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Team: Chia Hui Yen, Ren Tian Ye, Hu Yao, Xia An Qi
Contributions: Concept 70%, Structure design and optimization 100%

Design optimization: Network

_Light-weight Interactive Light & Art Installation, group project

December 2022

Introduction

Located in Wangjing, Chaoyang District, Beijing, within the Vanke Times Center, the surrounding area boasts modern architecture and a bustling commercial district, including office spaces, shopping malls, and hotels. Moreover, Wangjing is also one of Beijing's cultural and creative hubs, attracting many young designers, artists, and entrepreneurs.

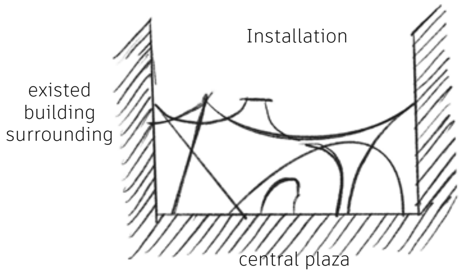
Our objective is to design a landscape installation for the central square of Vanke Times Center. The square is enclosed by five-story buildings, creating an enclosed courtyard-style central plaza.

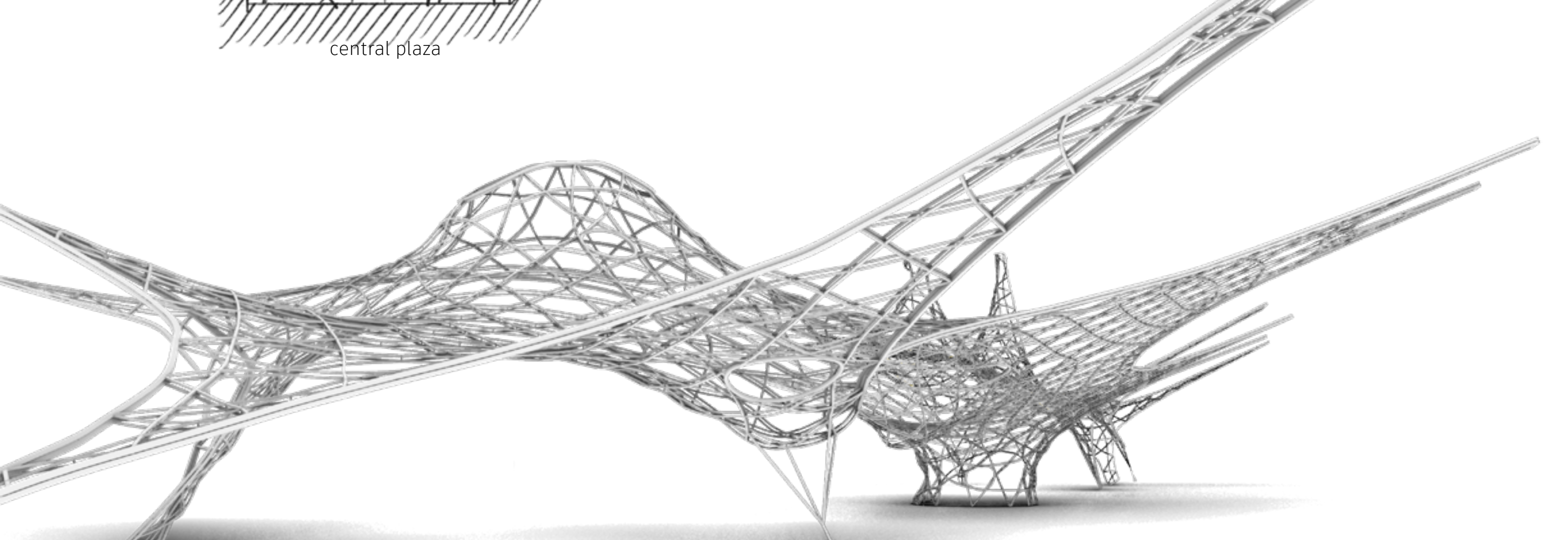
Abstract:

Design Concept — **Structure & Design Development**

- Design Concept
  - Interactive design
  - Concept mesh
- Rationalization: Structure Analysis
  - Saddle surface as basic form
  - Factors affecting structure performace
- Multi-objective optimization
  - Form finding
  - Waeving grid finding
  - Materialization
- Structure and Details Refinement

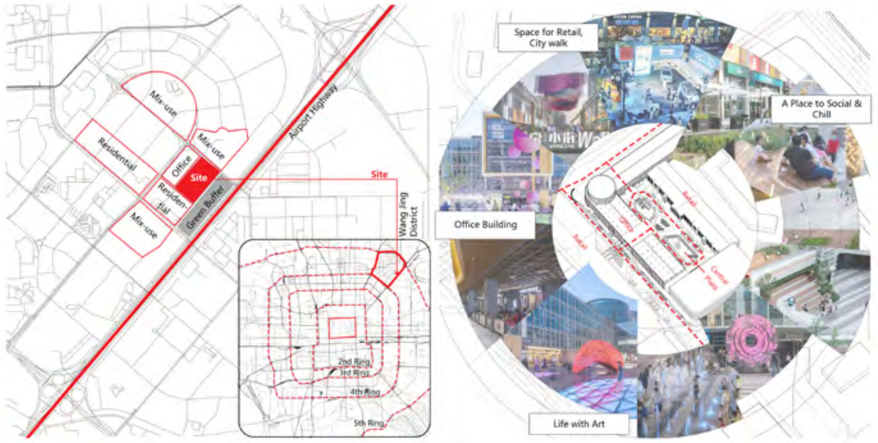
A net that intergrated into space and connect people together.





