LOGIC TO ARTEFACT

- ADEYINKA ADEWOYIN
- 22043639

INTRODUCTION

Project Brief

The tuition focuses on computational design techniques at the microscale level, encompassing areas such as interior architecture, building systems, and architectural-scale interventions. Microscale design approaches typically concentrate on material testing, system validation, and digital fabrication methods inspired by natural and biological systems. The primer brief for this project is the design of a small structure with capacity for 1-3 users based on set of simple rules that when repeated create a complex systems.

Project Task

- Interpret Pattern Language theory and form-finding methods and recognise the interrelationship with computation design processes in academia and practice.
- Identify and apply the types and fundamentals of visual programming, material testing, and digital fabrication methods to represent microscale design in response to a primer brief.
- Apply researched knowledge of pattern and form-finding algorithms in design processes to produce a well-crafted artefact (simulation/fabrication).
- Flexibly and creatively select appropriate computational and fabrication methods by proactively undertaking substantial investigations to address an architectural system design.
- Present an interpretation of fundamental Pattern Language and form-finding theories in a crafted artefact, graphical and verbal illustration at ahigh level of abstraction, arguing from competing perspectives.

Proposal

This project aims to explore the ways in which a shelter can adapt to users' need, to offer an optimal, enjoyable experience that fosters a sense of playfulness. The objectives of the proposal include creating a shelter that promotes both indoor and outdoor activities, and designing an interactive shelter that both the interior and exterior surfaces offer interaction with the users.

Proposal

The proposal seeks to achieve this by investigating the potential of employing the deployable folding pattern found in origami system to create a dynamic shelter that can alter its form. The investigation entails examining how various parameters can impact the shape of the shelter's form by converting a 2D tessellation pattern into a 3D configuration.

A series of steps were undertaken to accomplish these goals. The first step investigates the dynamic properties of origami geometries by creating paper models to compare various elementary folding configurations. This comparison aims to gain a better understanding of the overall movement exhibited by these structures at a global scale.

In the second stage, Parametric modelling tools are utilized to create diverse kinetic origami modules by optimizing various parameters that affect the form.

Typology

The play shelter is to create both impressive and thrilling experience, with rods set at different heights that create exciting climbing paths through the structure connecting to the top. To descend quickly, kids can slide down the valley of the origami structure fun slides. Overall, the shelter is an ideal climbing destination that challenges children's physical abilities and helps develop their coordination.

Elements of Parametric Design

Robert Woodbury's book offers valuable insights into the workings of parametric systems, including their structural mechanics, historical and current usage in design, and ways to acquire proficiency in utilizing them. Parametric modelling is characterized as a type of design where various components are interconnected and modified in unison through a cohesive set of parameters and rules, commonly referred to as an algorithm. The strength of Parametric Design is primarily attributed to its constituent components, which comprise novel skills and strategies, programming, geometry and associated gestures, and patterns.

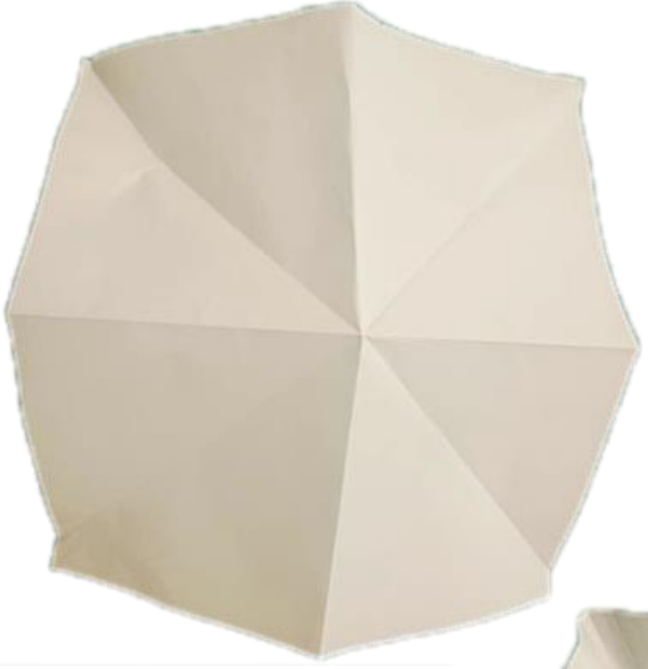
Design Patterns

The approach of Patterns for parametric design has been embraced by this project.
Within the context of parametric design, Woodbury explores 13 patterns that serve as critical conceptual instruments. These patterns represent distinct examples of relationships that yield specific geometric outcomes.
Christopher Alexander first introduced the idea of a design pattern in his book Pattern Language, which refers to a pre-existing architectural arrangement and its contextual usage and resulting outcomes. This system was further elaborated by (Robert Woodbury, 2010), their provision of parts aids in solving the "conquer" element of the divide-and-conquer tactic. By offering distinct solutions to problematic parts, they can facilitate the clarification of the data flow through a model. When articulated correctly, they serve as informal tools for expressing modules in principle. The main objective of patterns is to address issues. A well-crafted pattern clearly defines a problem and offers multiple unambiguous solutions. They expedite the creation of rough models during the sketching phase. Typically, patterns integrate insights from geometry, mathematics, and algorithms.

Origami

Robert Woodbury describes Paper Folding, also known as Origami, as an instance of the Place Holder design pattern. Deployable structures have made use of the concepts of kinetic origami and folding. The folding technique enables control over the structure by manipulating some or all its components. One can show how certain origami and paper folding techniques can be used to create deployable structures that move. By utilizing the distinct mountain and valley patterns of origami, we can construct a shelter that offers a fun experience of climbing and sliding. The way origami folds depend on specific parameters, such as corner angle, distance between parts, and number of sides. These techniques can be limited and categorized and can be tested through parametric modelling software. Ultimately, origami provides a limited but structured set of techniques for creating kinetic deployable structures.

Learning paper folding technique. Defining the mountain and valley feature of the origami system

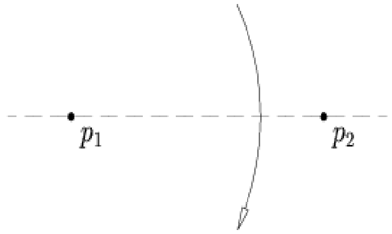


METHODOLOGY

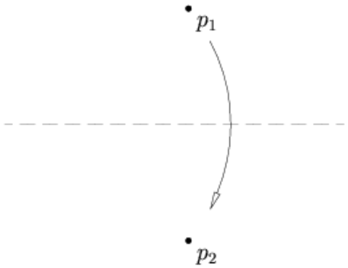
The geometric, material, and mechanical properties of deployable structures allow them to undergo expansion and/or contraction (Rivas-Adrover, 2017). Origami designers typically create a three-dimensional shape by planning and marking out creases on a two-dimensional surface using mathematical and computational techniques. These creases collectively form a crease pattern, which is then used to fold a flat sheet into a complex three-dimensional structure with the ability to bear a certain amount of weight (Chen, Yan and Feng, 2017).

Mathematical Theory for Origami Design

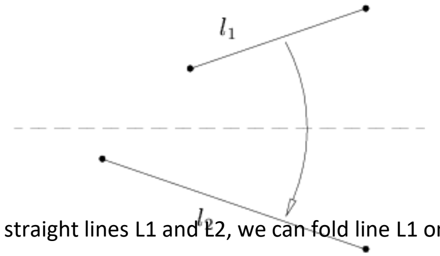
The theorems of Kawasaki regarding crease distribution at a single vertex, as well as Maekawa's theorem, the two-color theorem and Huzita–Justin (or Huzita–Hatori) axioms, provide the necessary conditions for achieving flat-foldability, (Chen, Yan, & Feng, 2017) are listed below:



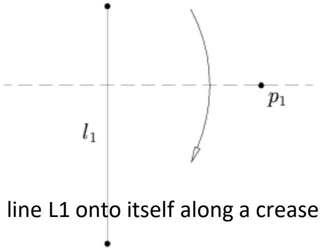
Given two points of P1 and P2, we can make a crease over P1 and P2;



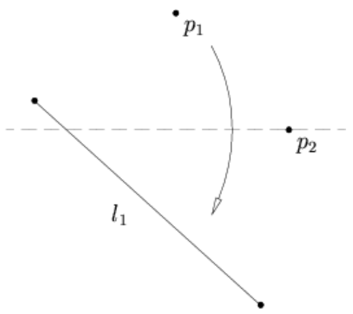
Given two points of P1 and P2, we can fold P1 onto P2 along a crease to make the two points coincide;



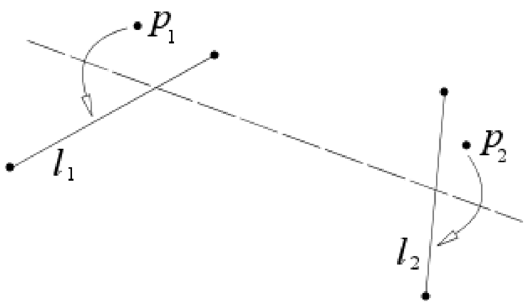
Given two straight lines L1 and L2, we can fold line L1 onto L2 along a crease to make the two lines coincide;



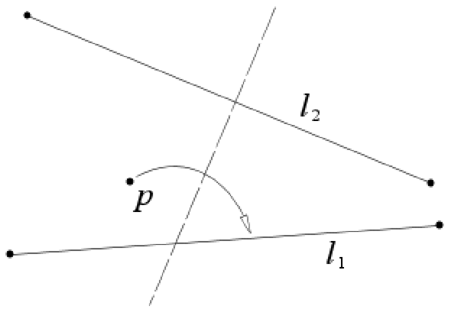
Given a point P1 and a line L1, we can fold line L1 onto itself along a crease passing through point P1;



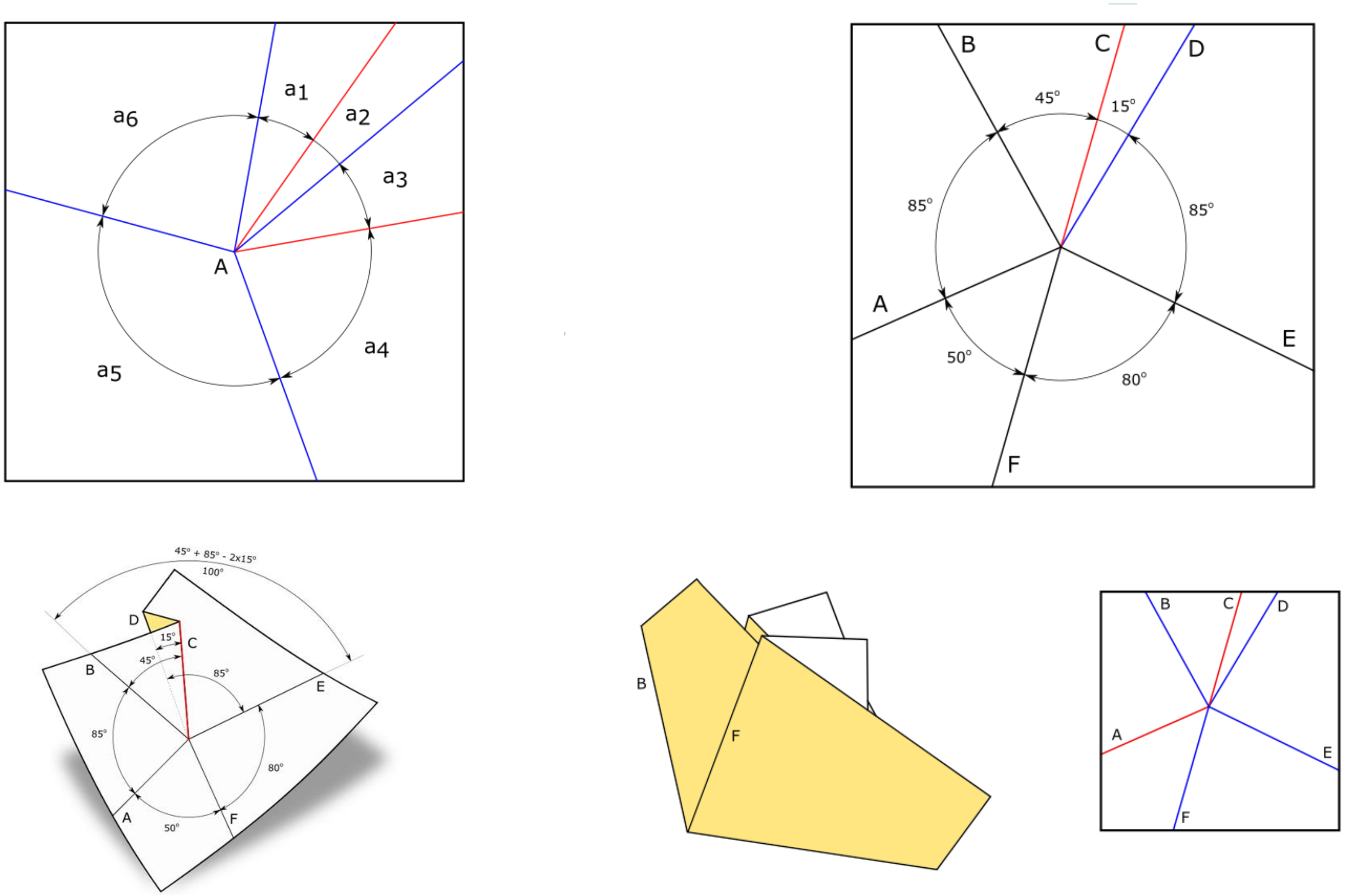
Given two points P1 and P2 and a line L1, we can fold point P1 onto line L1 along a crease passing through point P2;



Given two points P1 and P2 and two lines L1 and L2, we can fold P1 and P2 onto L1 and L2, respectively, along a crease; and



