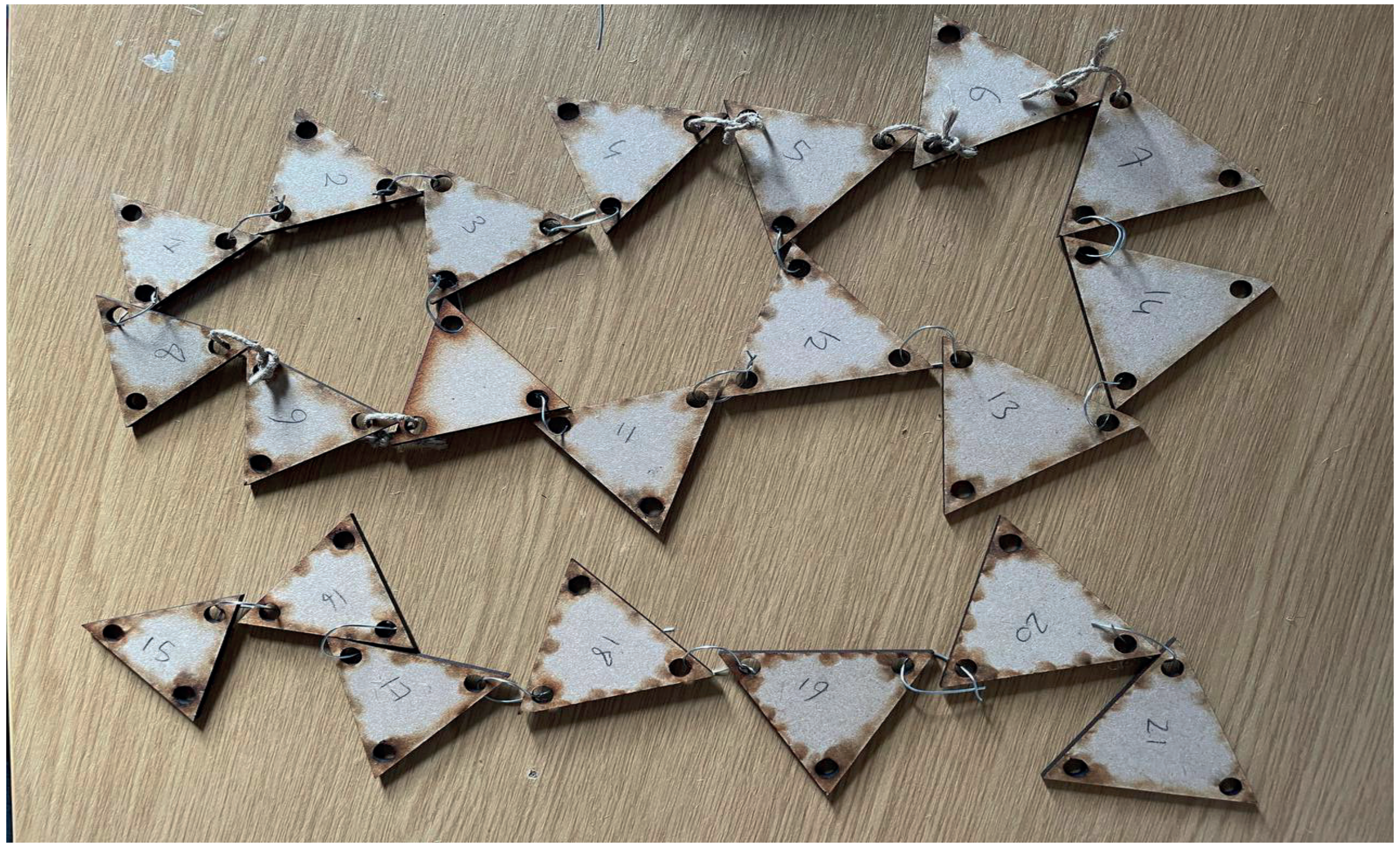


Numbering

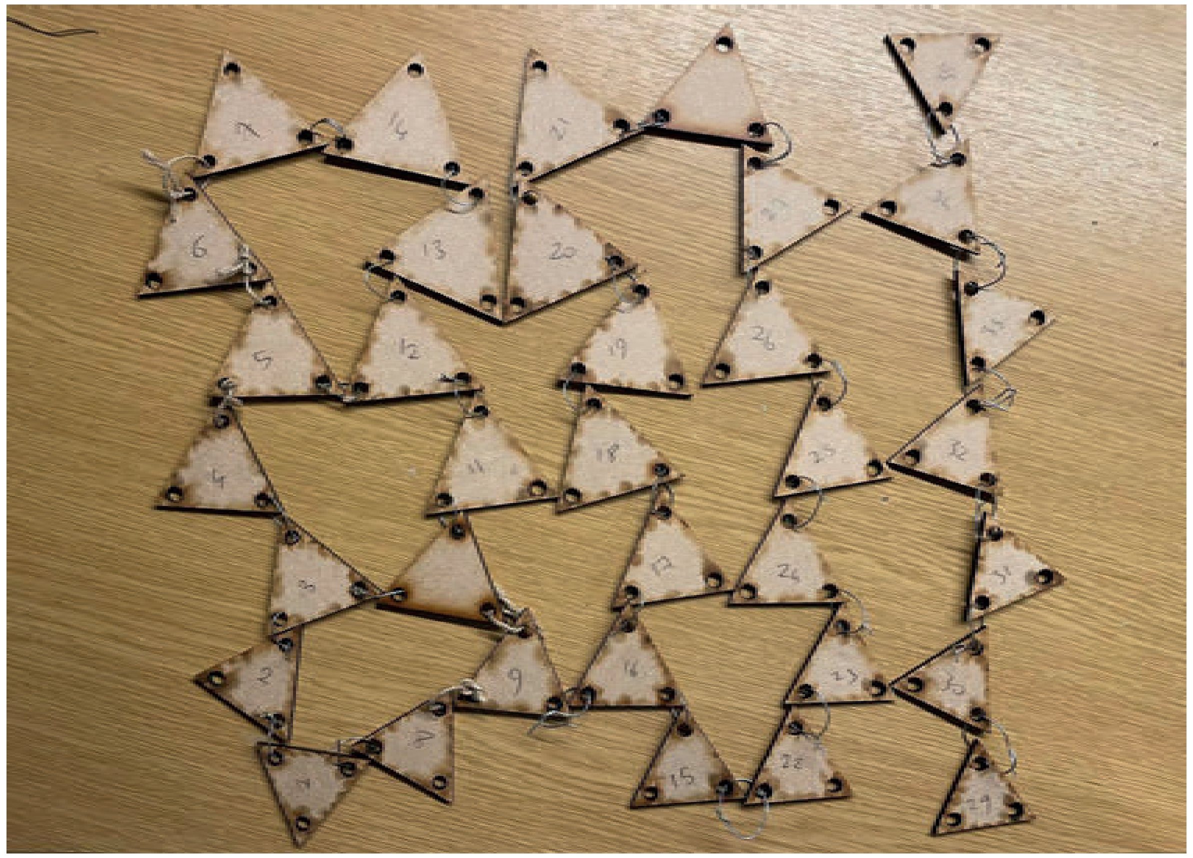


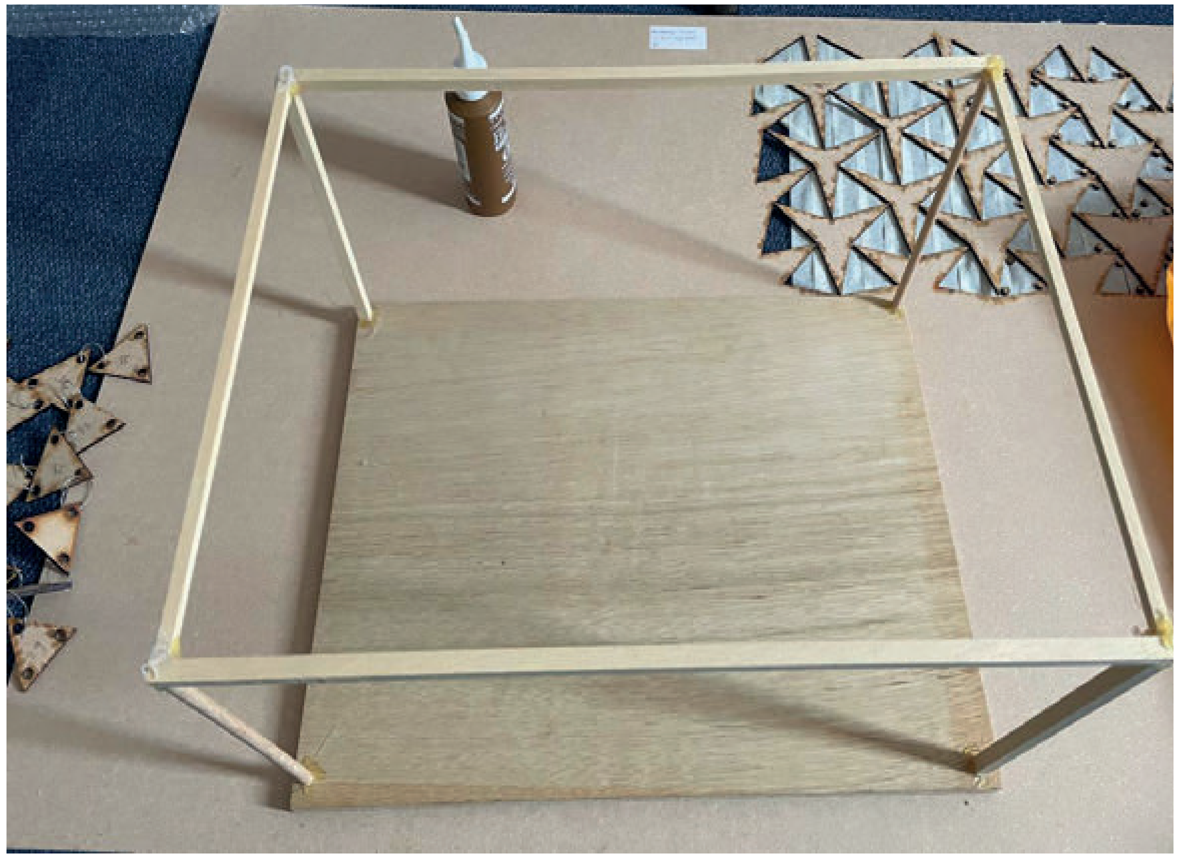
4.3.2 Fabrication

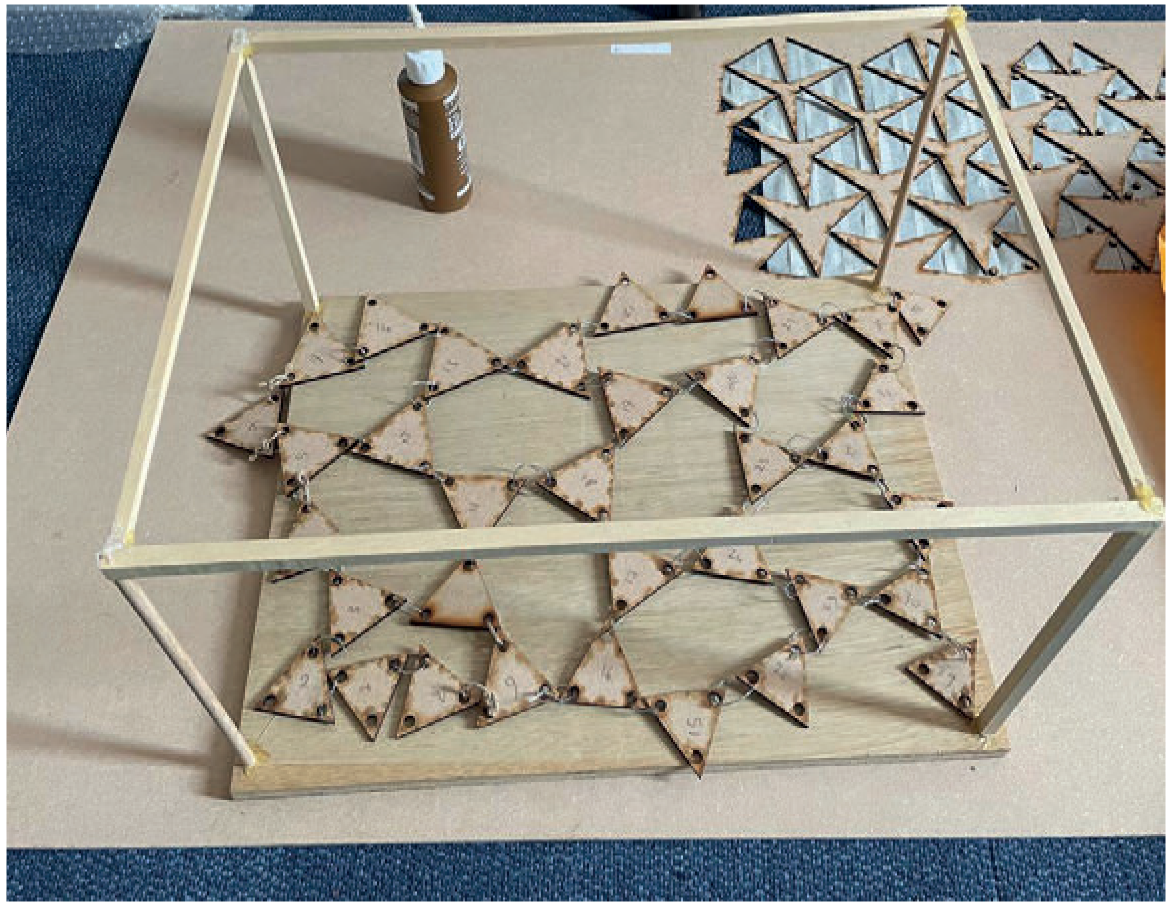


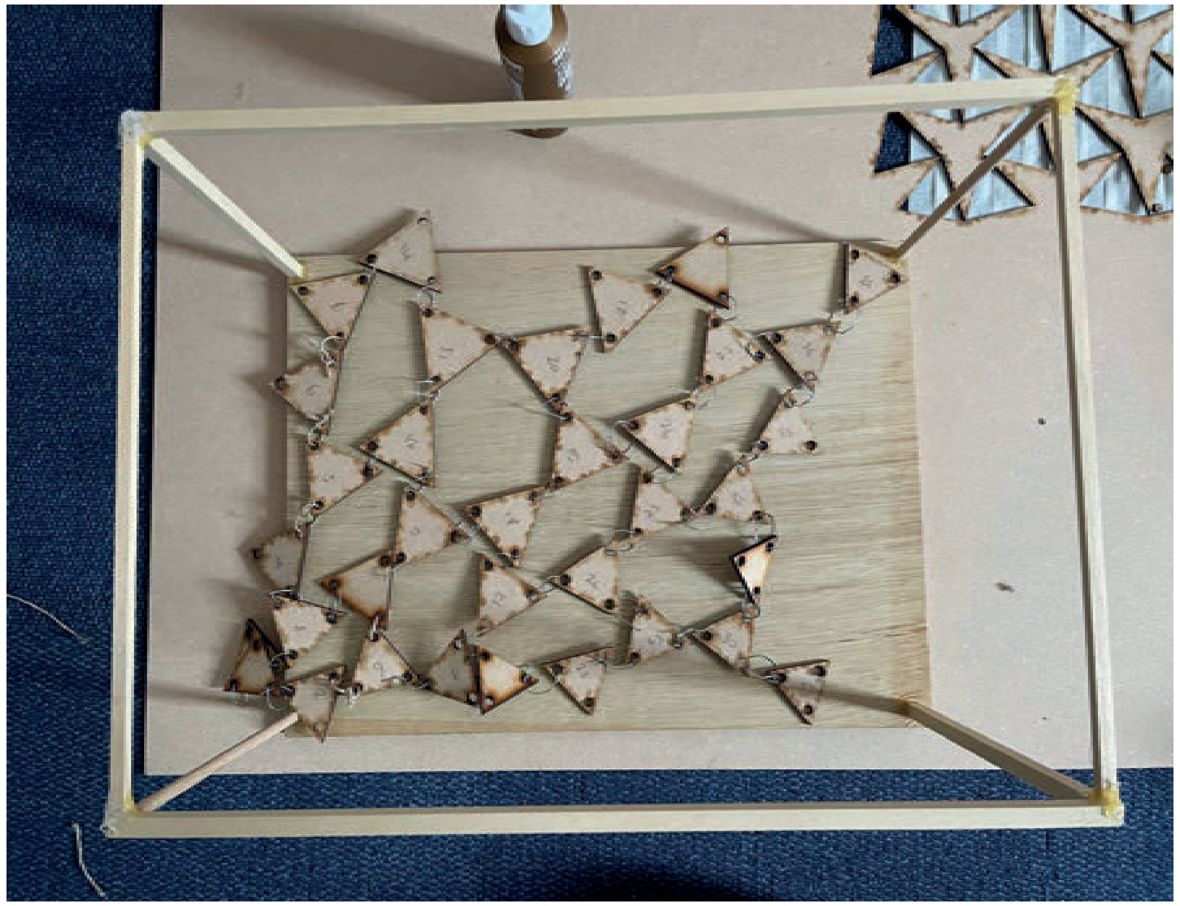


4.3.2 Fabrication

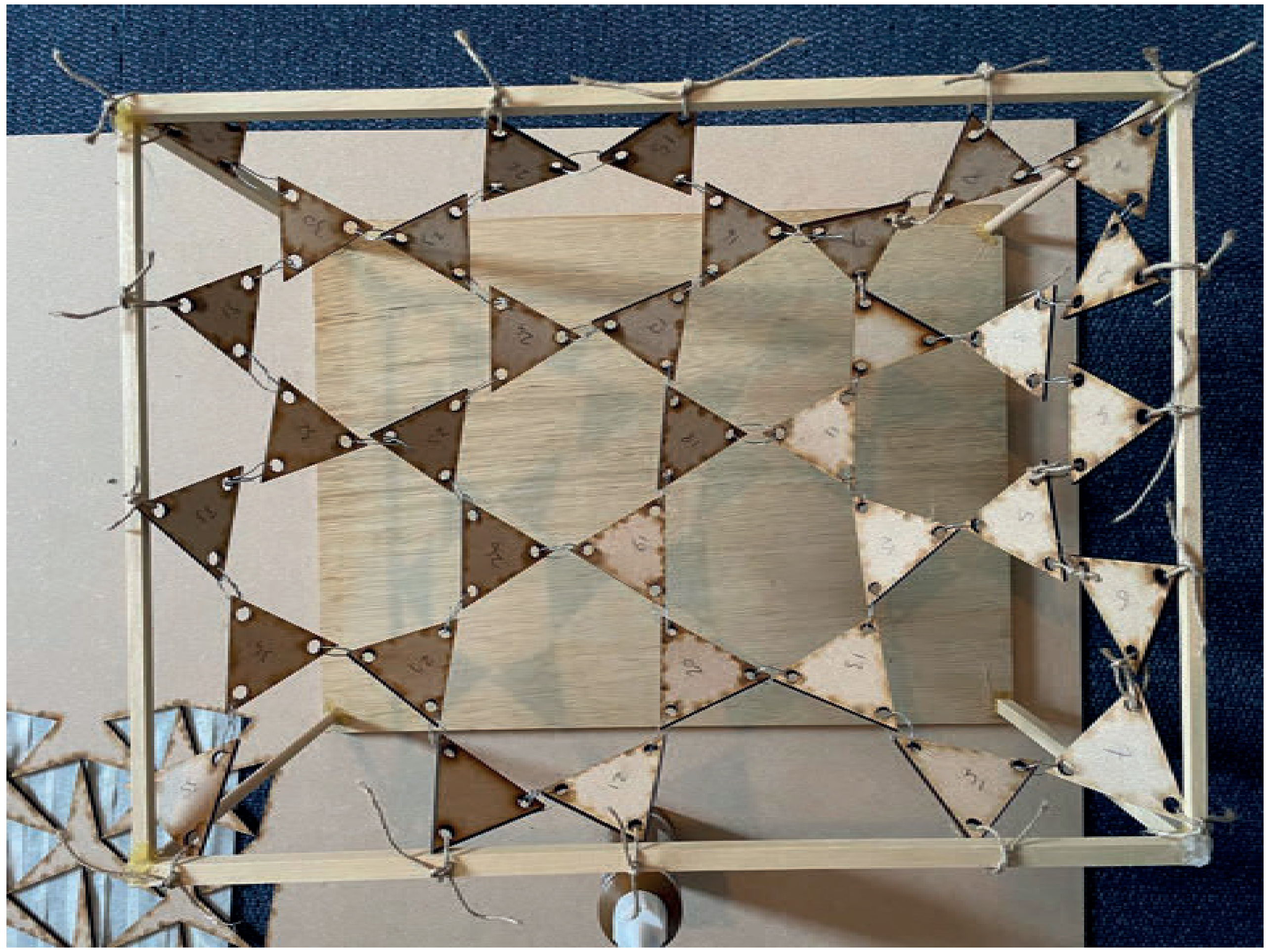