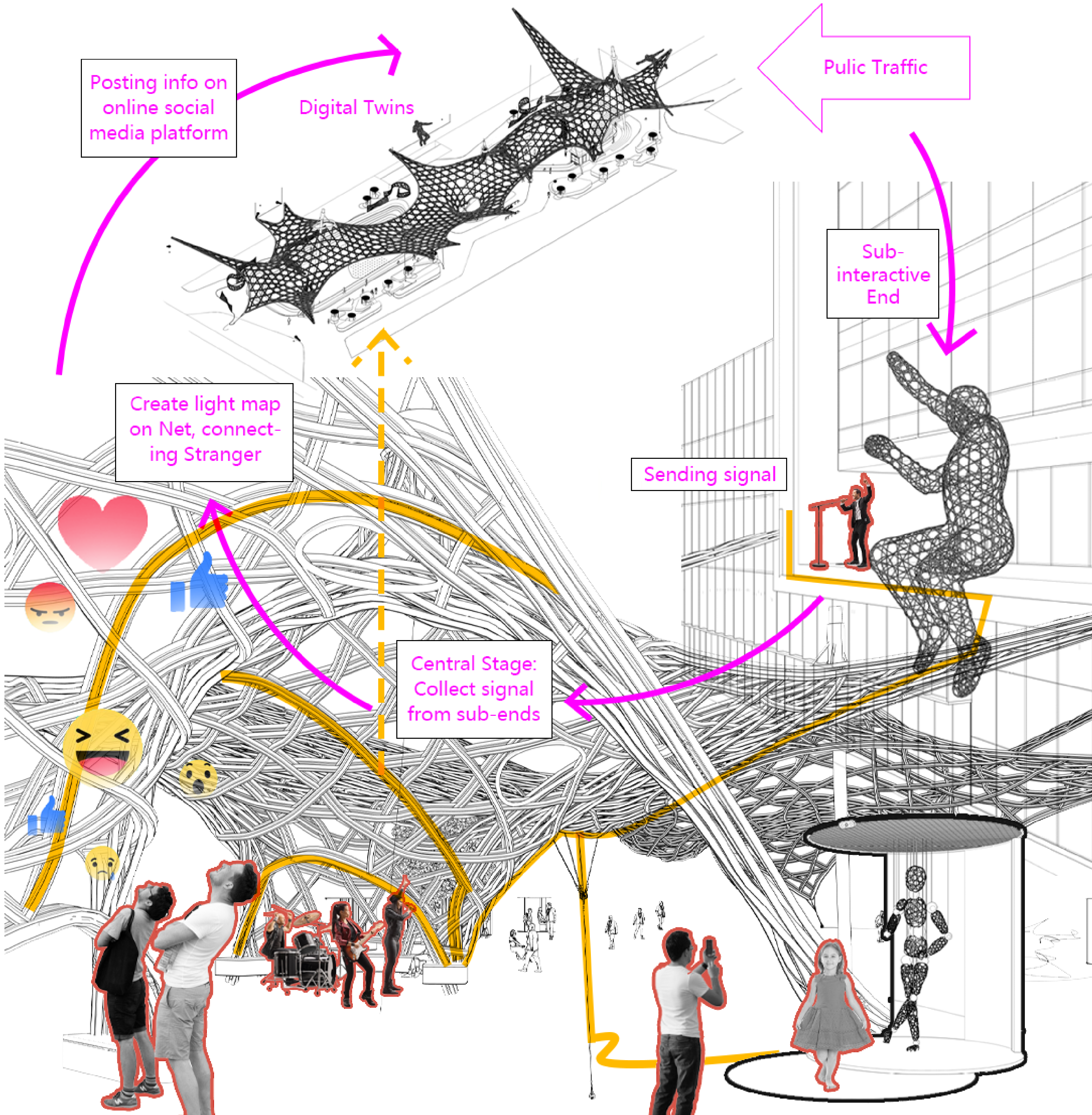
Site Study

The site map included the brief funtions of surrounding:



The square serves as a vital gathering, leisure, and activity space for the surrounding community. With the objective of landscape installation design, we can fully leverage the modern and cutting-edge atmosphere and vitality of this location. Our aim is to create a large-scale interactive game that engages people proactively, using uniquely designed spatial art installations. These installations will entice participants to interact with the game, receive feedback from the installations, and encourage them to capture and share their experiences on social media. This will attract more people to visit the square, as the installations are projected into the virtual world of the internet. Ultimately, this design will infuse the square with vibrancy and charm, stimulating commercial activity and enhancing the overall ambiance.