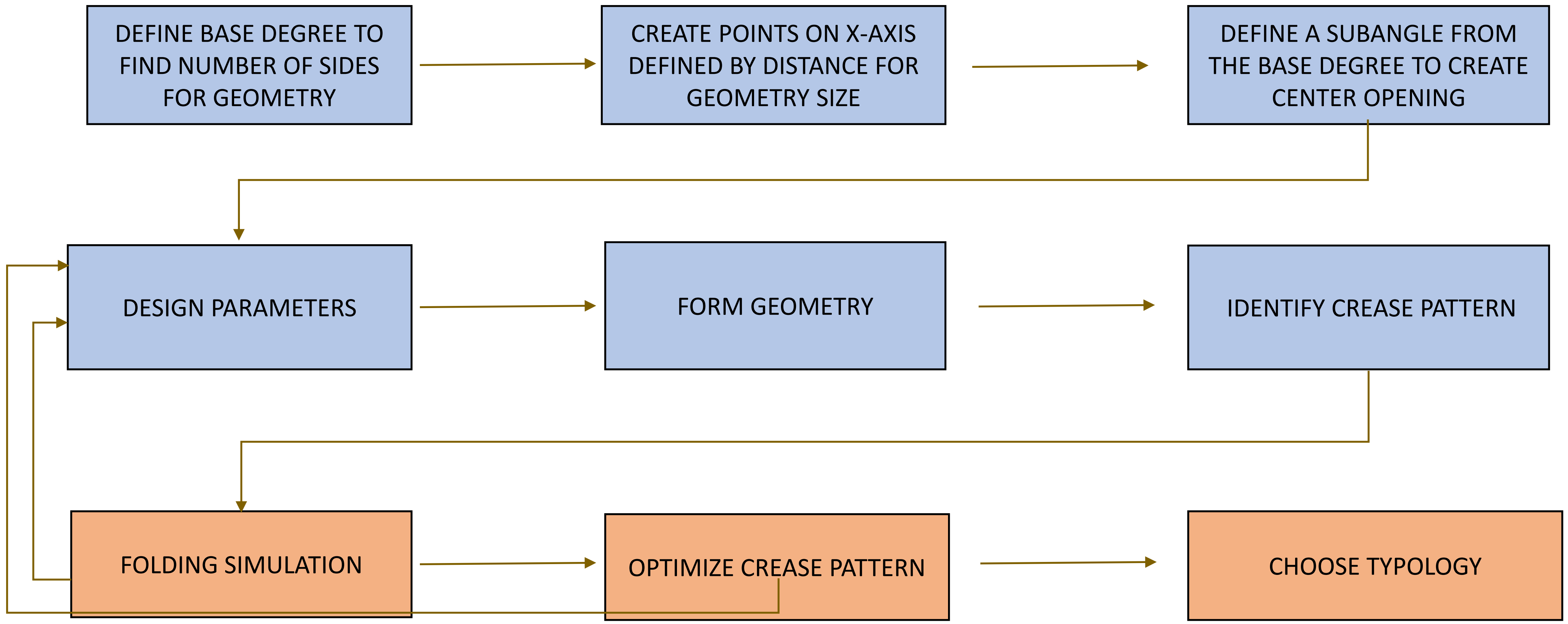
Given a point P and two lines L1 and L2, we can fold point P onto line L1 along a crease perpendicular to L2.



In accordance with Kawasaki's theorem, the creases around a vertex must be numbered sequentially, such that the sum of odd-numbered angles equals the sum of even-numbered angles, with a total sum of 180, in order to achieve flat-foldability in origami.

Computational Approach for Origami Design

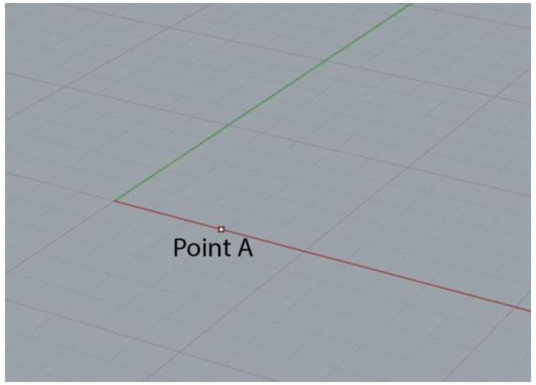
For this project, Rhinoceros and Grasshopper have been chosen as a software platform to generate a parametric folding pattern focusing on single surface folding, particularly where surfaces can transform from one configuration to another while retaining their planarity. Crane solver (Grasshopper plugin) interprets the folding logic from the flat reference sheet, deploys the folding through a controlled folding speed.



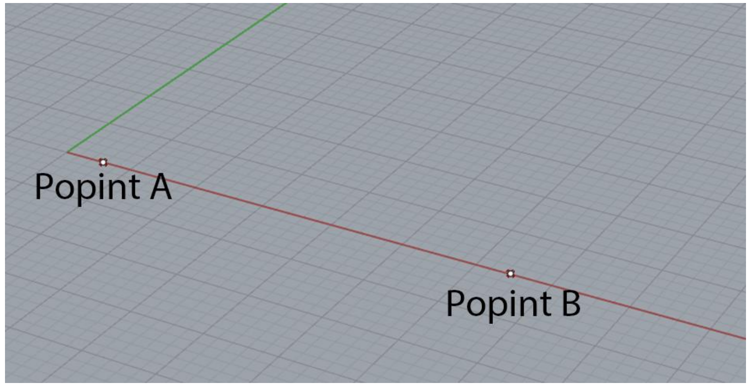
Logic

Following the Kawasaki's theorem, the number of sides for the shelter (n) was determine and calculated by the base angle as 180/n .

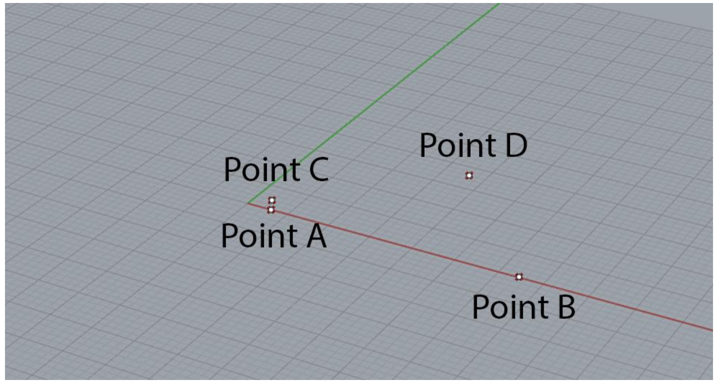
Define a starting point A along the x-axis.



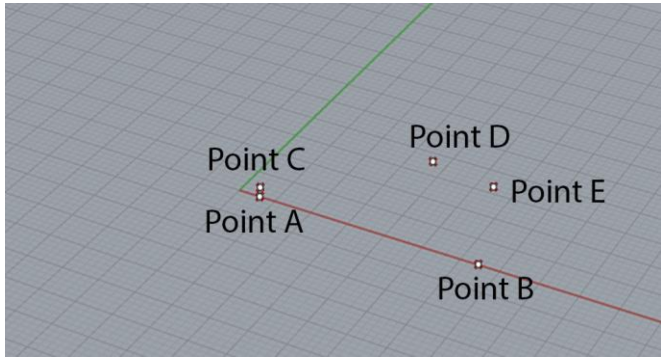
Offset point A by n units to generate point B (A + x), where n is the distance between A and B.



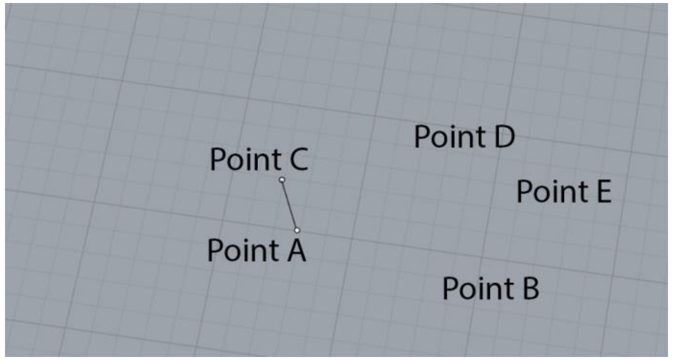
Rotate points A and B by the base angle to create a new set of points C and D.



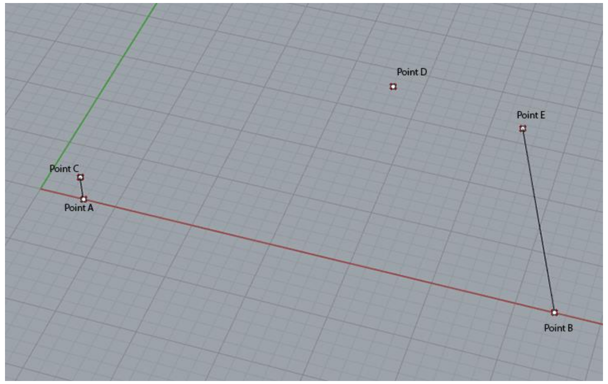
Define another point E between the x-axis and the base angle (more than 0 and less than 1 factor of the base angle)



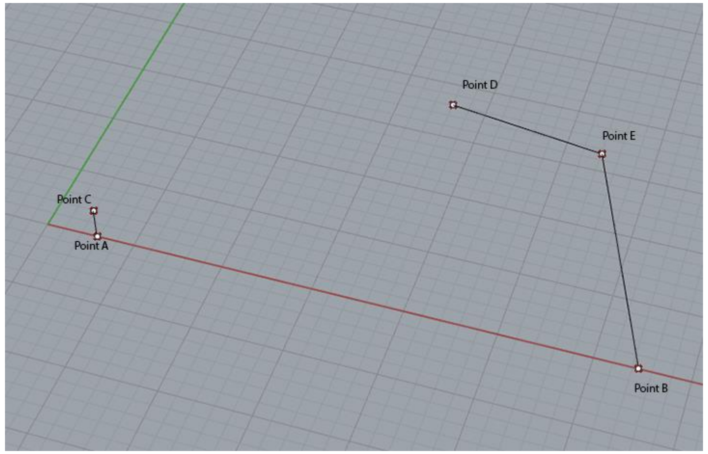
Draw a line from point A to point C (line AC).



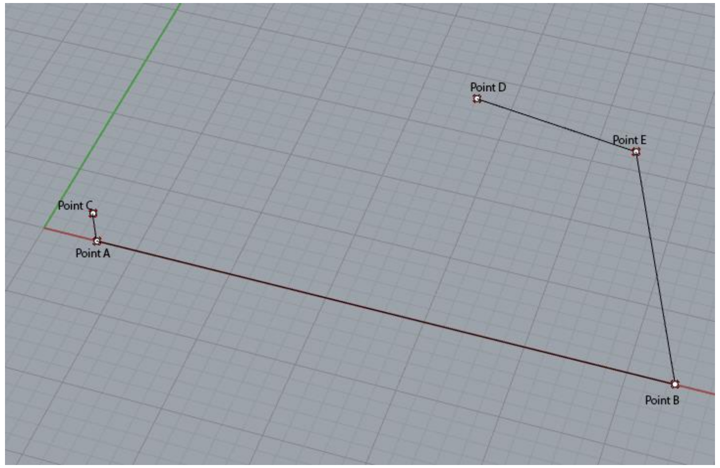
Draw a line from point B to point E (line BE).



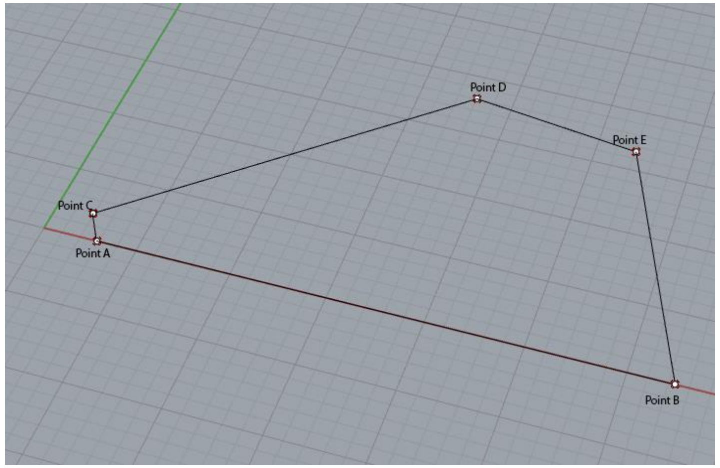
Draw a line from point E to point D (line ED).



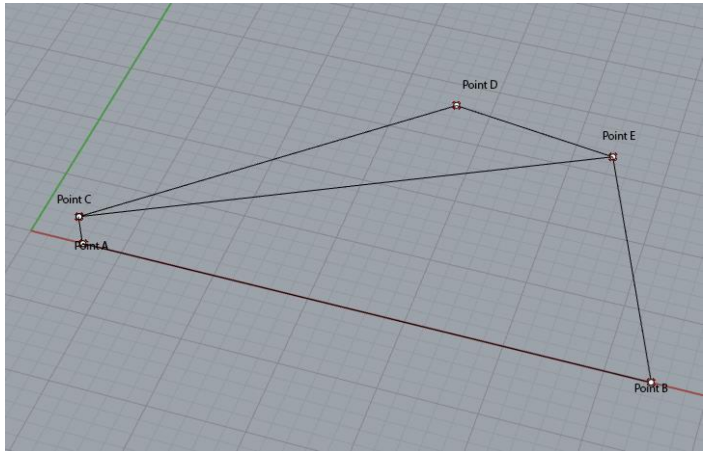
Draw a line from point A to point B (line AB).



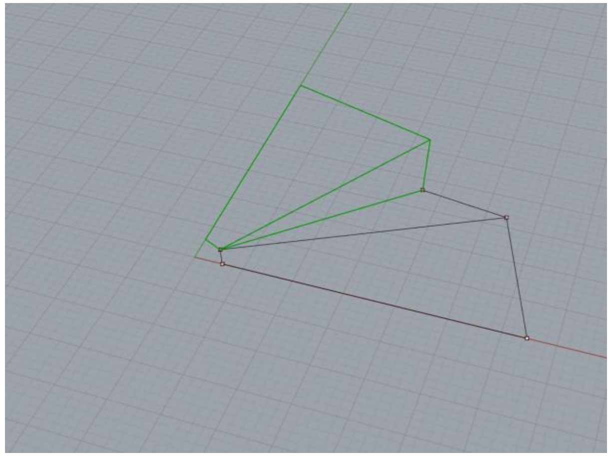
Draw a line from point C to point D (line CD).