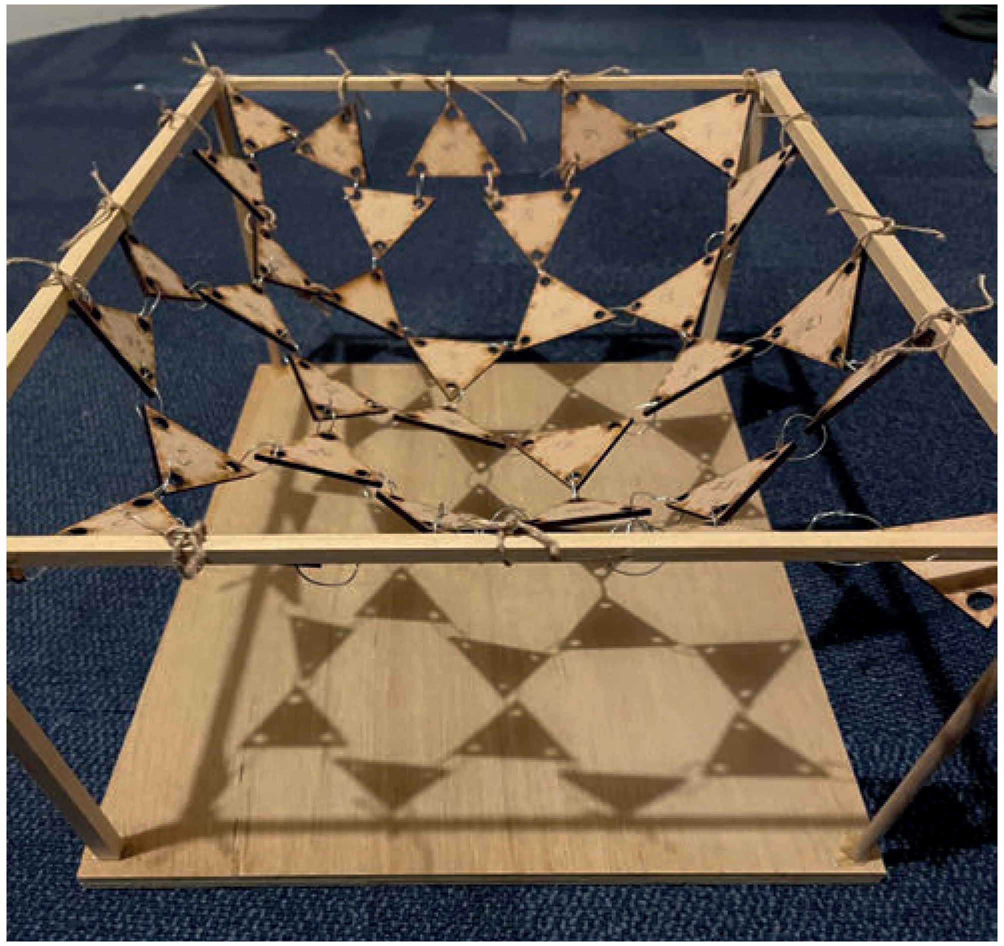


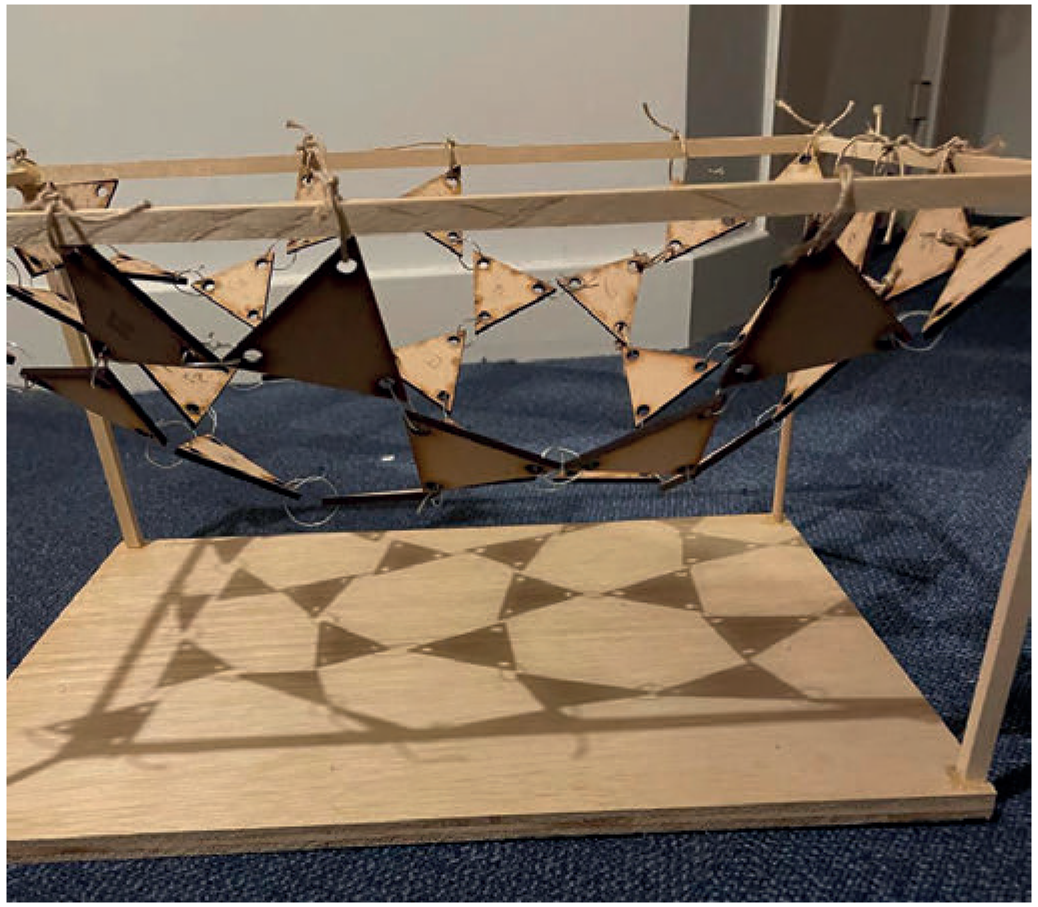


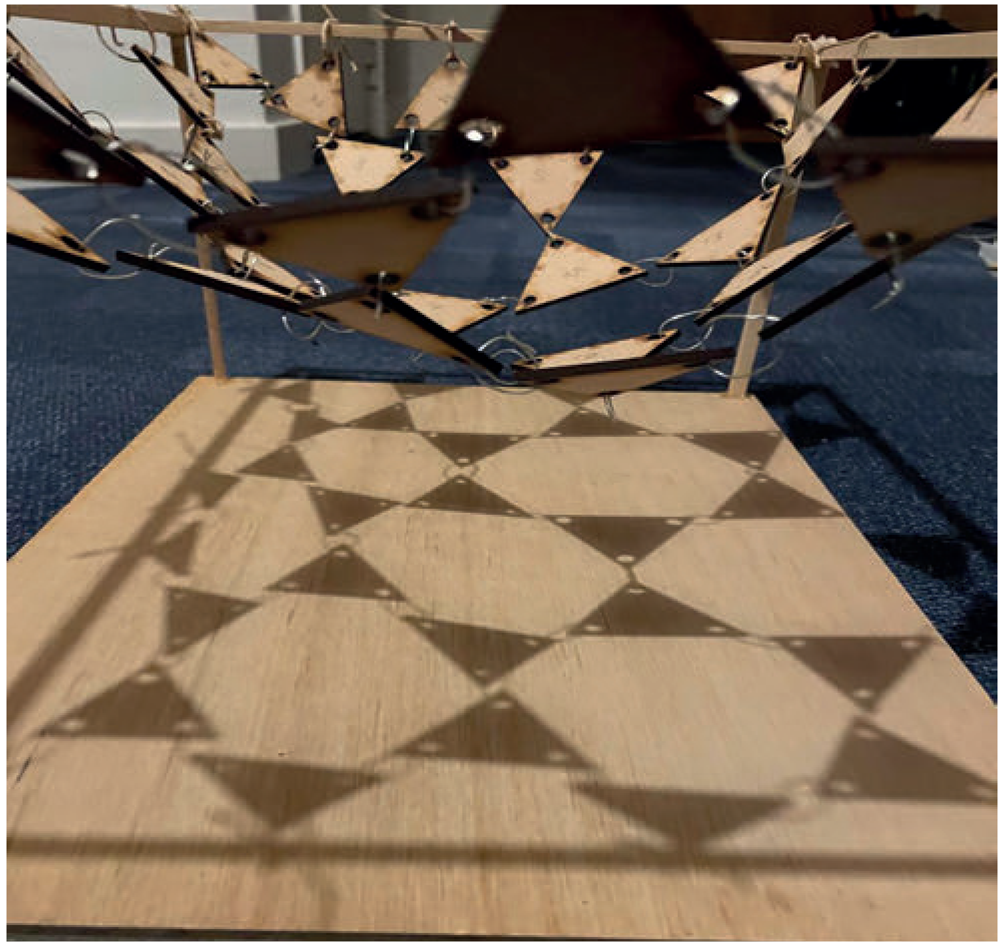


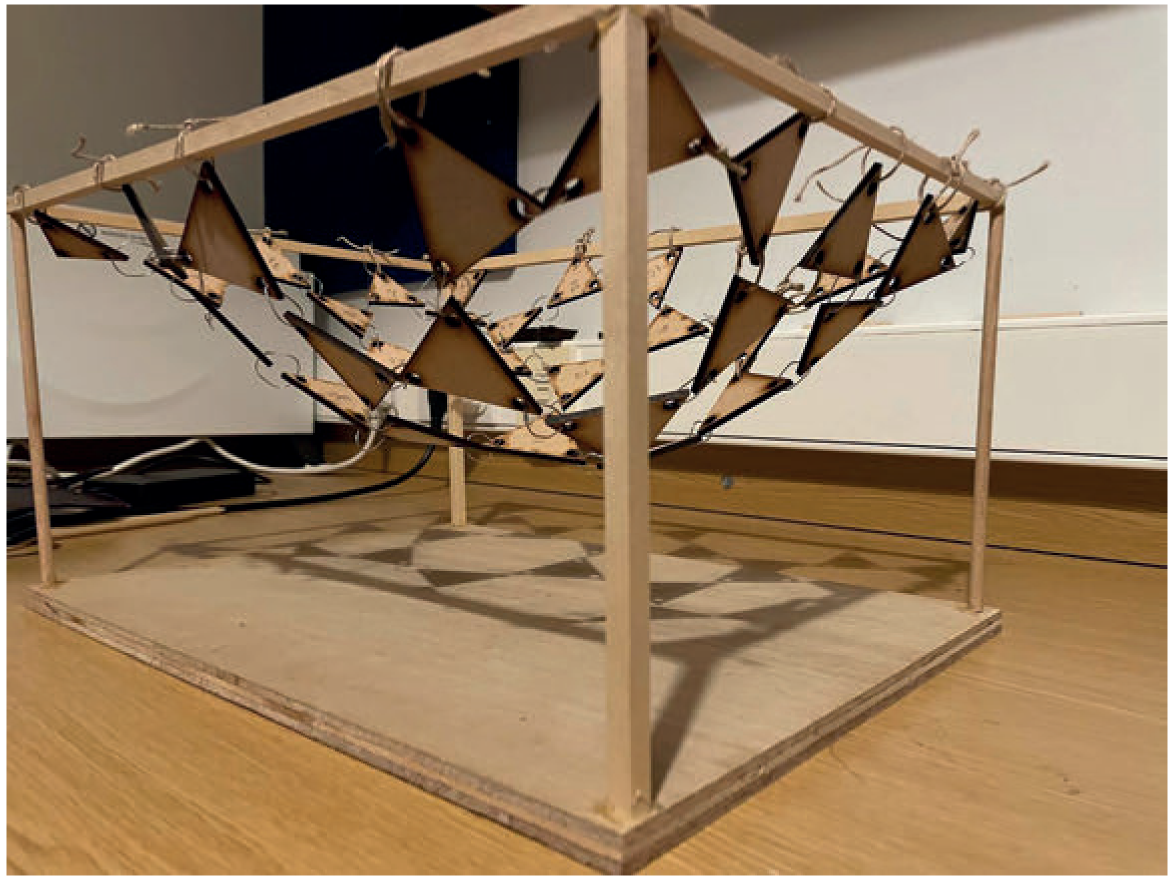
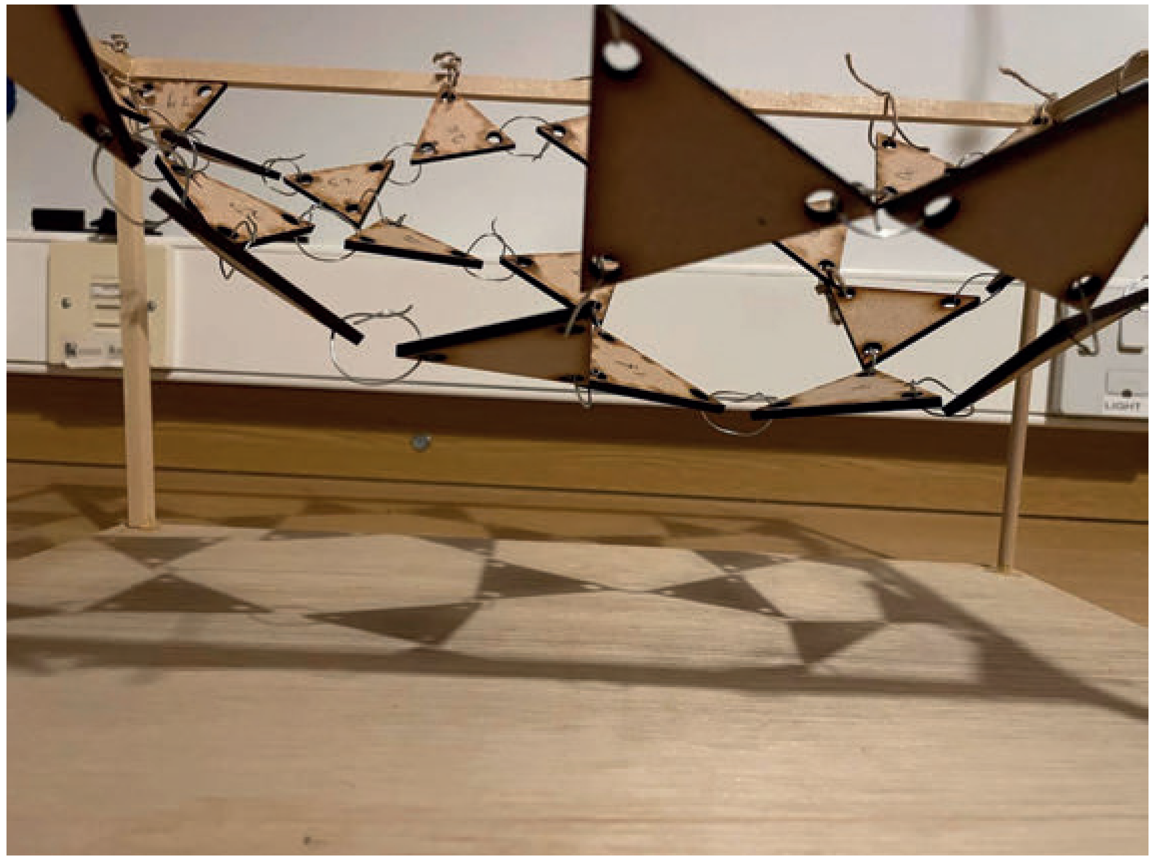
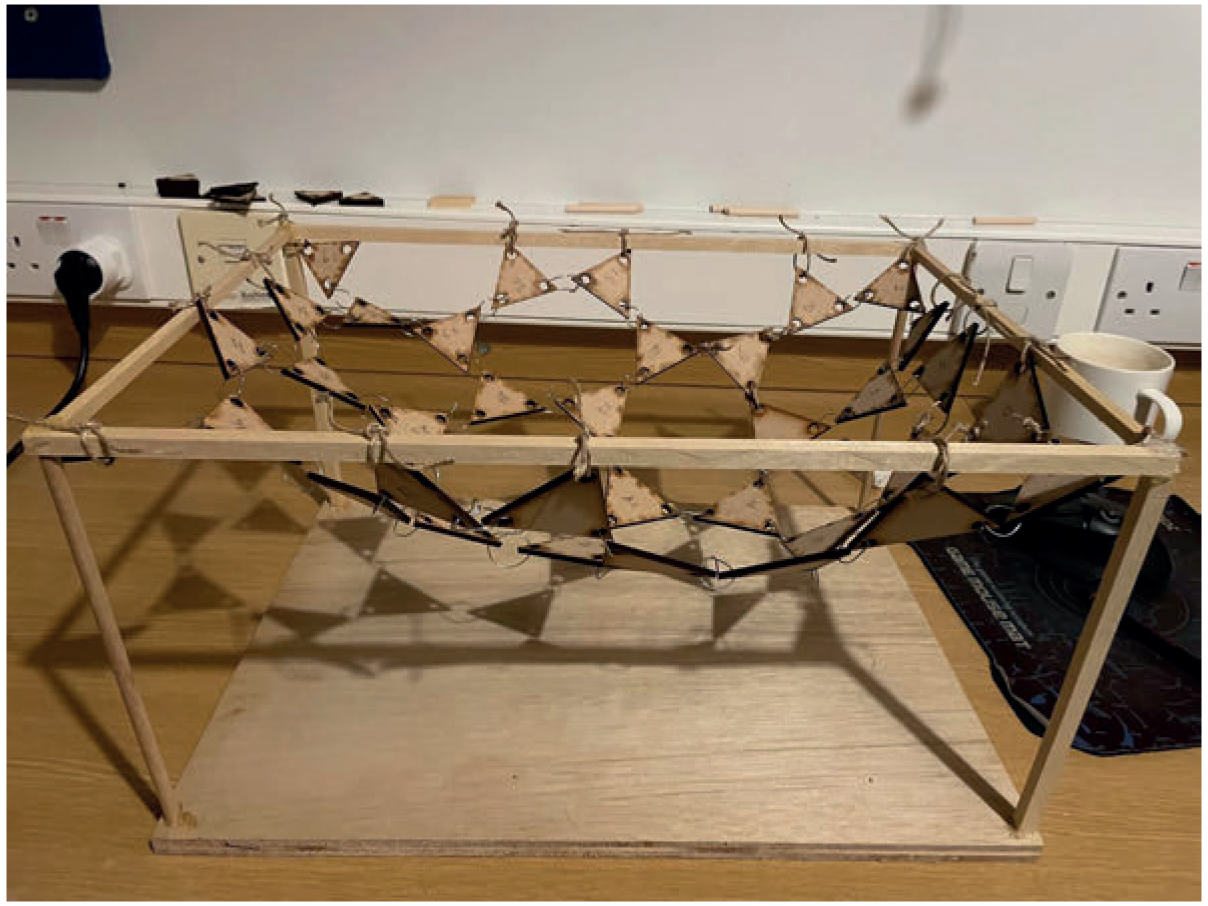
4.3.2 Fabrication










5.Conclusion

1. Types of approaches for designing shelters with auxetic patterns are expored

Various methods have been proposed for using auxetic structures in shelter design, such as:

-Incorporating auxetic structures into shelter components, such as facade, fee-form or roofing, to enhance their performance and durability.

-Using auxetic structures as standalone components, such as walls, frames, to achieve free-form architectural forms and functions.

2.Computational phases in auxetic shelter design:

Computational design tools and methods are used to model, simulate, and optimize auxetic structures for shelter applications. These phases can involve various steps, such as:

-Defining design goals and constraints, such as strength, stiffness, weight, cost, or energy efficiency.

-Generating and testing different geometries and configurations of shelter by using auxetic pattern.

3. Fabrication options for auxetic shelters:

Various fabrication techniques can be used to produce auxetic structures and materials for shelter applications, such as:

-Additive manufacturing, such as 3D printing, laser cutting, which can create complex and customizable shapes and patterns with high precision and reproducibility.