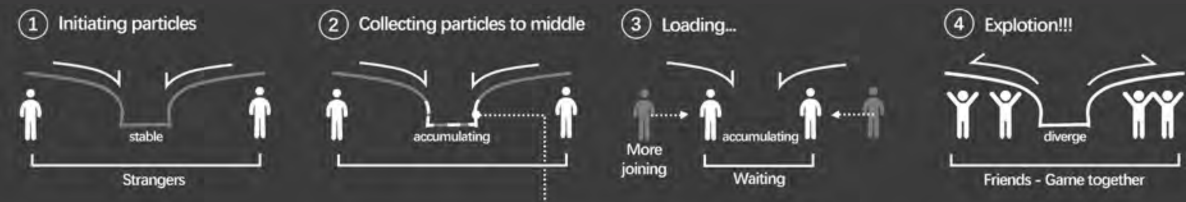
NETWORK

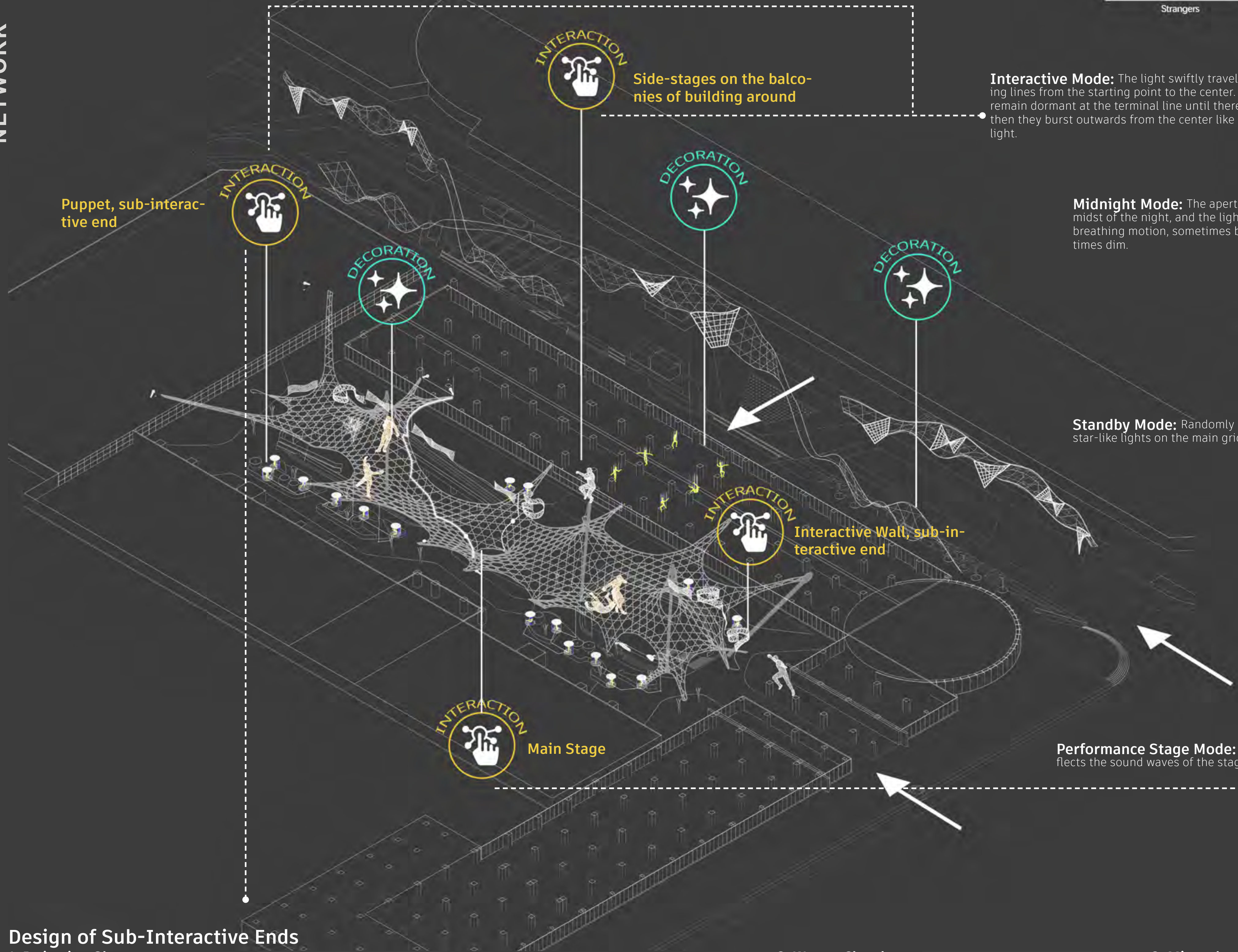


NETWORK

Design Concept: Interactive design of installation

The design of the installation is divided into decorative and interactive components. The interactive design features a main network structure constructed with weaving techniques, along with other woven accessories. Participants can interact with the accessories at the ends, and the light is then transmitted to the main network.



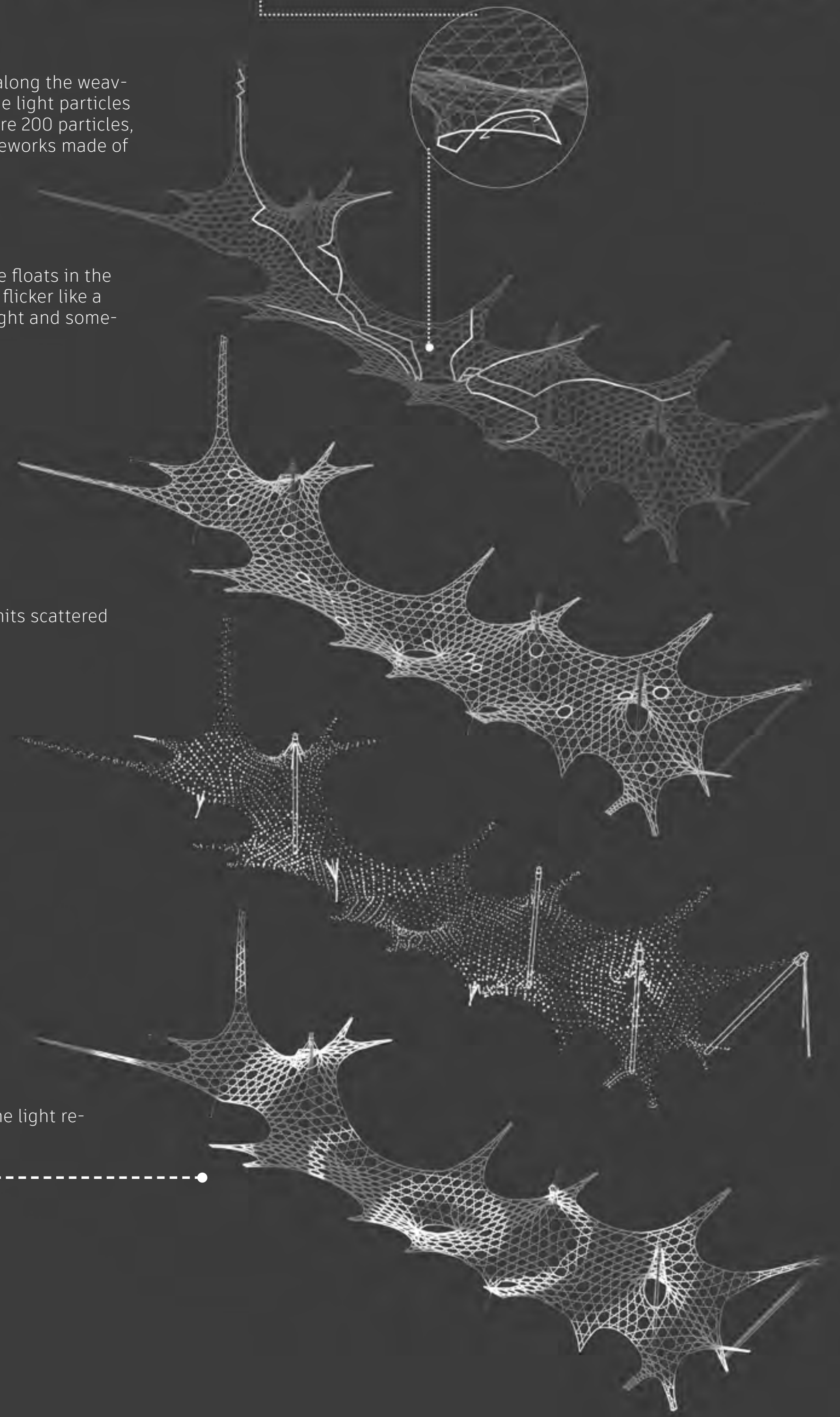


Interactive Mode: The light swiftly travels along the weaving lines from the starting point to the center. The light particles remain dormant at the terminal line until there are 200 particles, then they burst outwards from the center like fireworks made of light.

Midnight Mode: The aperture floats in the midst of the night, and the lights flicker like a breathing motion, sometimes bright and sometimes dim.

Standby Mode: Randomly emits scattered star-like lights on the main grid.

Performance Stage Mode: The light reflects the sound waves of the stage.



NETWORK

Design of Sub-Interactive Ends

1. Imitation Show

Imitate dance movements and illuminate the little figure! The figure is suspended among the trees on either side of the courtyard. By controlling the hanging points of its joints, the limbs of the figure can be arranged into different dance poses. If you imitate the figure's movements correctly, you will receive a photo opportunity and a light dot will merge into the main network.

2. Woven Chords

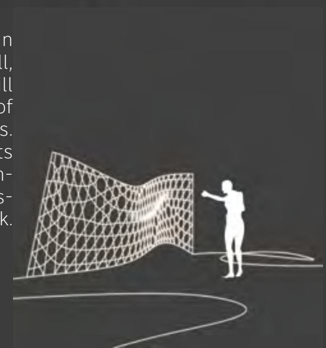
How can woven chords produce sound? It turns out to be an electric guitar! Strum the strings of this giant guitar and create a folk melody unique to this evening. The guitar will generate light dots that change with the sound.

3. Microphone

Want to sing a song together in the courtyard? Come to the balcony and find the microphone! Your voice will be transformed into light signals and transmitted to the main network through anchor points on the walls.

4. Graffiti Wall

By waving your hand in front of the graffiti wall, light dots on the wall will following the direction of your hand movements. Eventually, these light dots will converge along connecting lines and transfered to the main network.