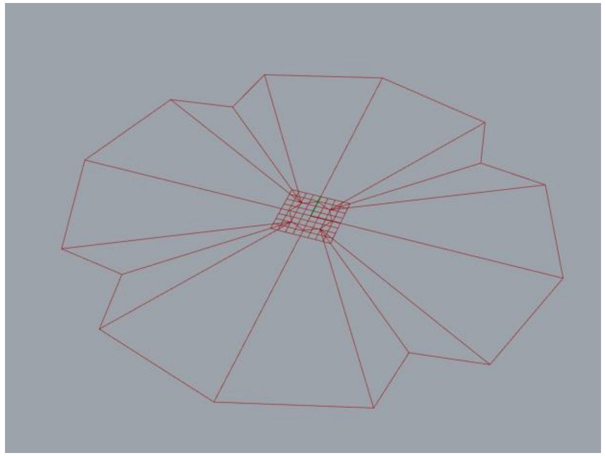
Draw a line from point C to point E (line CE).



Group and mirror the lines to complete a 90-degree section.

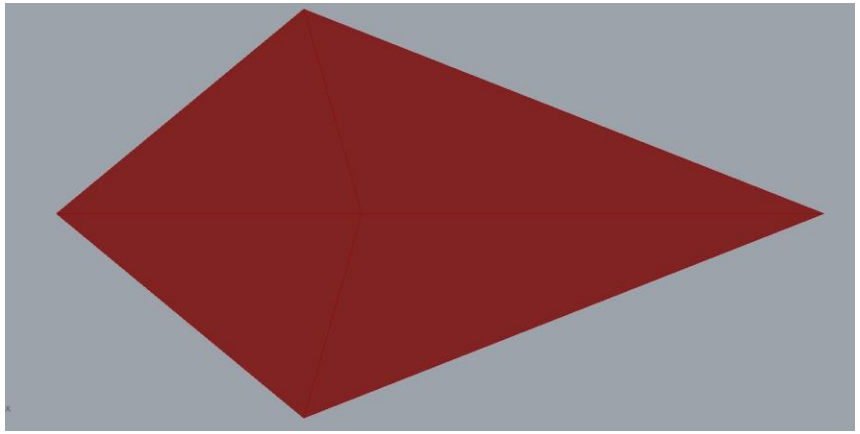


Use the geometry from the 90-degree section to create a complete circumference. Set array

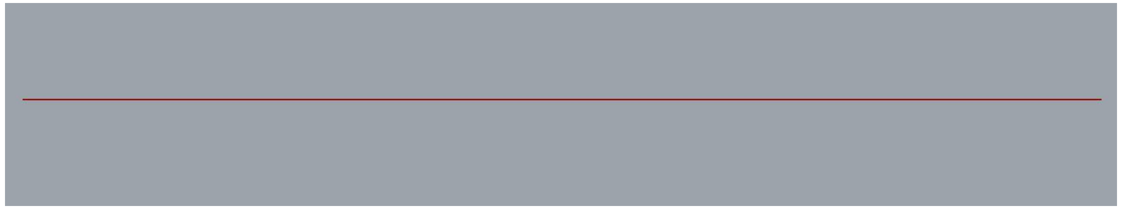


Optimize the positions of the points to create different forms for the shelter. Use a Crane solver/algorithm to generate the final origami shelter design.

Iteration 1 : Base angle set at 1 resulting in 2-sided geometry. No folding found in the simulation

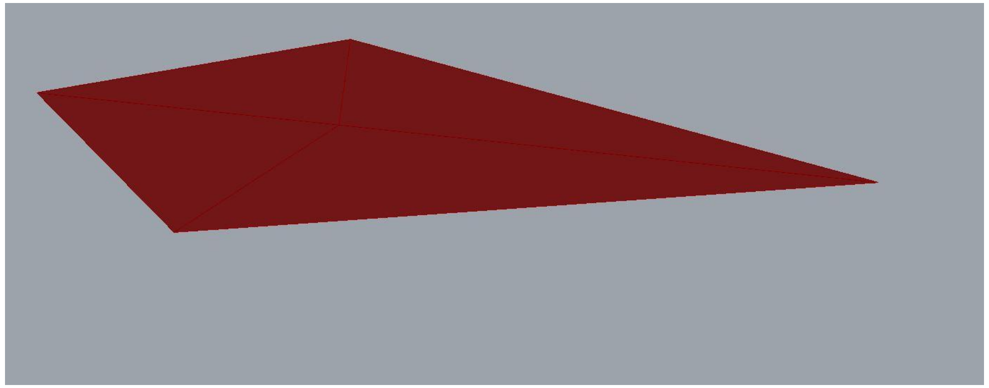


Top view



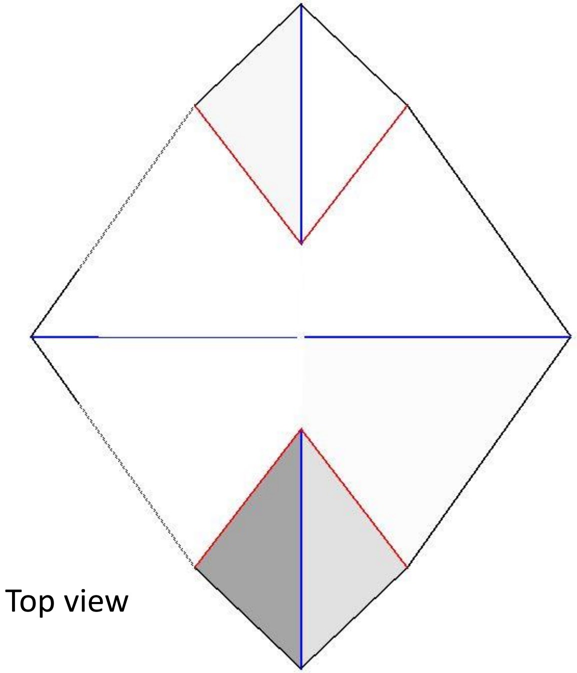
Front view

Right view

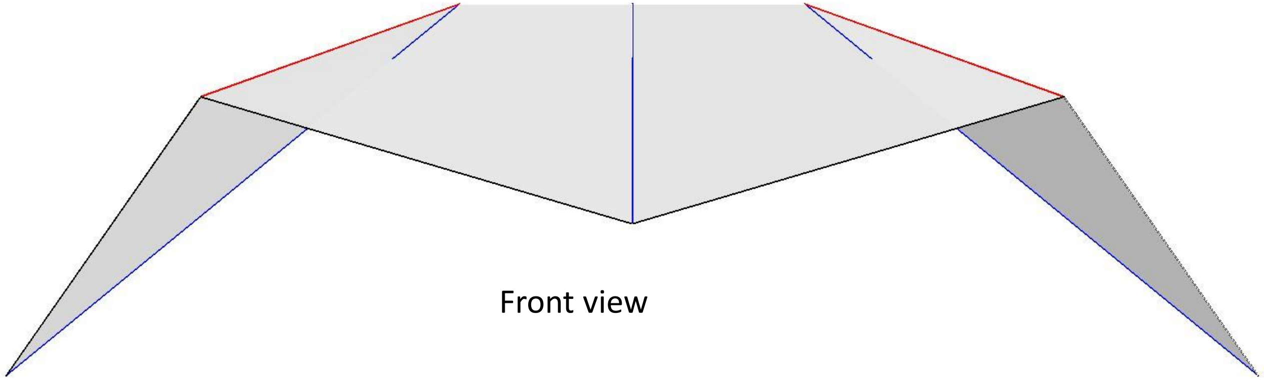


Perspective

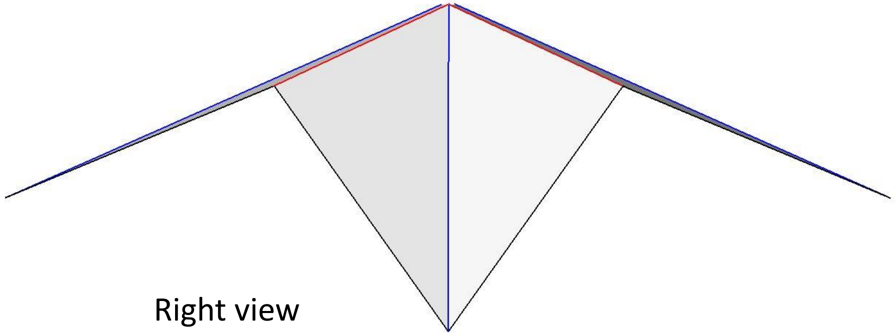
Iteration 2 : Base angle set at 2 resulting in 4-sided geometry. No center opening found in the simulation



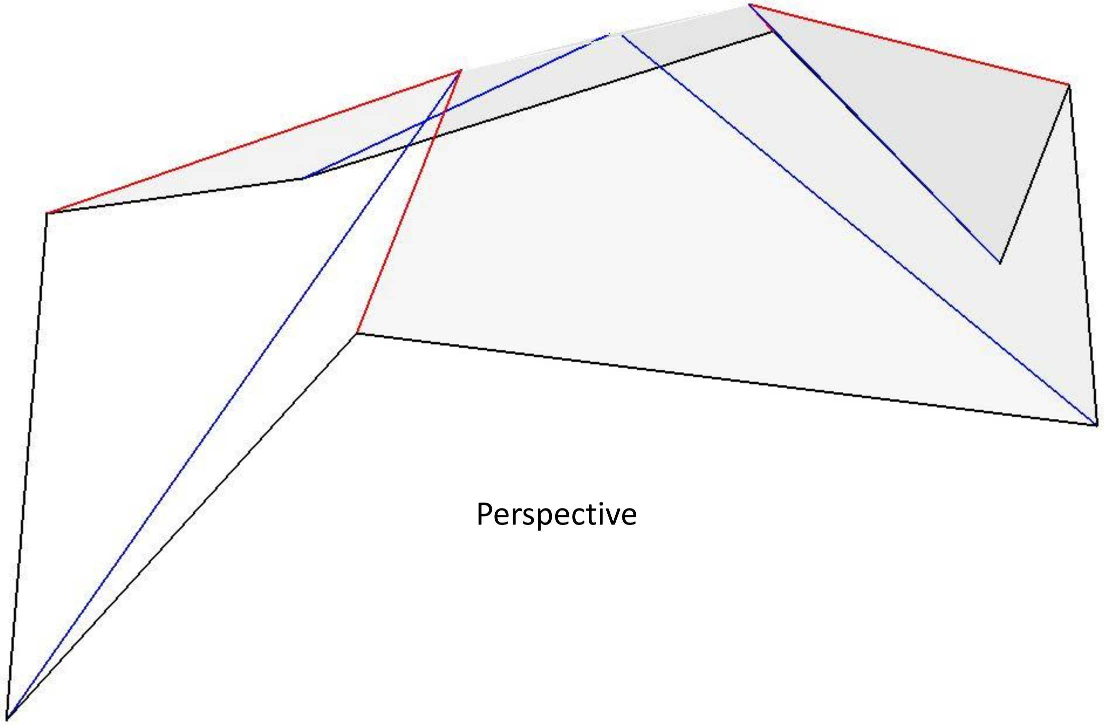
Top view



Front view

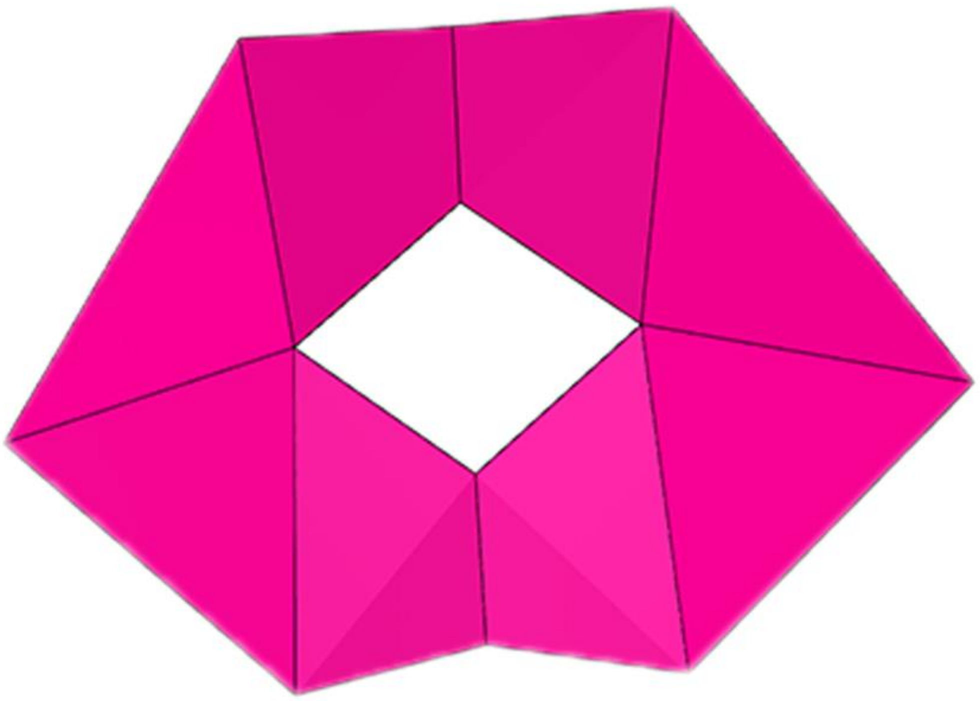


Right view

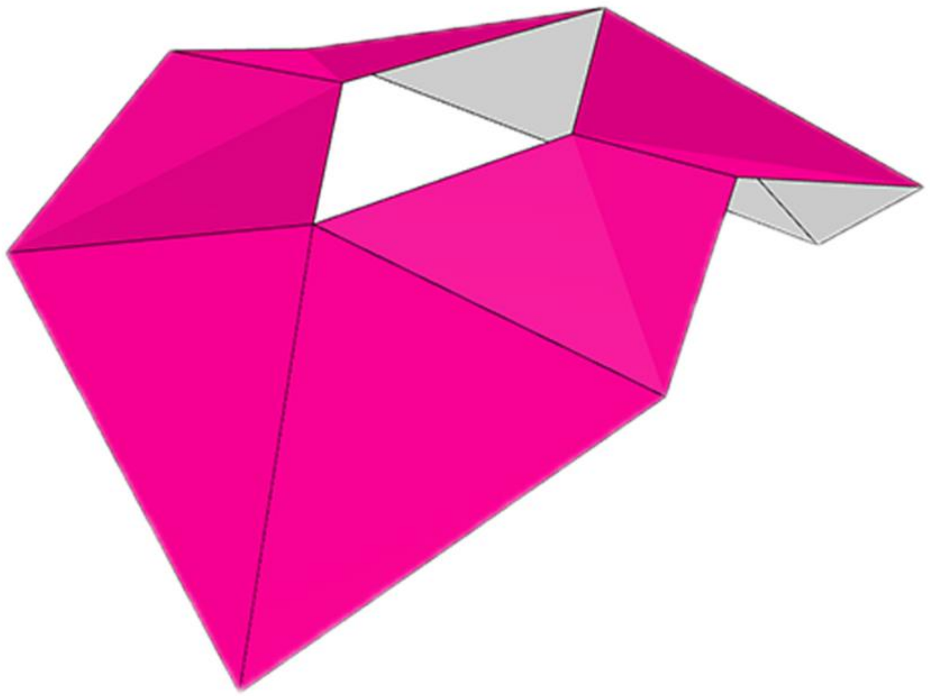


Perspective

Iteration 2b : Base angle set at 2 resulting in 4-sided geometry. Center opening found in the simulation with origamisimulator.org.