6. Further Investigations

Further investigations for auxetic shelter design:

Despite the potential benefits of using auxetic structures and materials in shelter design, there are still many challenges and opportunities for further research and development, such as:

-Understanding the fundamental physics and mechanics of auxetic structures and materials, such as their deformation mechanisms, fracture behavior, or thermal expansion.

-Developing new computational tools and methods that can handle the complexity and variability of auxetic patterns, and can integrate multiple design criteria and constraints.

-Exploring the environmental and social impacts of using auxetic materials and structures in shelter design, such as their carbon footprint, resource efficiency, or cultural appropriateness.

-Testing and validating the performance and usability of auxetic shelters in real-world contexts, such as extreme weather conditions, emergency situations, or long-term durability.

-These investigations can help to advance the state of the art in auxetic shelter design, and can contribute to the broader goals of sustainable, resilient, and equitable built environments.

References

- Bistable Auxetic Surface Structures,Tian Chen, Switzerland, Julian Panetta, UC Davis, United States, Max Schnaubelt TUM, Germany, Mark Paul, EPFL, Switzerland

- Beyond Developable: Computational Design and Fabrication with Auxetic Materials, Mina Konakovi´c, Keenan CraneBailin, DengSofien Bouaziz, Daniel Piker Mark Pauly

- Computational Design of Deployable Auxetic Shells, Mina Konakovic-Lukovic, Pavle Konakovic, Mark Pauly, 2018

- Form-finding bending-active structures with temporary ultra-elastic contraction elements Julian Lienhard, Riccardo La Magna, 2014

- Rapid Deployment of Curved Surfaces via Programmable Auxetics, Mark Pauly, Julian Panetta,

- Gaurav Bharaj, Danny Kaufman, Etienne Vouga, and Hanspeter Pfister. 2018. Metamorphs: Bistable Planar Structures.

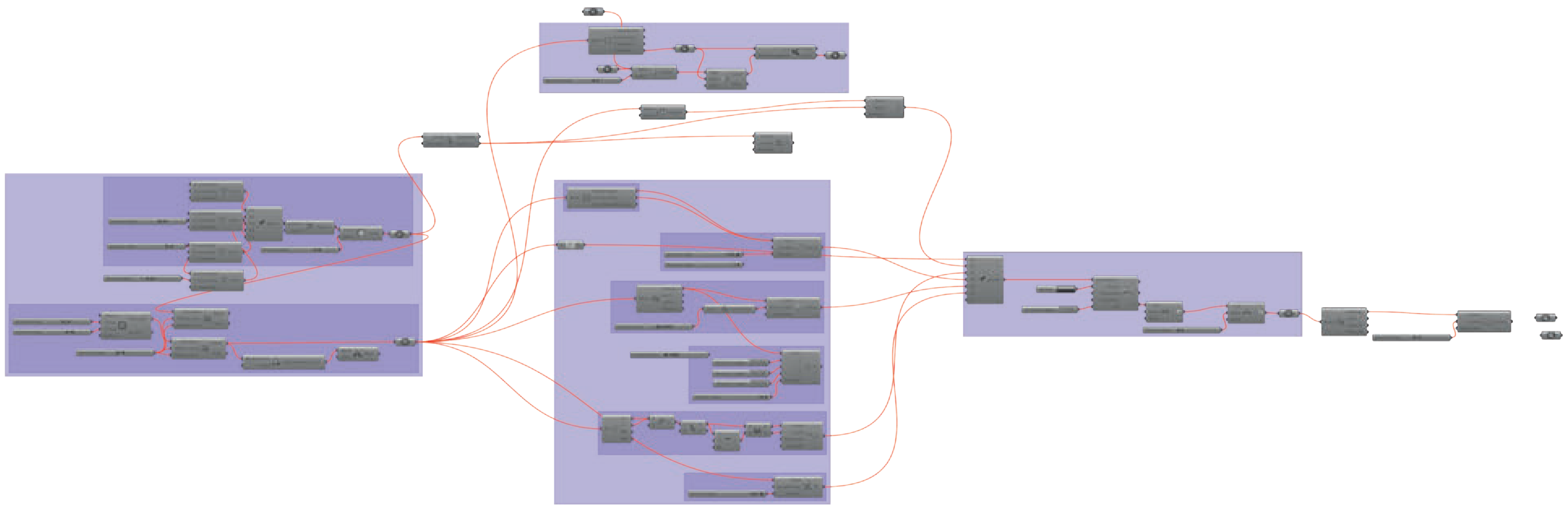
- Luigi Malomo, Jesús Pérez, Emmanuel Iarussi, Nico Pietroni, Eder Miguel, Paolo Cignoni,and Bernd Bickel. 2018. FlexMaps: Computational Design of Flat Flexible Shells for Shaping 3D Objects

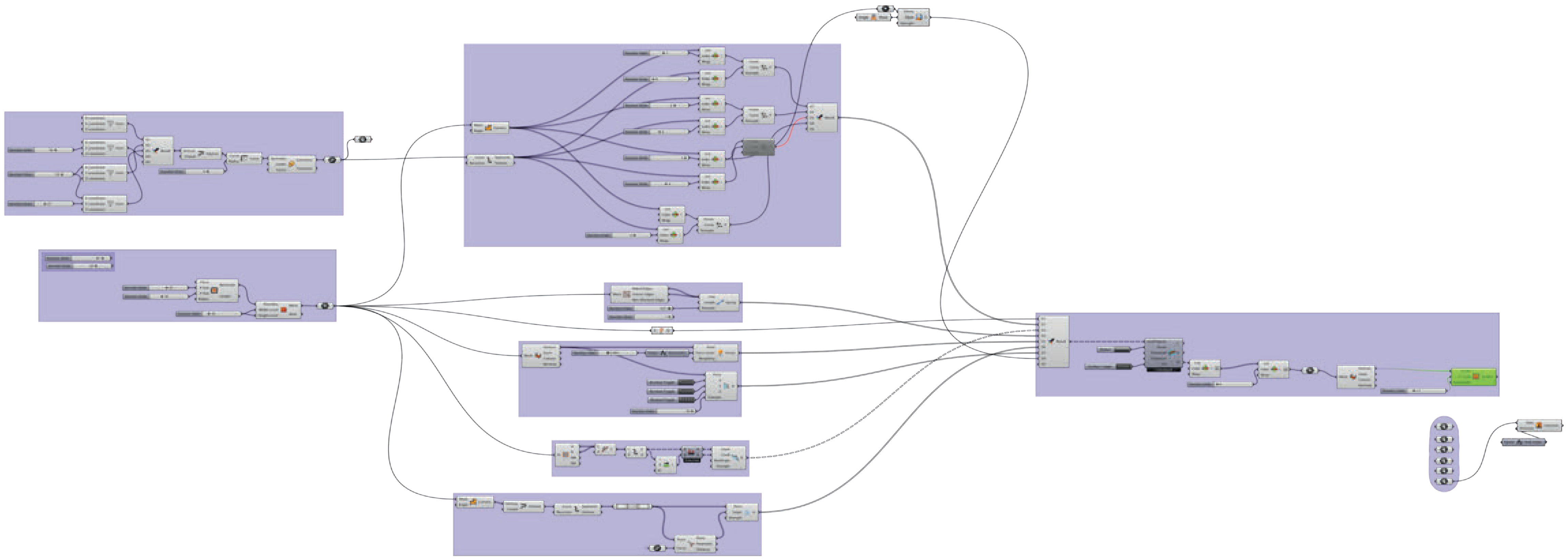
- Mathiass Rippmann, Philippe Block, Funicular Funnel Shells