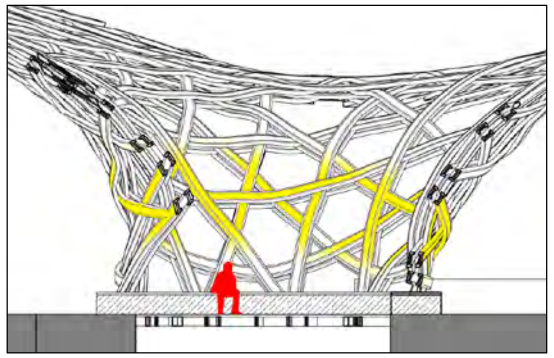


The View from East Entrance

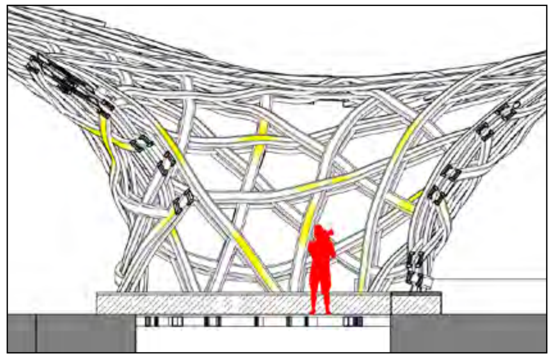
Midnight Mode: The aperture floats in the midst of the night, and the lights flicker like a breathing motion, sometimes bright and sometimes dim.

Operate from 12.00am to 7.00am

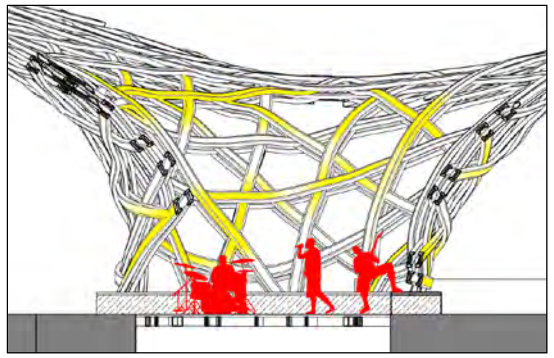
Midnight Mode: Performance mode



Midnight Mode: Performance mode

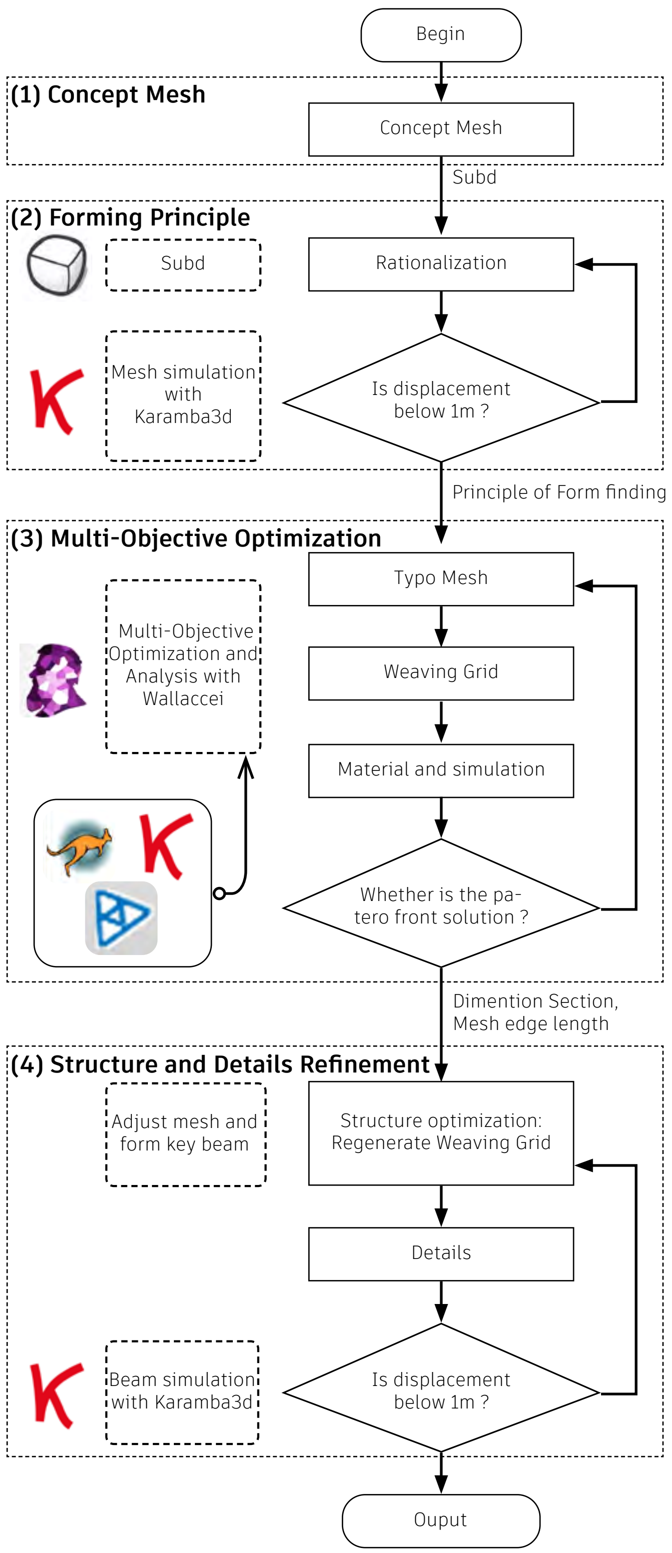


Midnight Mode: Performance mode

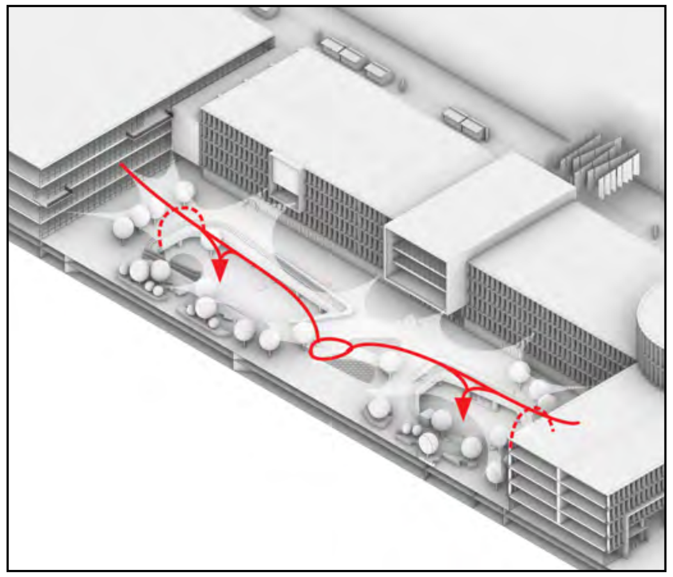


NETWORK

Structure Development:



(1) Concept Mesh

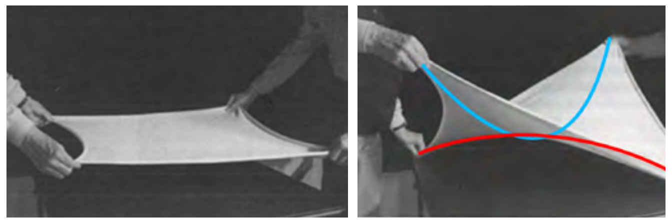


Saddle surfaces, characterized by negative Gaussian curvature, are advantageous in anticlastic forming due to their unique properties. These surfaces enhance structural integrity, distribute stress efficiently, and allow for material-efficient designs. The Gaussian curvature formula for a saddle surface (K) is given by:

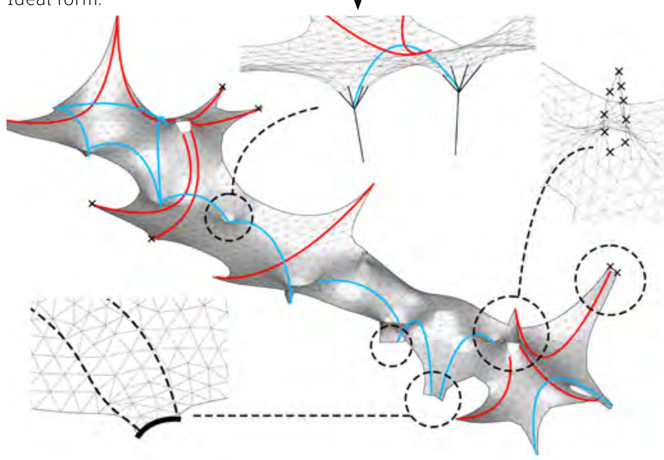
$$K = \frac{f_{xx} f_{yy} - f_{xy}^2}{(1+f_x^2+f_y^2)^2}$$

This formula helps analyze and utilize the negative curvature, contributing to the creation of visually appealing and structurally robust forms in various design and engineering applications.

Basic form idea:



Ideal form:

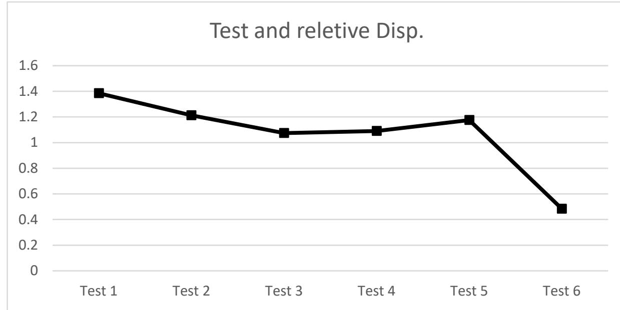


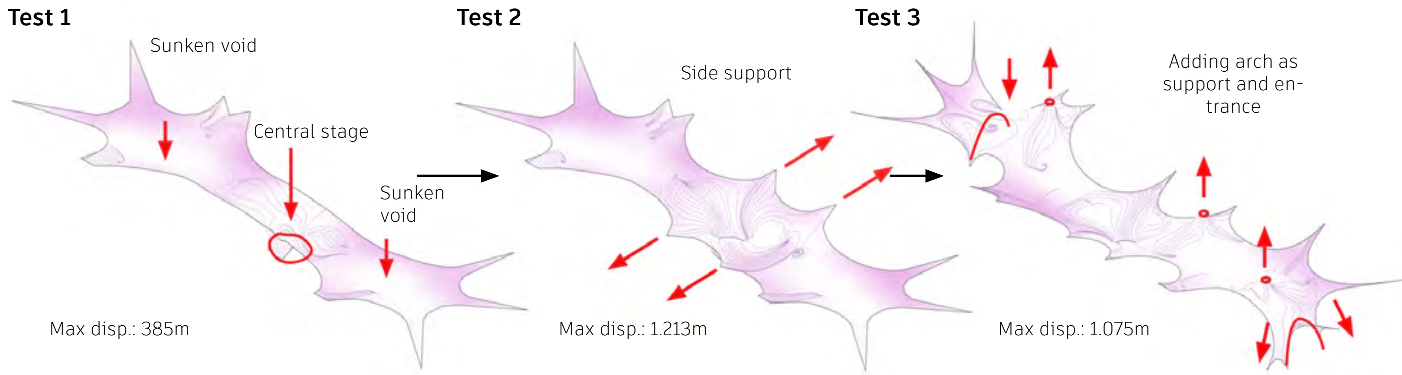
(2) Form Principle: Form finding & Structure Simulation

The main design of the structural design is based on the prototype of the woven structure generation technique using grid reconstruction algorithms, achieving large-scale freeform curved surfaces.
Try several type to test out the signifincant factor that affecting structure performance in order to apply it in the Multi-objective optimization later.

Factors affecting structure performance:
1) By utilizing the mechanical characteristics of saddle surfaces combined with tensioned membrane forms, the basic form is determined according to spatial functional requirements.
2) Adjustments are made to the positioning of anchor points and additional bracing elements to achieve a more evenly distributed stress distribution and strengthen the anchor points.
3) Material selection, grid pattern developement, and cross-sectional dimensions of the members are adjusted.

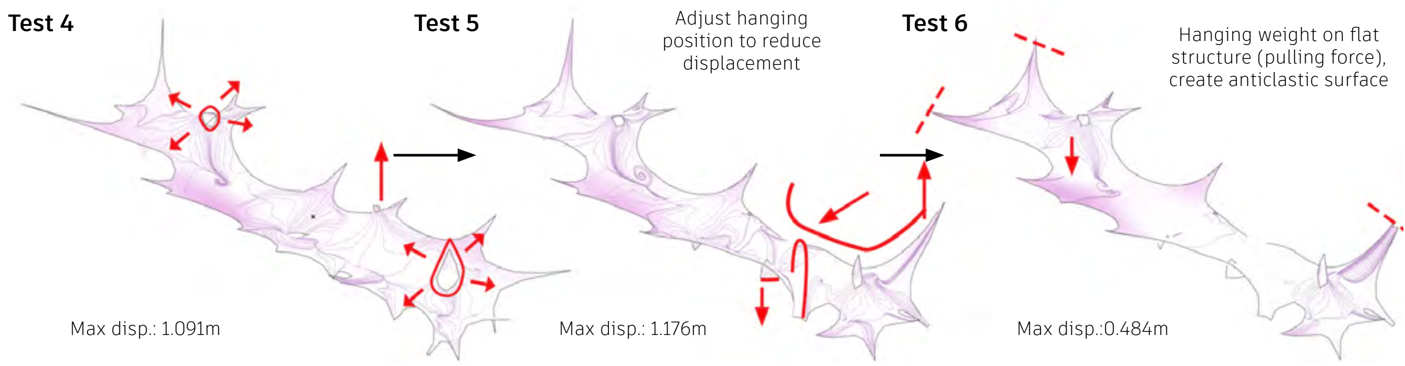
Different strategy and structure performance:



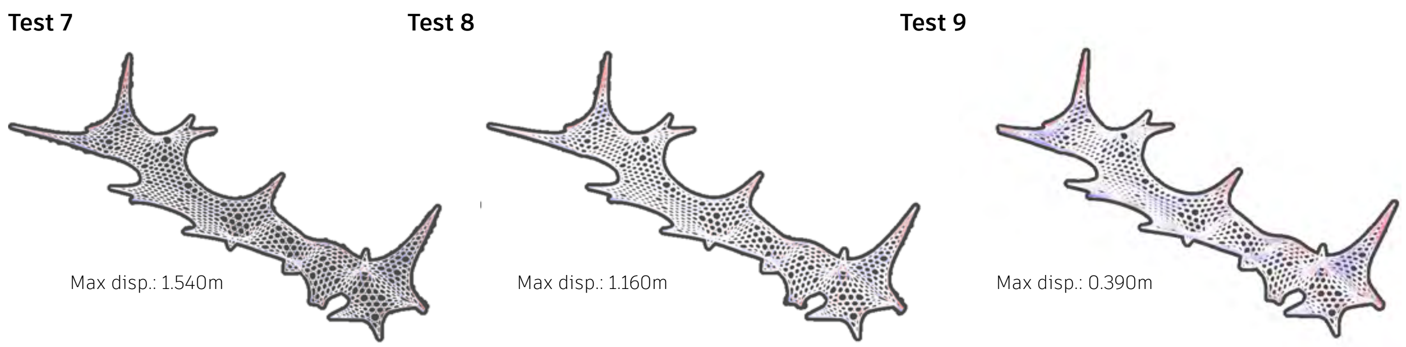


Factors affecting performance:

Begin base mesh from concept | (1) number of support | (2) movement z of support points



(3) number of sub-support points | (4) movement z of support points | (5) hanging load on mesh



(6) Cross section of elements is affecting structure performance

NETWORK
NETWORK

(3) Multi-Objective Optimization

Design Optimization by Multi-Objective Optimization. Split the process to three part, with different iteration times. Splitting parts to save iteration time spent, giving particular part more iteration round, more accurate result, and provide manual adjustment between process.
Process using Wallacei[1].

Part 1: Form finding
Geo: mesh
iteration: 300
total time: 20 min

→ Manual Adjust →

Part 2: Grid finding
Geo: curves
iteration: 100
total time: 20 min

→ Manual Adjust →

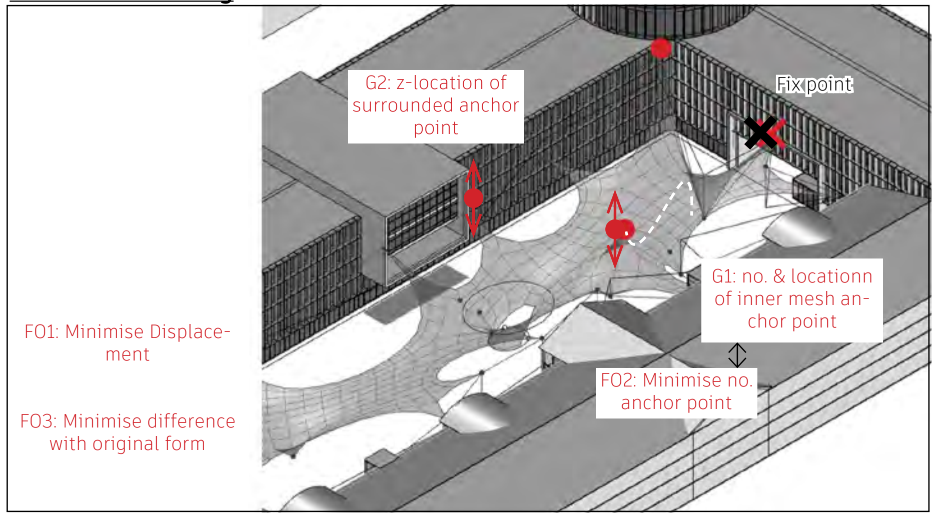
Part 3: Materialization
Geo: mesh
iteration: 50
total time: 20 min

less time spent, total iteration time: 01:17:54
higher flexibility, manually adjustment in the middle
higher accuracy, more iteration round at every part of optimization

NETWORK

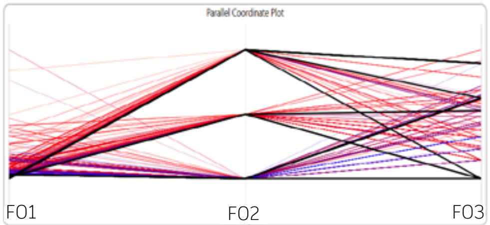
**FO: Fitness Objective, FV: Fitness Value, G: Gene

Part 1: Form finding

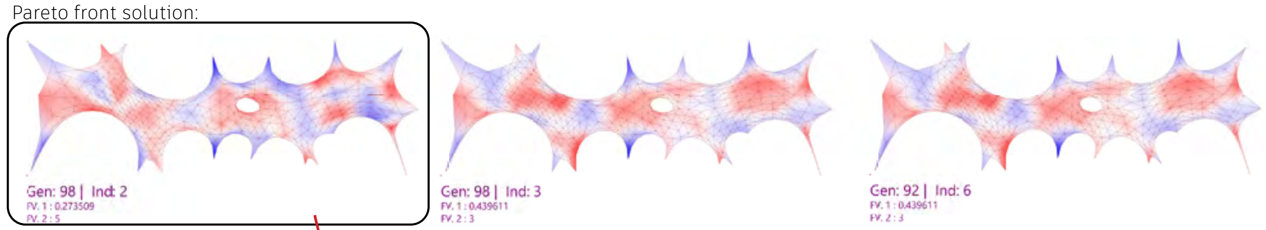


Go throught shell strength simulation by Karamba 3D plugin to find out the best structure performace mesh form.
Giving support point variable z-axis movement, to find the suitable height of support to form saddle surface.