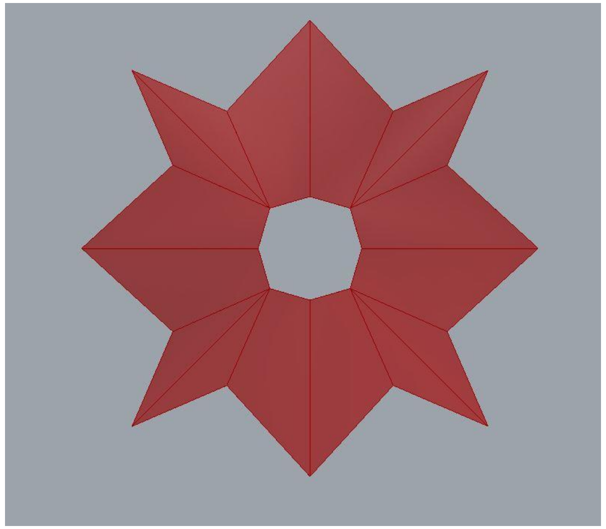


Top view

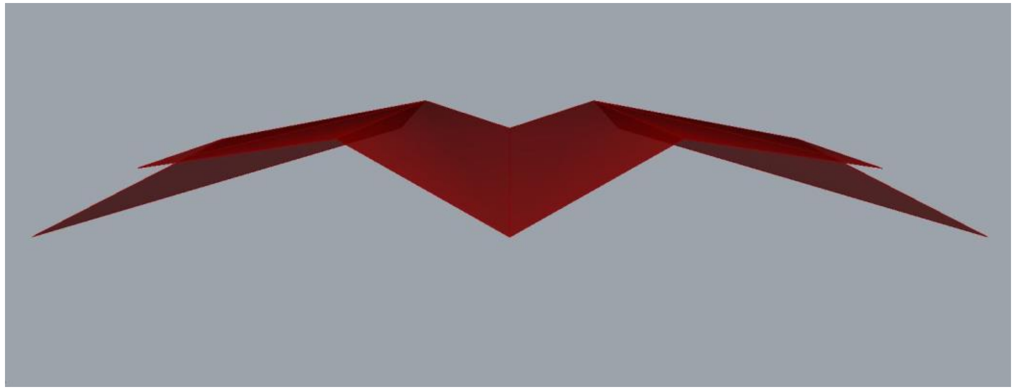


Perspective

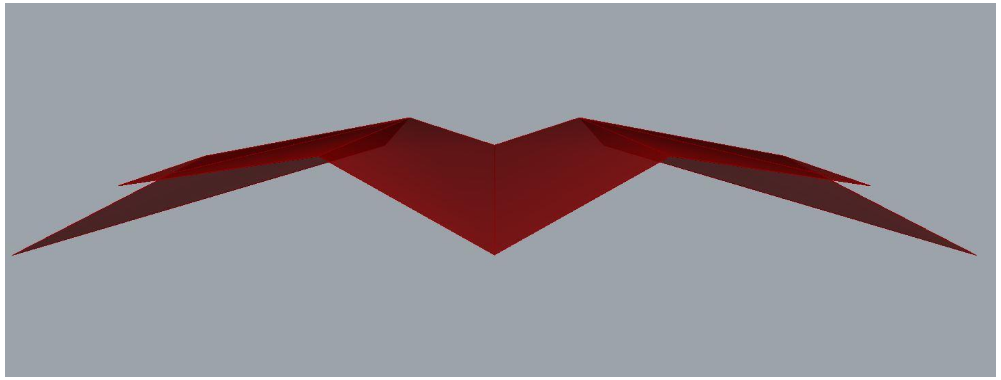
Iteration 3 : Base angle set at 3 resulting in 6-sided geometry. Center opening found, folding was carried out in the simulation



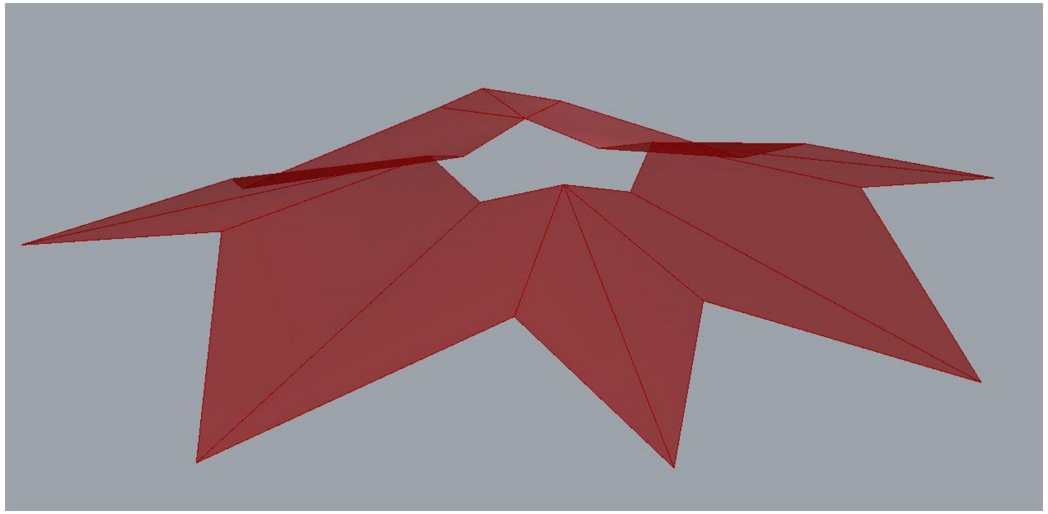
Top view



Front view

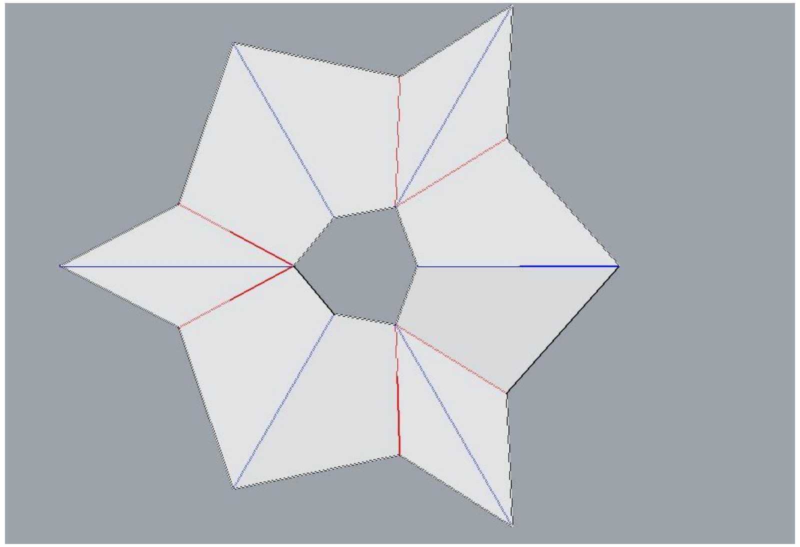


Right view

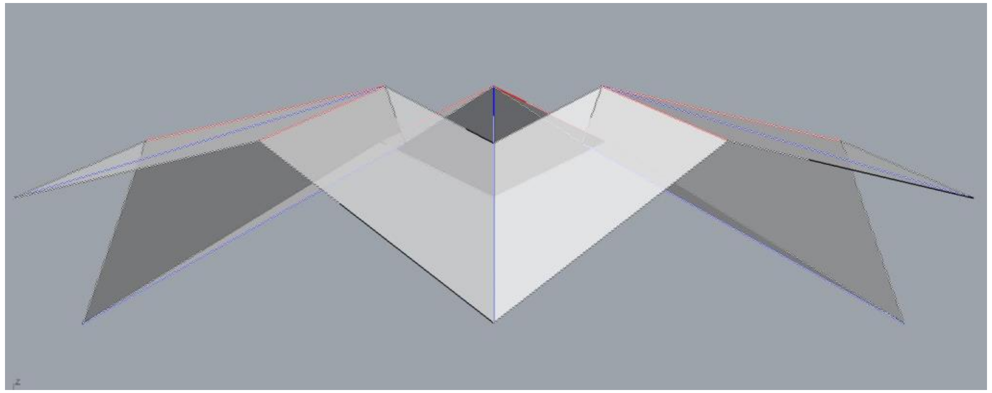


Perspective

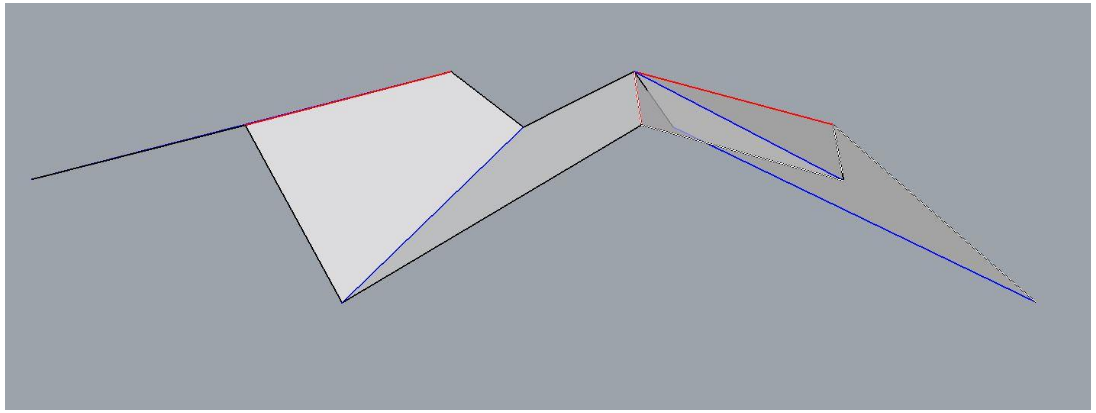
Iteration 3 : Base angle set at 3 resulting in 6-sided geometry. Center opening found, folding was carried out in the simulation



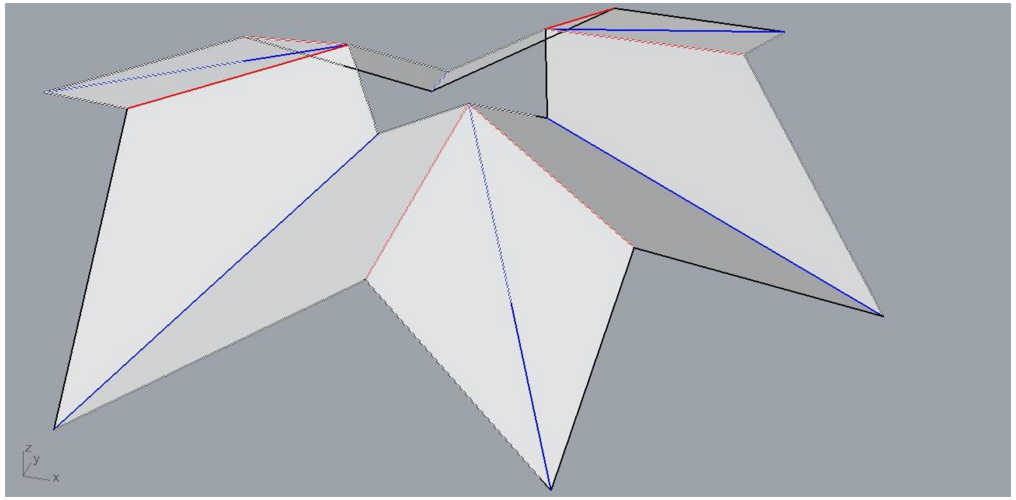
Top view



Front view

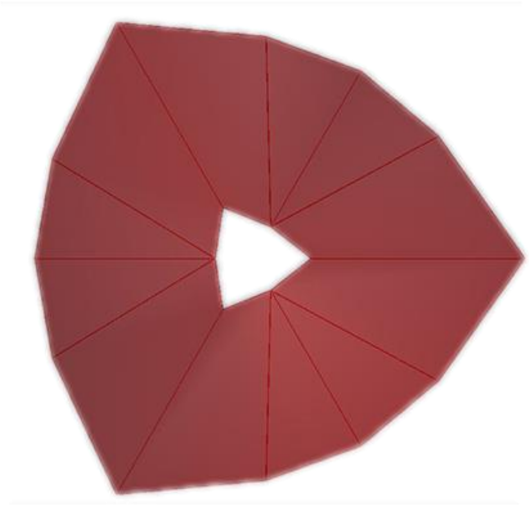


Right view



Perspective

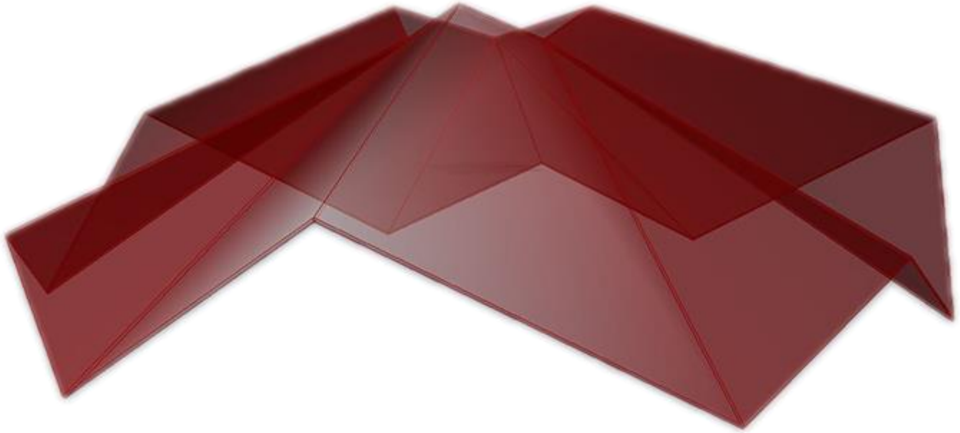
Iteration 3b : Base angle set at 3 resulting in 6-sided geometry. Center opening found, folding was carried out in the simulation