- Marinella Contestabile, Ornella Iuorio, An Investigation of Alternative Form-Finding Methods for Free-Form Masonry Shells

Grasshopper Scripts

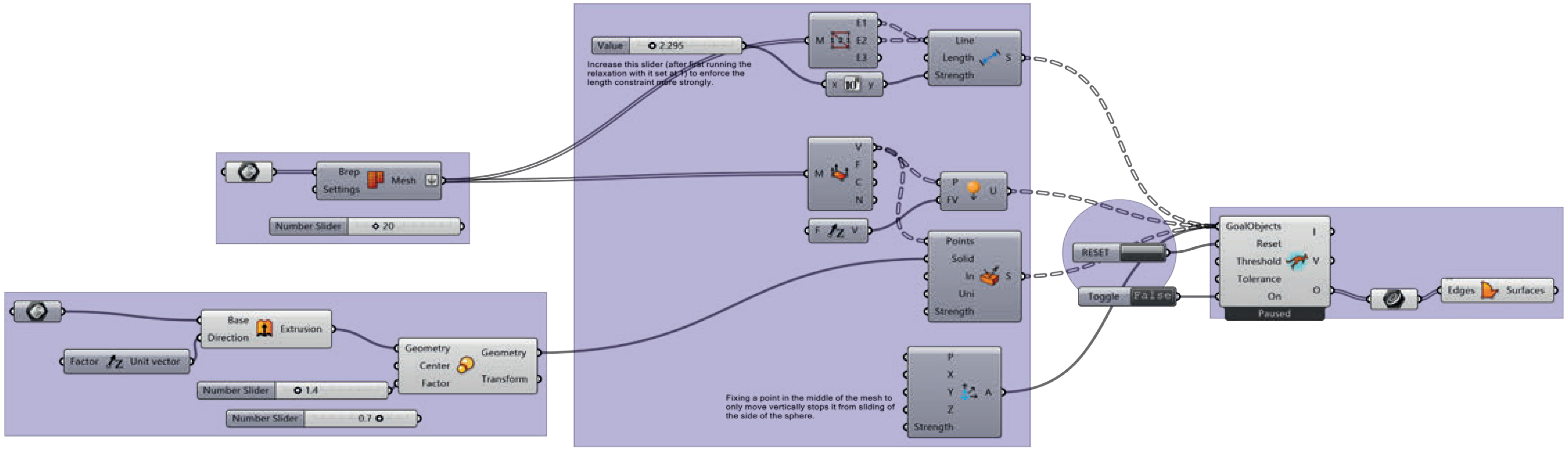
FORM FINDING

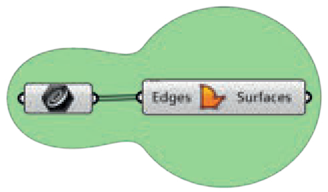


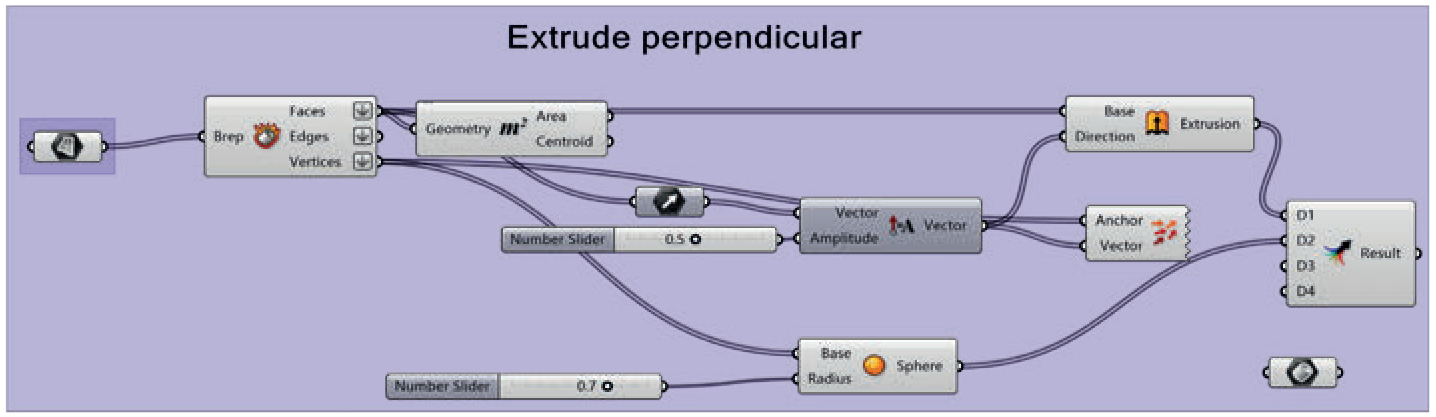


Grasshopper Scripts

Computed Auxetic Structure

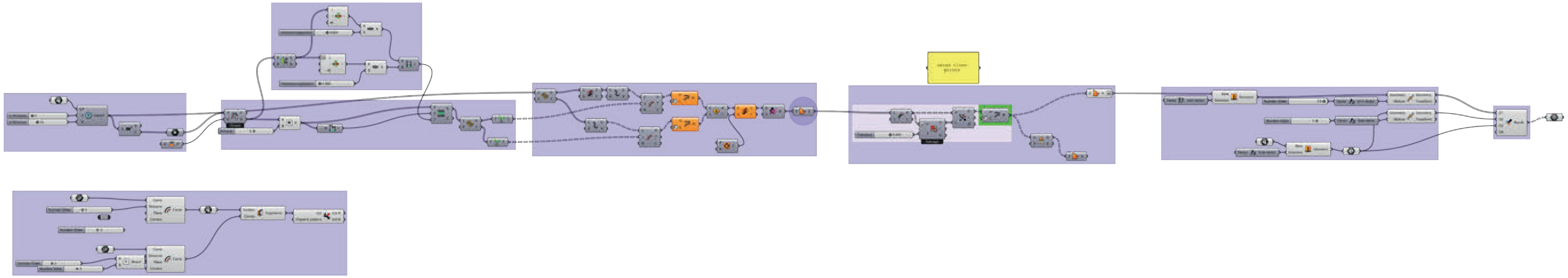






Grasshopper Scripts

Breathing Facade



LASER CUTTNG APPROACH