Top view

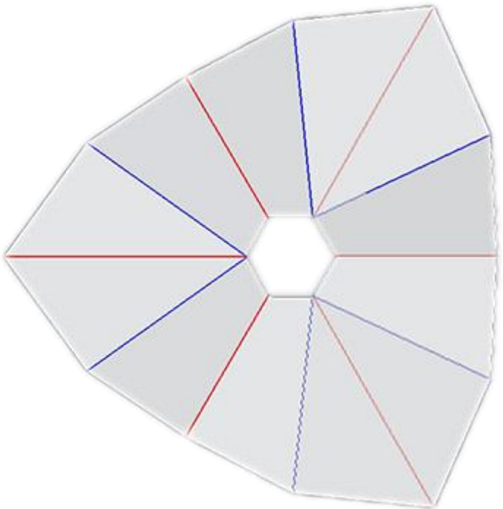
Front view

Right view

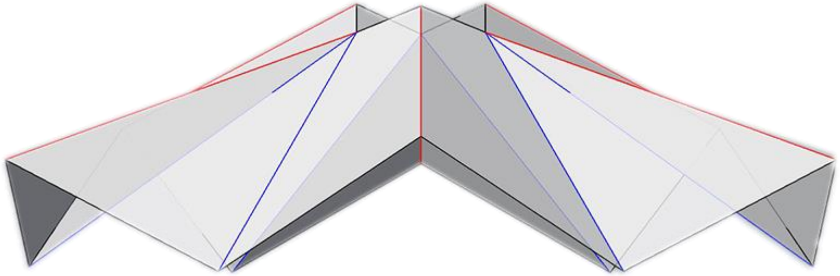


Perspective

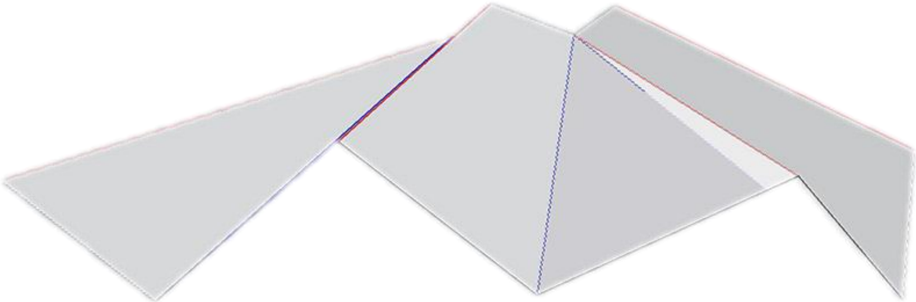
Iteration 3b : Base angle set at 3 resulting in 6-sided geometry. Center opening found, folding was carried out in the simulation



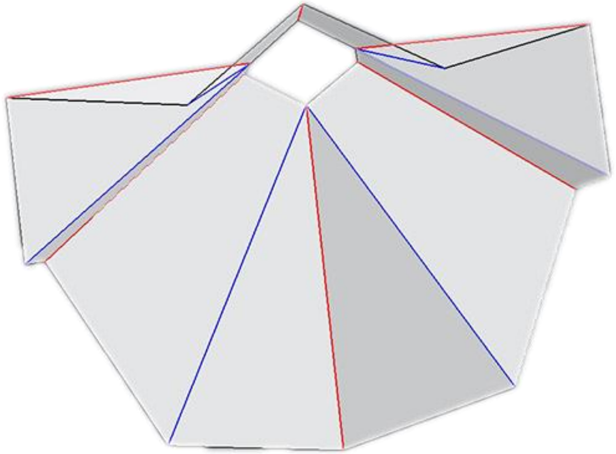
Top view



Front view

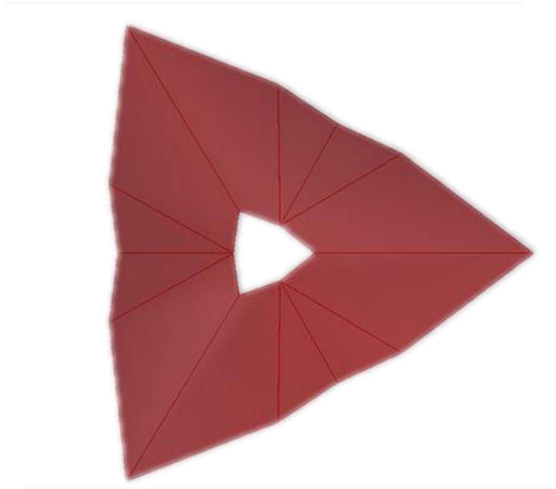


Right view

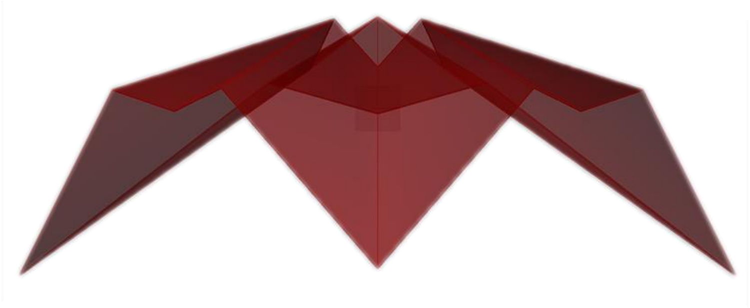


Perspective

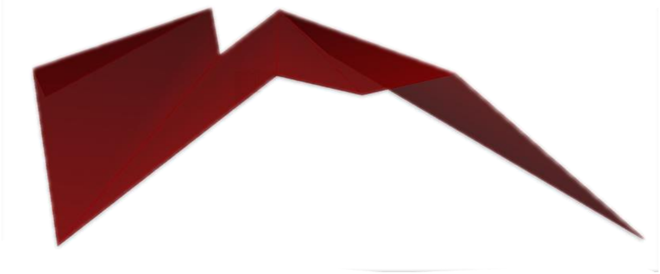
Iteration 3c : Base angle set at 3 resulting in 6-sided geometry. Center opening found, folding was carried out in the simulation



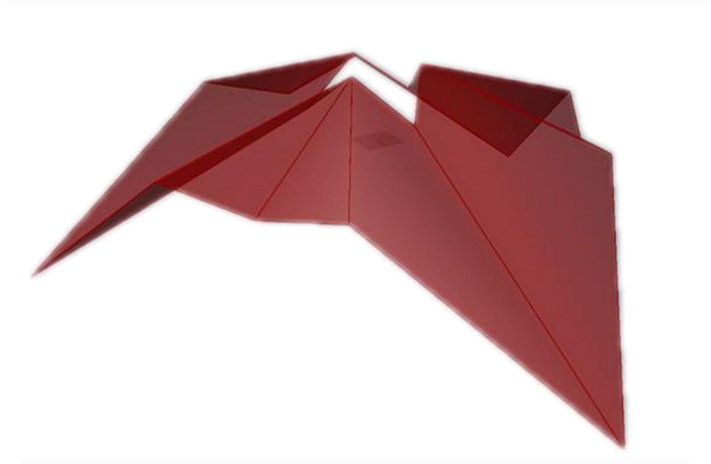
Top view



Front view

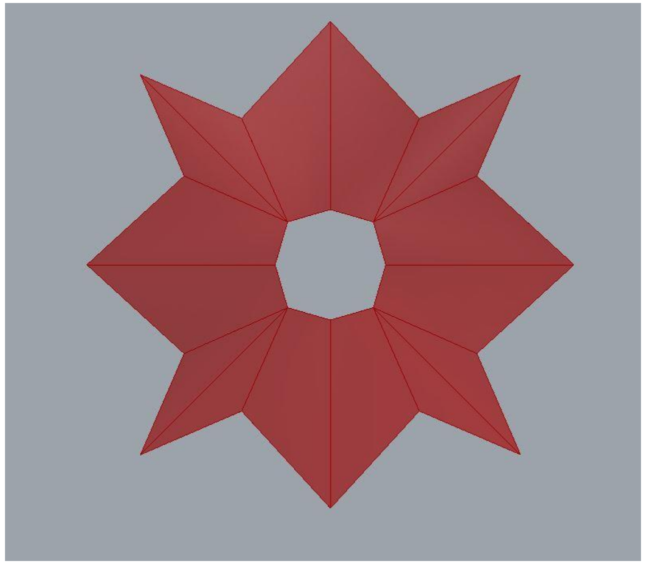


Right view

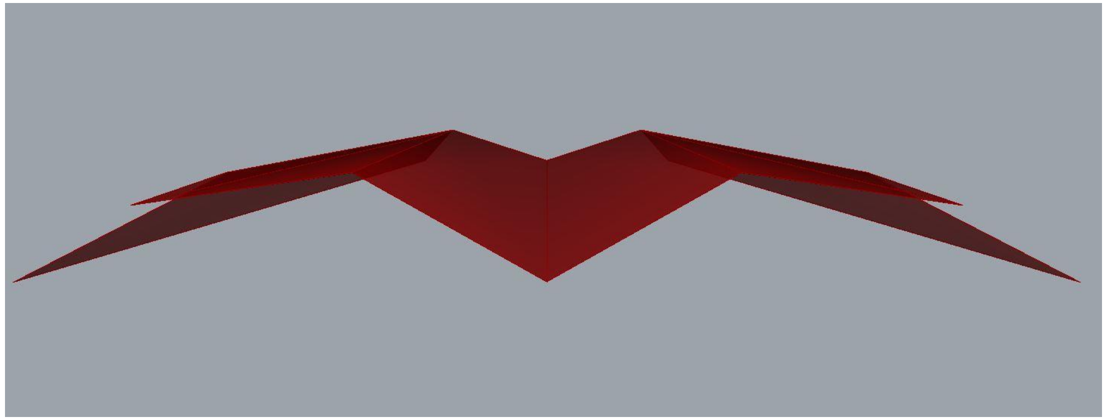


Perspective

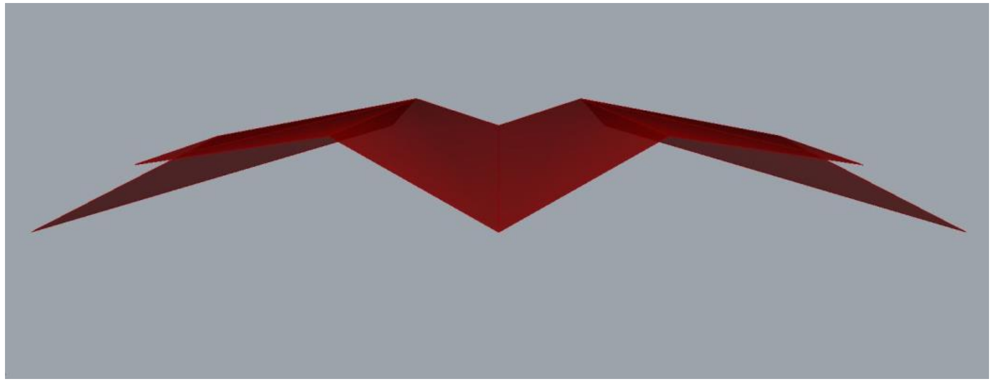
Iteration 4 : Base angle set at 4 resulting in 8-sided geometry. Center opening found, folding was carried out in the simulation



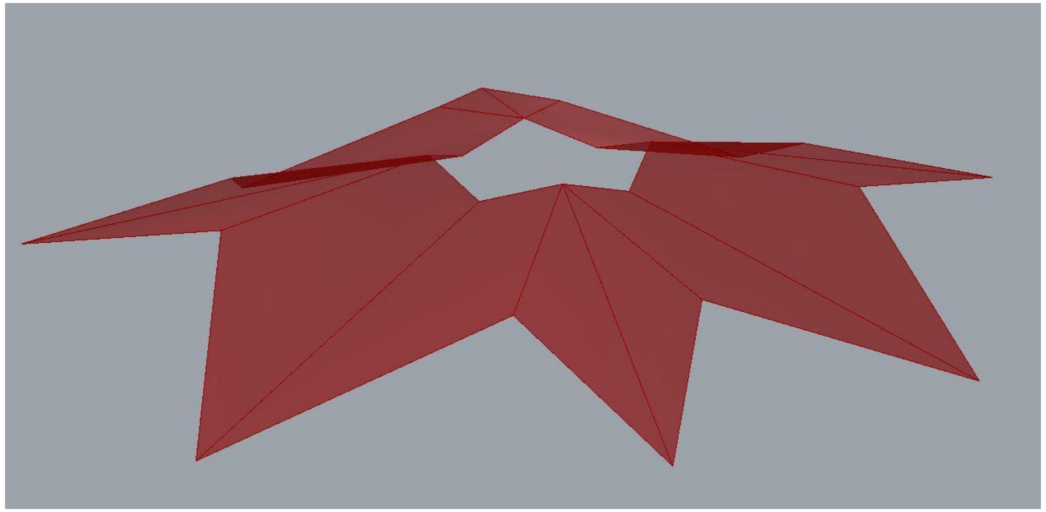
Top view



Front view

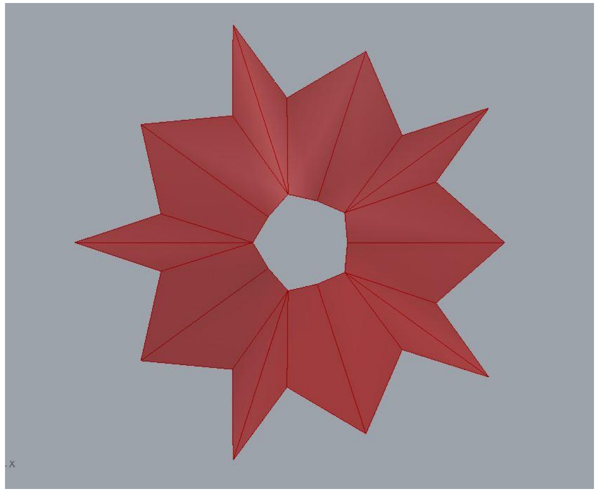


Right view

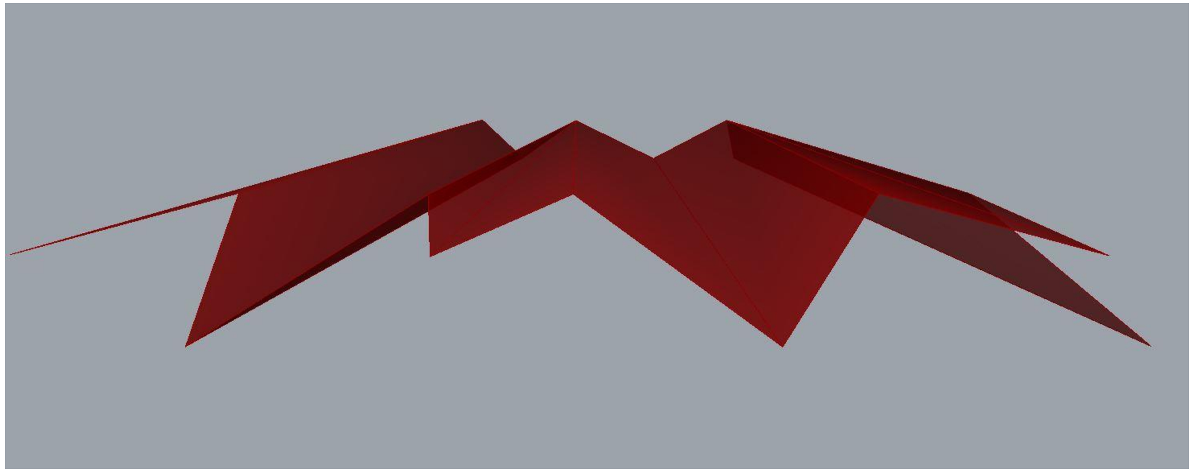


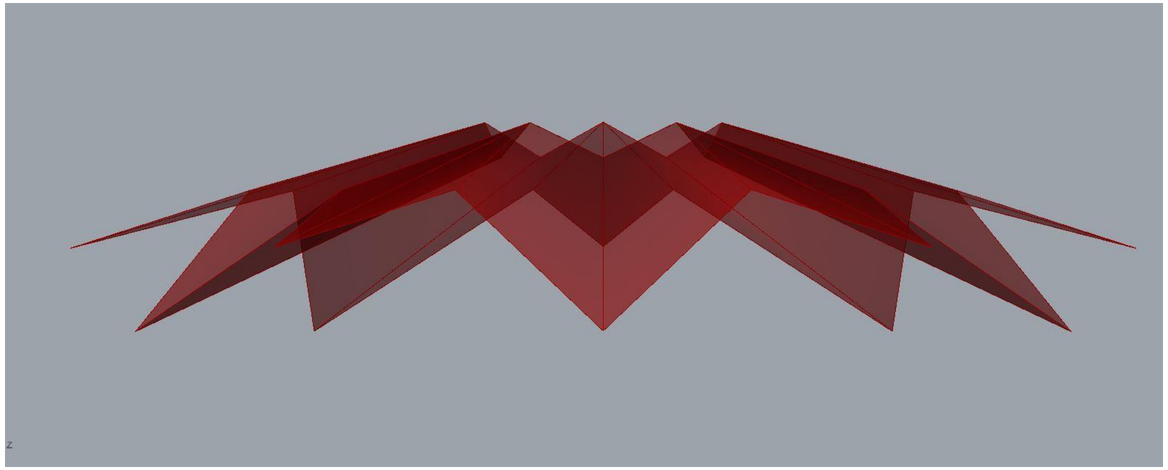
Perspective

Iteration 5 : Base angle set at 4 resulting in 10-sided geometry. Center opening found, folding was carried out in the simulation

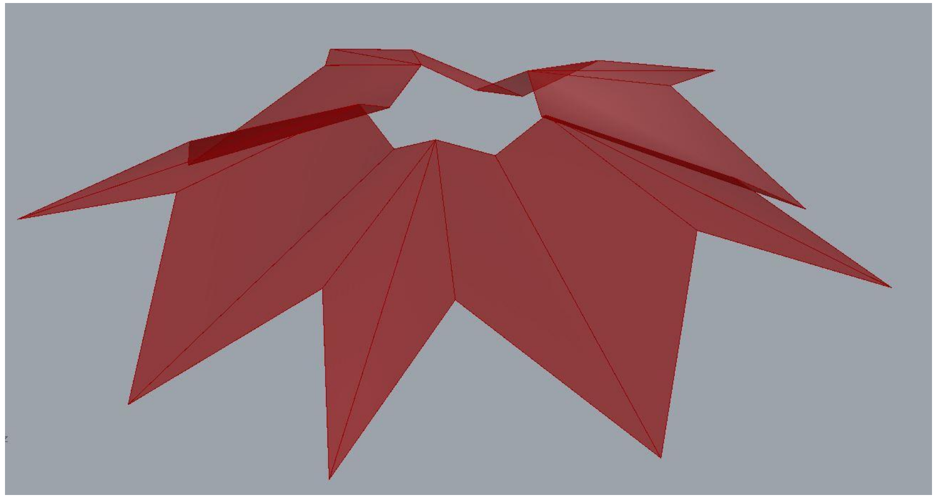


Top view



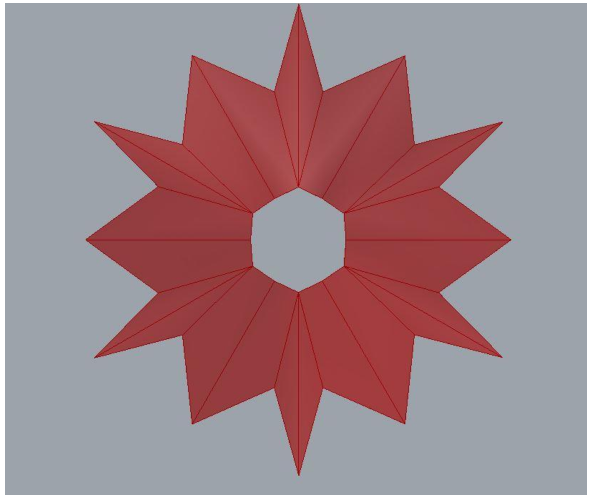


Right view

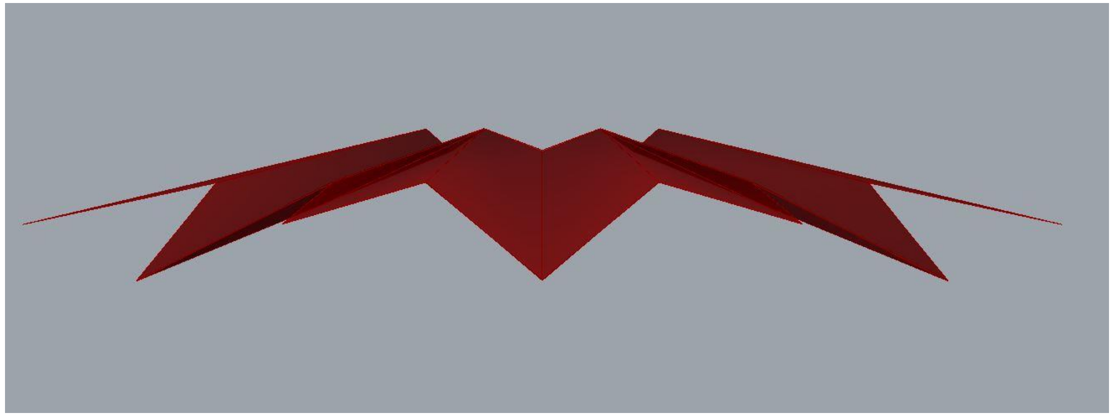


Perspective

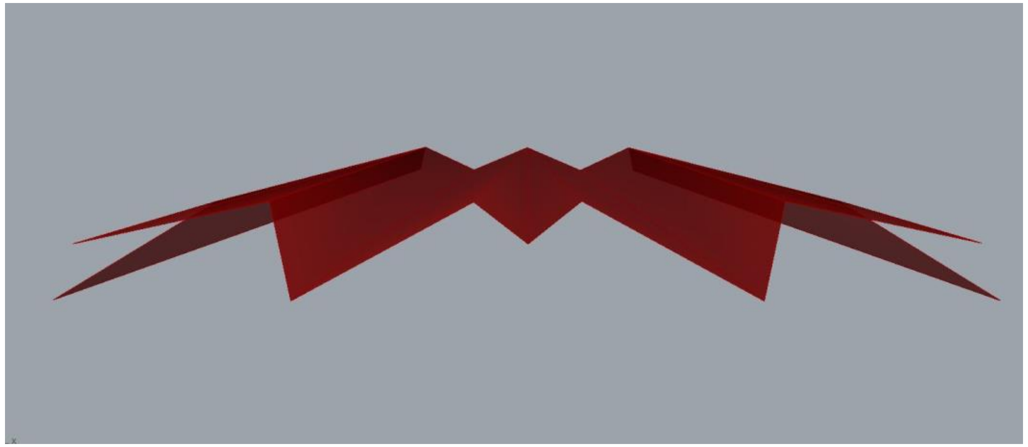
Iteration 6 : Base angle set at 4 resulting in 10-sided geometry. Center opening found, folding was carried out in the simulation



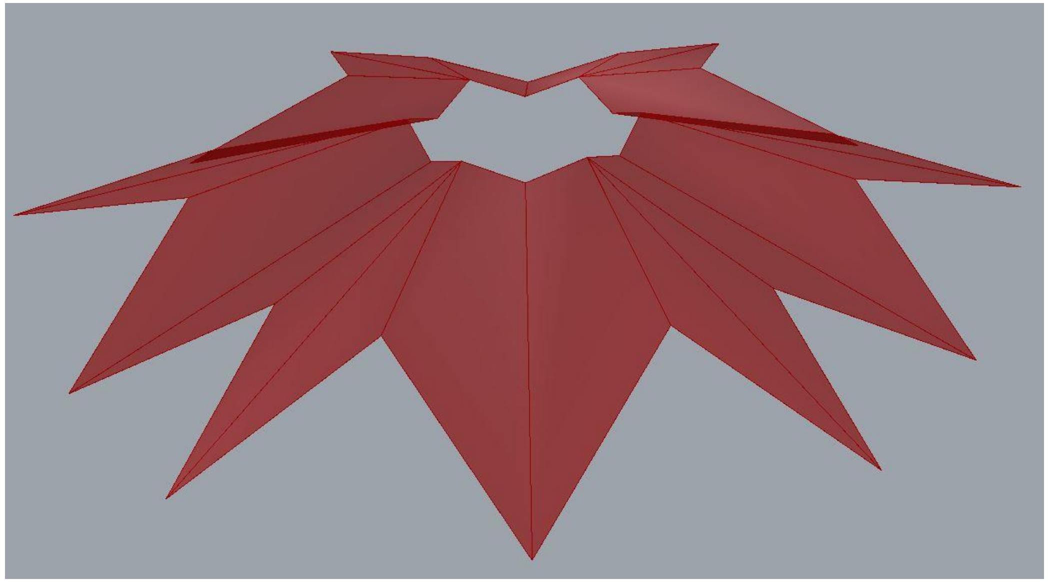
Top view



Front view

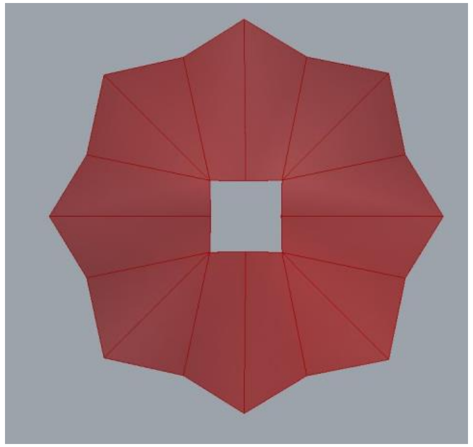


Right view

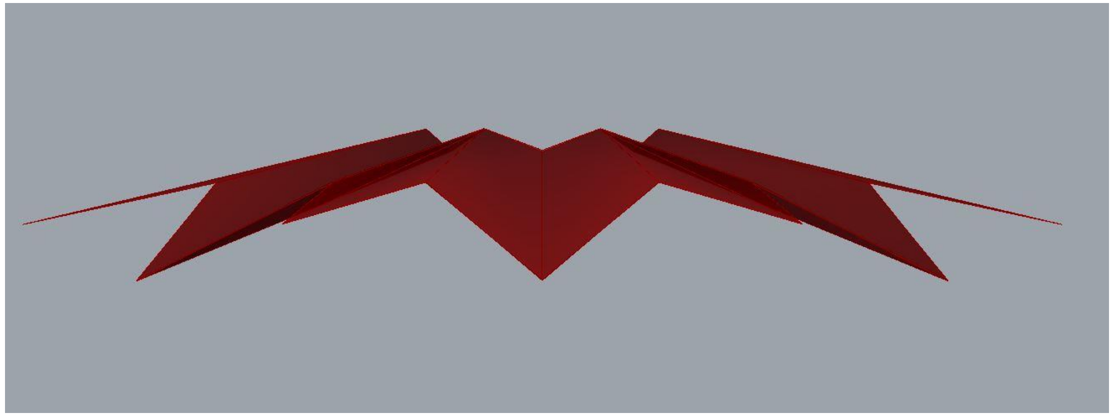


Perspective

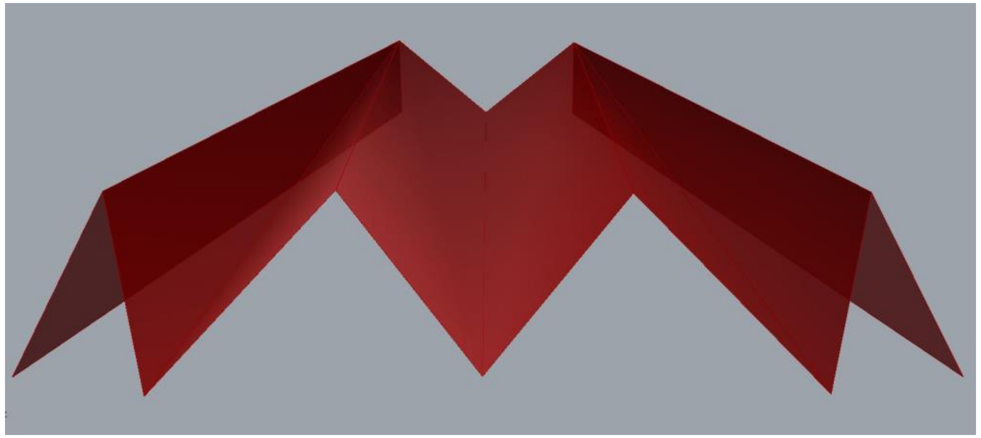
Iteration 7: Base angle set at 4 resulting in 16-sided geometry. Center opening found, folding was carried out in the simulation. This iteration has been selected for this project through the fittest value of the algorithm used for the iteration.



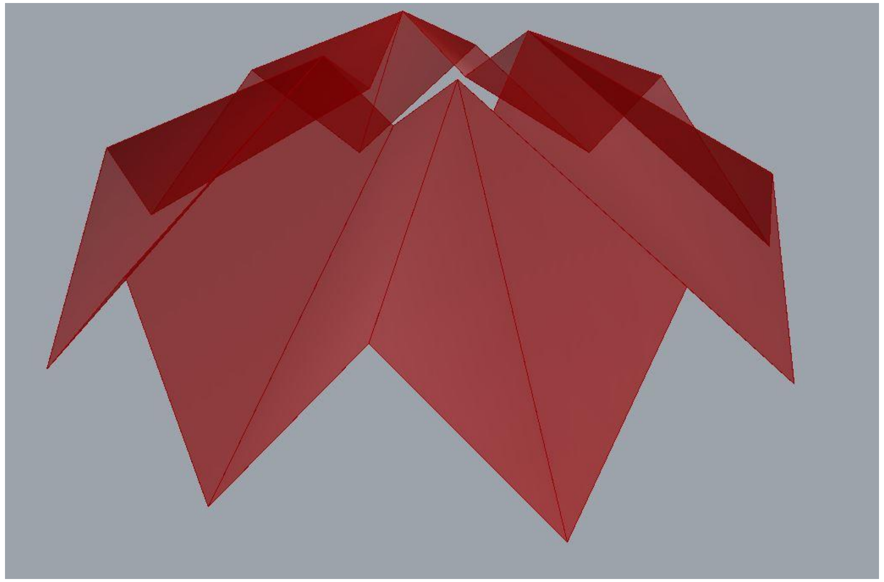
Top view



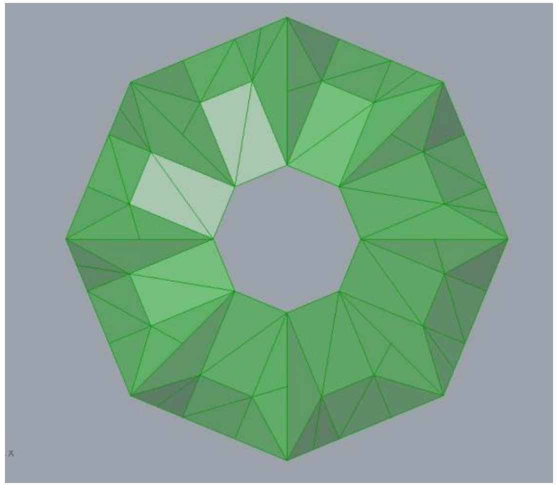
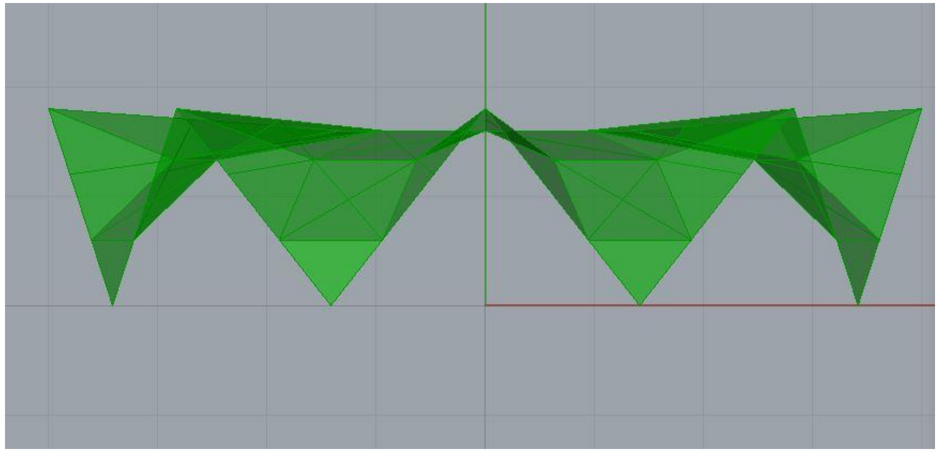
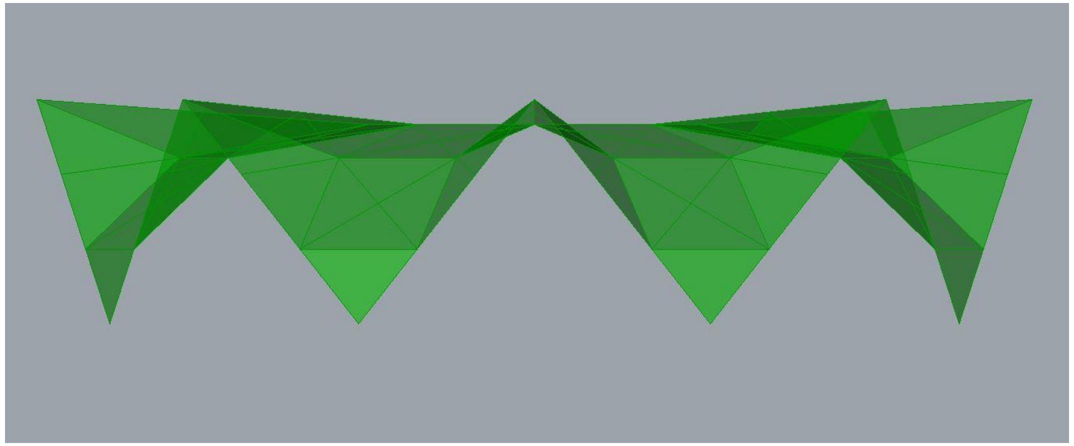
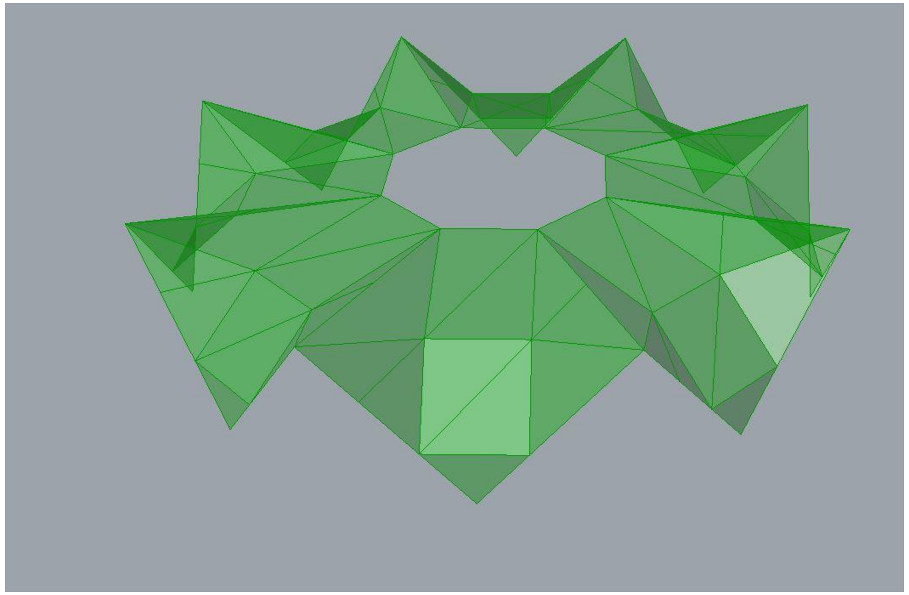
Front view



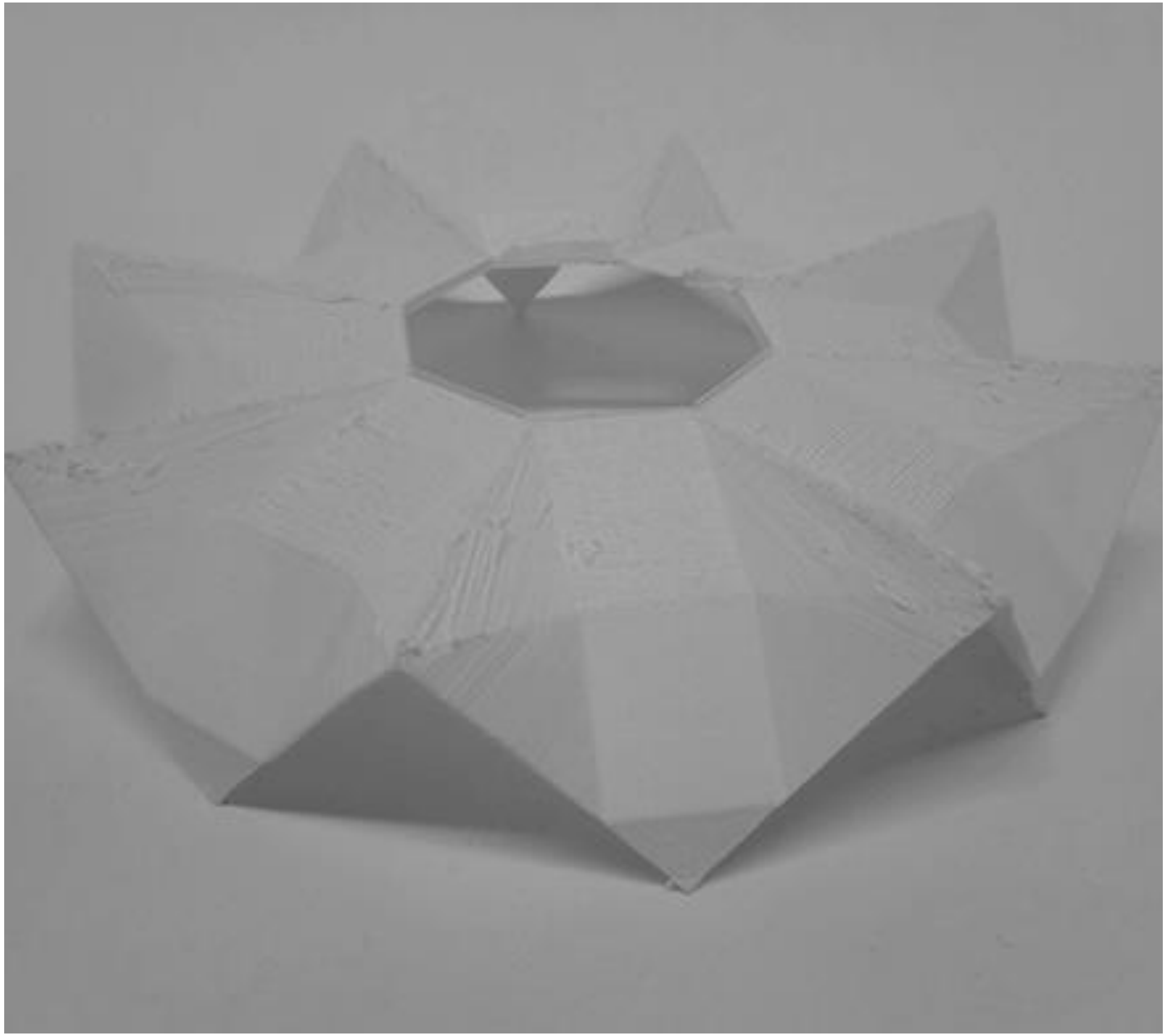
Right view



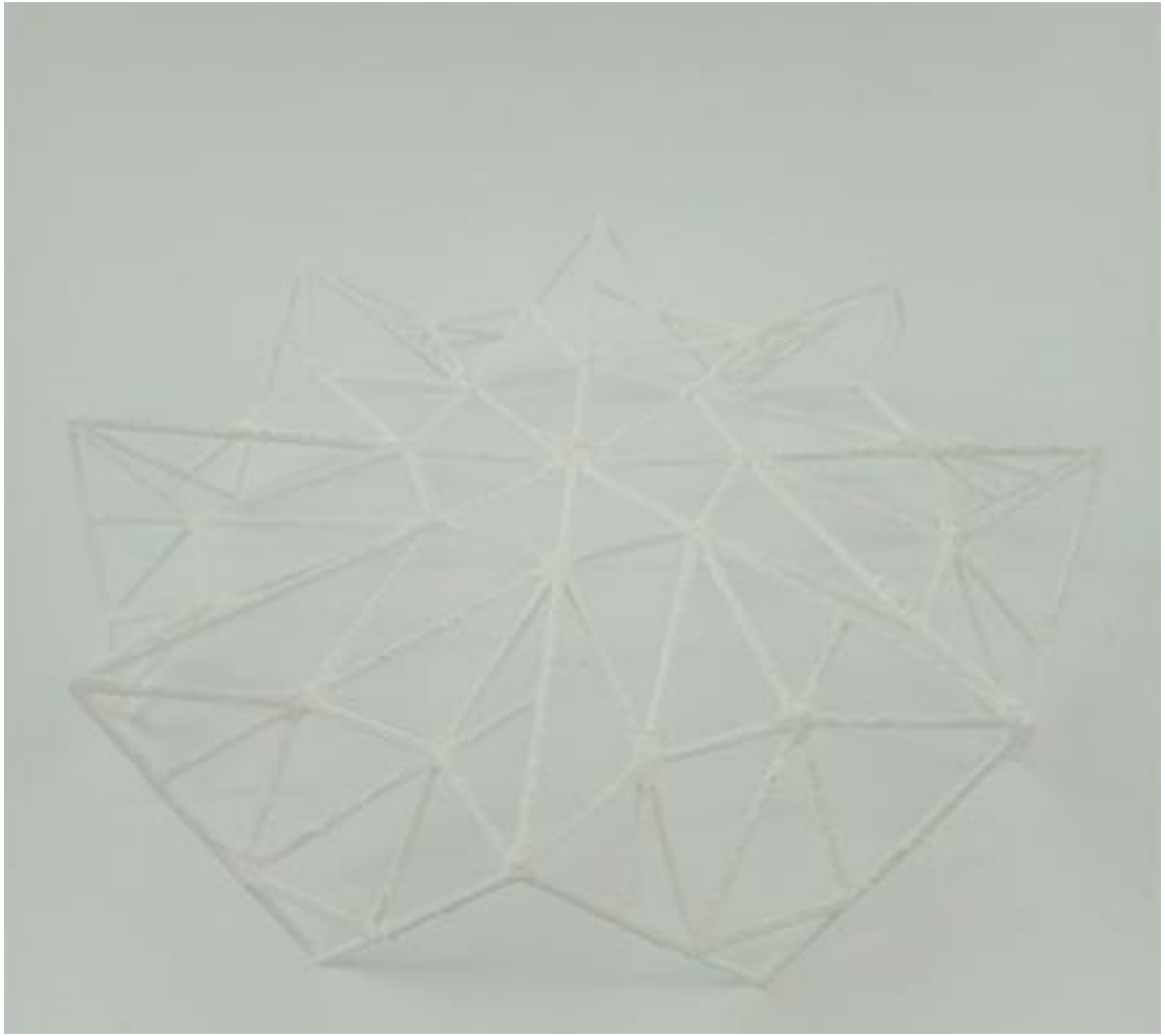
Perspective

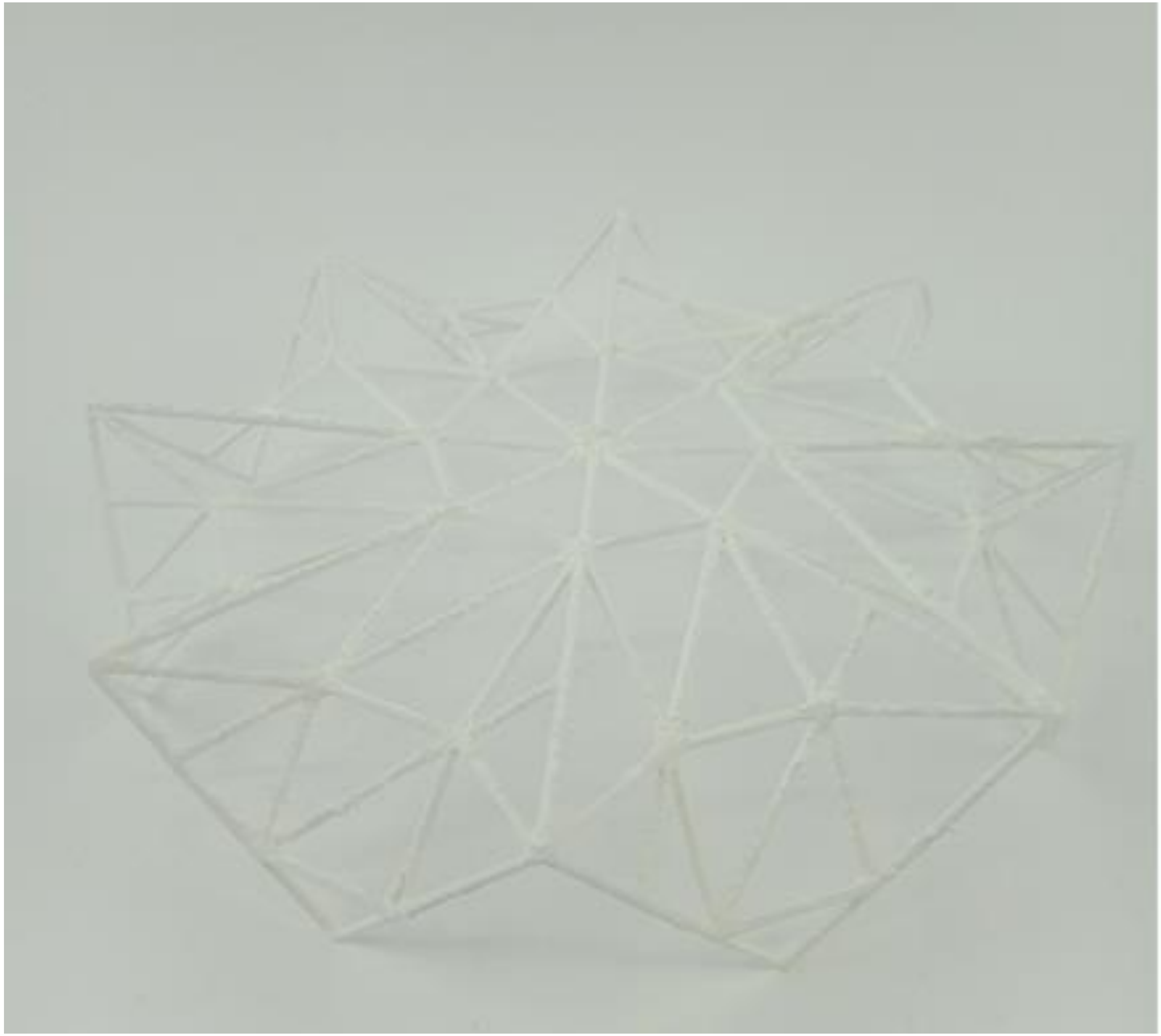
3D Model of the Shelter



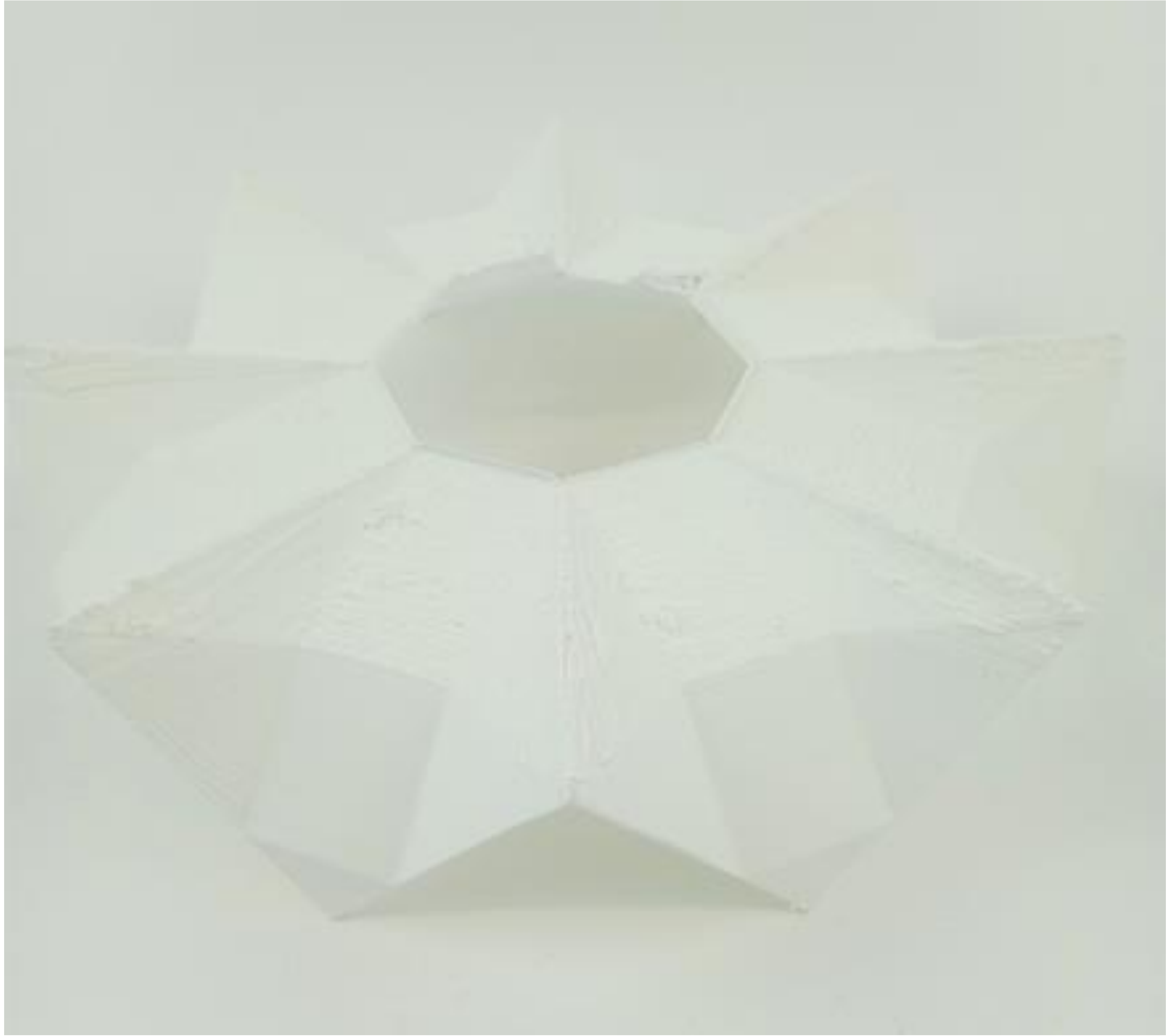
3D Model of the Shelter



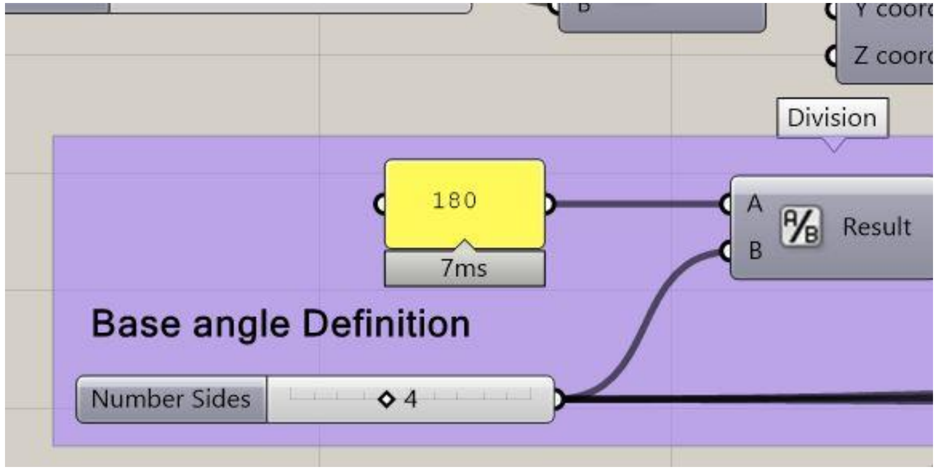
3D Model of the Shelter



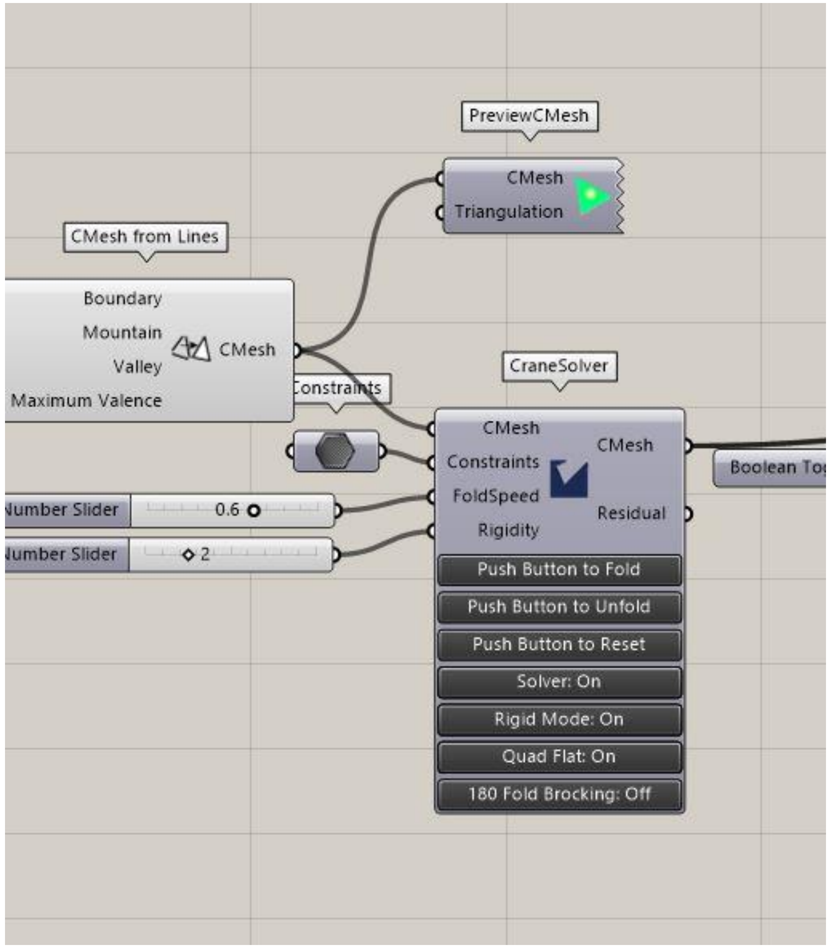
3D Model of the Shelter



The Logic



Simulation



Reference list

'BAU (Brearley Architects & Urbanists)' (no date) *Archello*. [online]. Available from: https://archello.com/brand/bau-brearley-architects-urbanists [Accessed 8 February 2023].

CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=642224. (no date)

Chen, Y., Yan, J. and Feng, J. (2017) *Geometric and Kinematic Analyses and Novel Characteristics of Origami-Inspired Structures*2 September 2017 [online]. Available from: http://creativecommons.org/licenses/by/4.0.

Lewis, W.J. (2008) Computational form-finding methods for fabric structures. *Proceedings of the Institution of Civil Engineers - Engineering and Computational Mechanics*. [online]. 161 (3), pp.139–149.

Rivas-Adrover, E. (2017) *Classification Of Geometry For Deployable Structures Used For Innovation: Design Of New Surfaces With Scissor 2 Bar, And Form Generation Method Of Relative Ratios*May 2017 [online]. Available from: https://www.researchgate.net/publication/317163051_Classification_Of_Geometry_For_Deployable_Structures_Used_For_Innovation_Design_Of_New_Surfaces_With_Scissor_2_Bar_And_Form_Generation_Method_Of_Relative_Ratios?enrichId=rgreq-56b749027a93d6bca67a242cc37d3e91-XXX&enrichSource=Y292ZXJQYWdlOzMxNzE2MzA1MTtBUzo1NDEzMjE5MzkzNTc2OTZAMTUwNjA3MjYxNTU0NQ%3D%3D&el=1_x_3&_esc=publicationCoverPdf.