Simulation result:
Simulation RunTime: 00:35:32
Size Generation: 10
Generation Count: 300

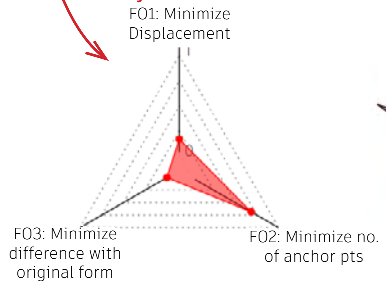


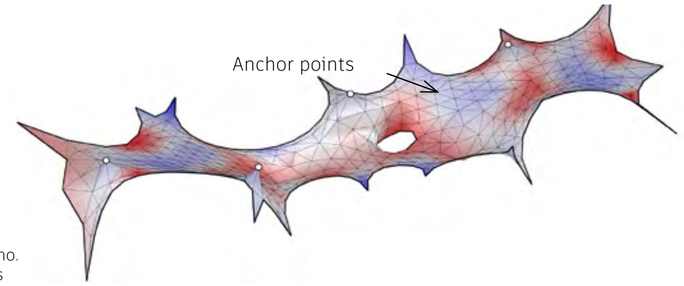
Pareto front solution:



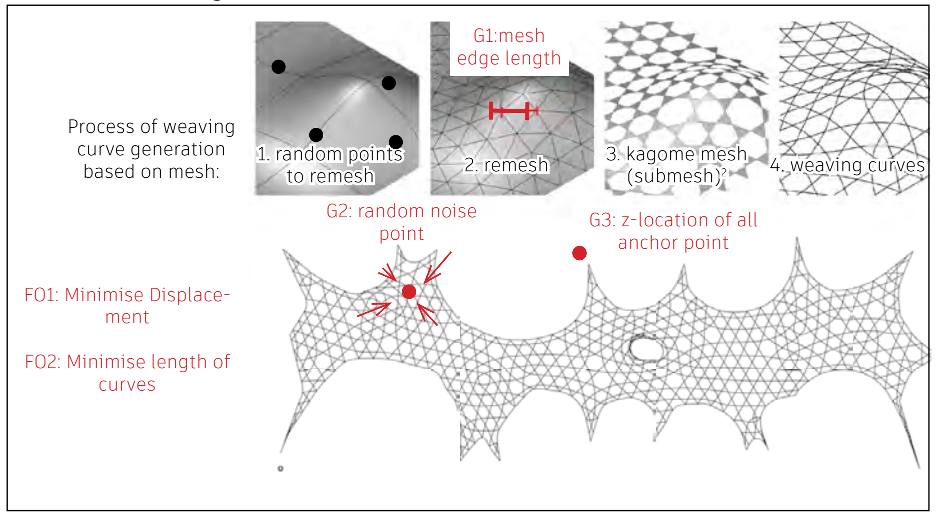
Final form result:
FO1: Minimize Displacement
Fitness Value: 0.240186 (m)
Fitness Rank: 504/2999
FO2: Minimize no. anchor point
Fitness Value: 5
Fitness Rank: 2047/2999
FO3: Minimize difference with origial form
Fitness Value: 72 690219
Fitness Rank: 0 / 2999

Visualy Suitable Form





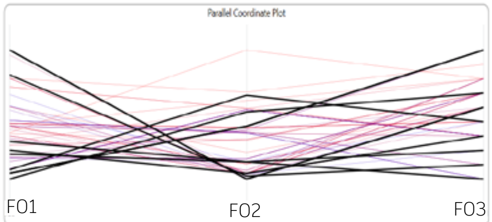
Part 2: Grid finding



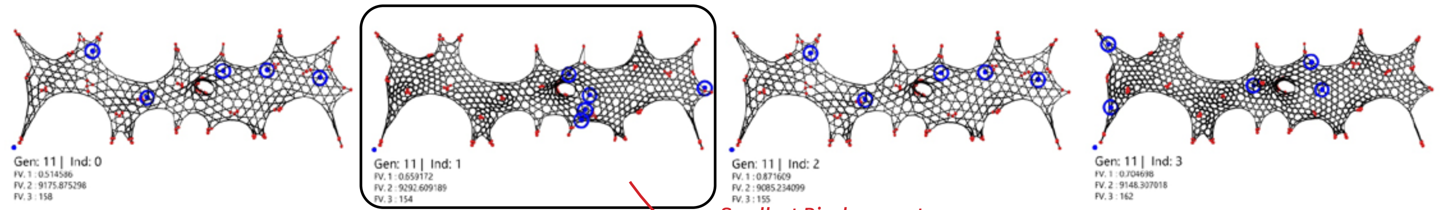
Weaving grid generate from the typology mesh from part 1 simulation. Go through grasshopper bending active simulation to find a suitable weaving grid size.
To set up kangaroo zombie solver, go through normal solver simulation, take a suitable threshold and tolerance for zombie solver in order to do repeatative simulation

Name	Threshold	Tolerance	Time	iteration	Disp
3	1.00E-15	0.0001	20.0s	6610	0.886242
normal solver	1.00E-15	0.0001	160.0s(?)	9120	0.886242

Simulation result:
Simulation RunTime: 00:22:55
Size Generation: 10
Generation Count: 20

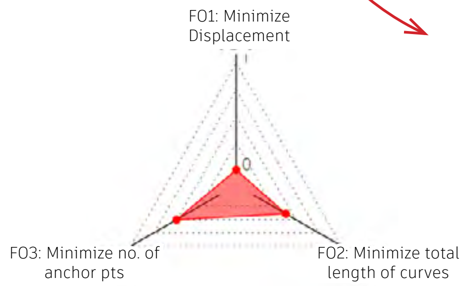


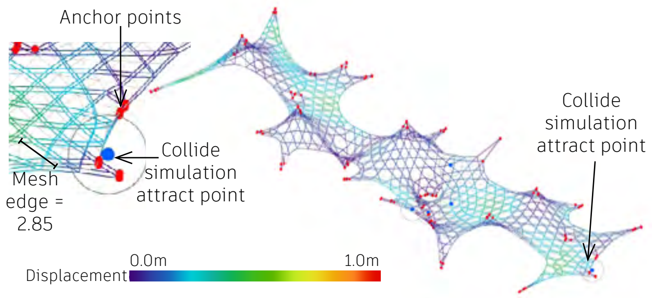
Pareto front solution:



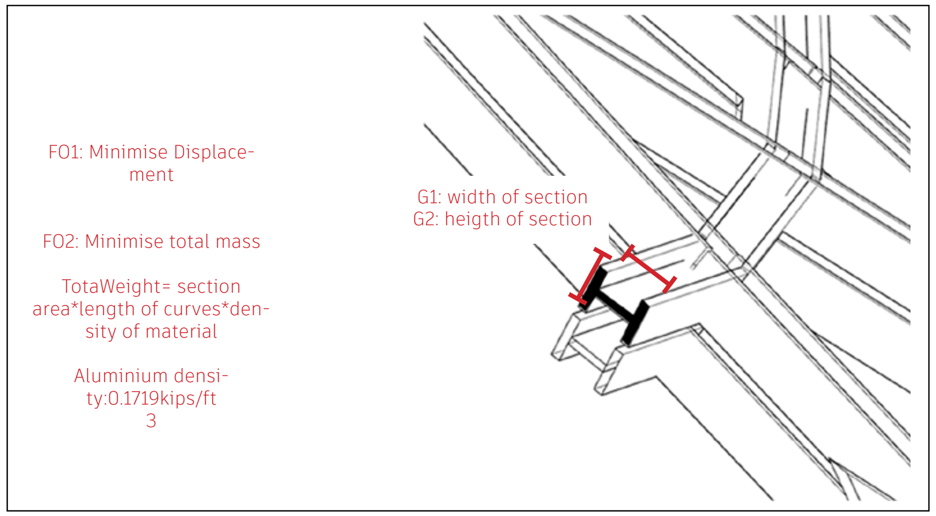
Smallest Displacement

Final form result:
FO1: Minimize Displacement
Fitness Value: 0.479445 (m)
Fitness Rank: 0 / 119
FO2: Minimize total length of curves
Fitness Value: 9565 854245
Fitness Rank: 92 / 119
FO3: Minimize no. of anchor pts
Fitness Value: 155
Fitness Rank: 80 119

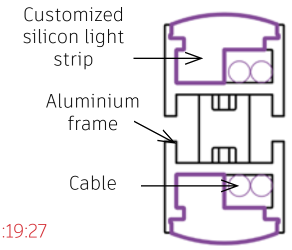




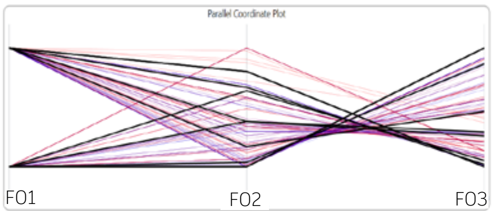
Part 3: Materialization



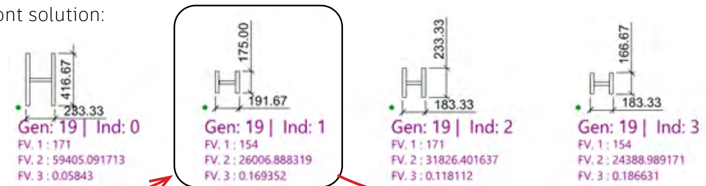
Propose a basic form for structure section that include light and electricity.
Go through Karamba 3d simulation to get a suitable section size

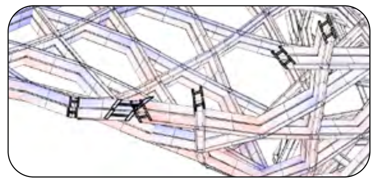


Simulation result:
Simulation RunTime: 00:19:27
Size Generation: 10
Generation Count: 20

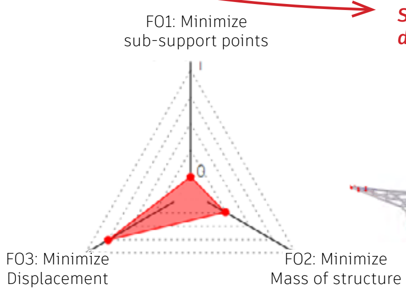


Pareto front solution:

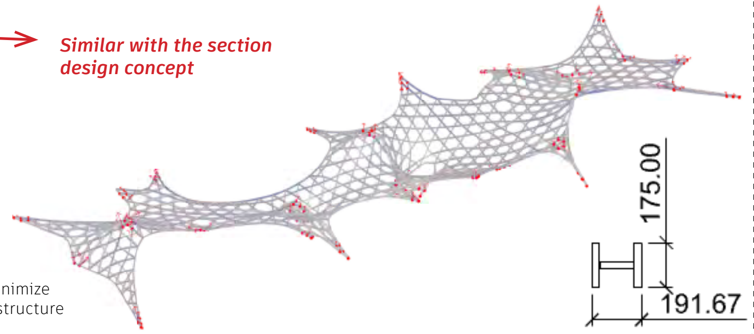




Final form result:
FO1: Minimise sub-support points
Fitness Value: 154
Fitness Rank: 0 / 199
FO2: Minimise mass of structure
Fitness Value: 26006.888319
Fitness Rank: 47 / 199
FO3: Minimise displacement
Fitness Value: 0.169352 (m)
Fitness Rank: 150/199



Similar with the section design concept



Reference:
1. Makki M, Showkatbakhsh M, Tabony A, Weinstock M. Evolutionary algorithms for generating urban morphology: Variations and multiple objectives. International Journal of Architectural Computing. 2019;17(1):5-35. doi:10.1177/1478077118777236
2. Huang, W., Wu, C., Hu, J., & Gao, W. (2022). Weaving structure: A bending-active gridshell for freeform fabrication. Automation in Construction, 136, 104184.

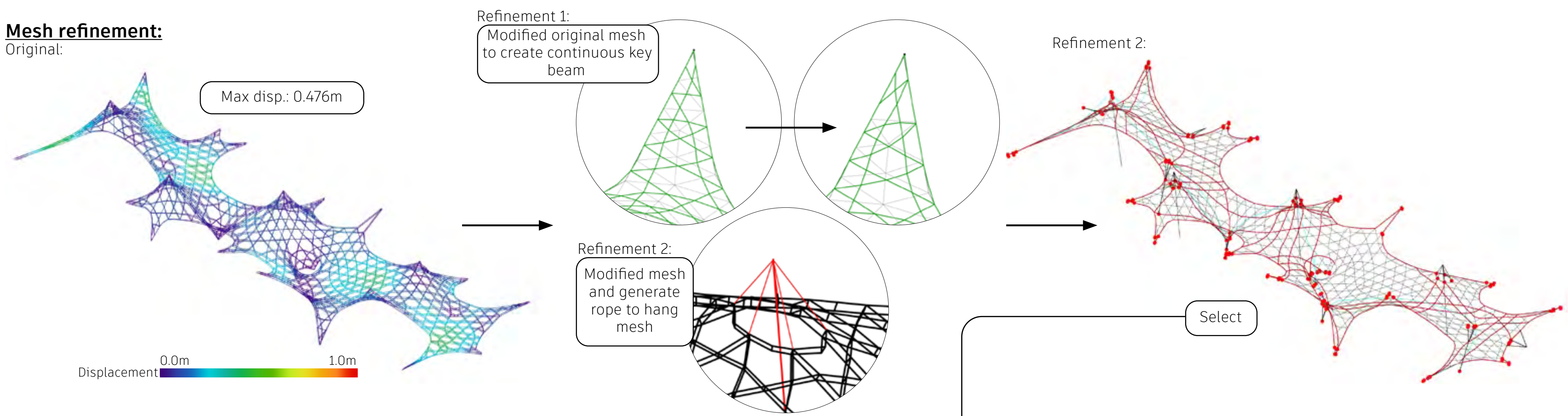
(4) Structure and Details Refinement

From optimizing the mesh pattern, make sure the main support is continuous

NETWORK

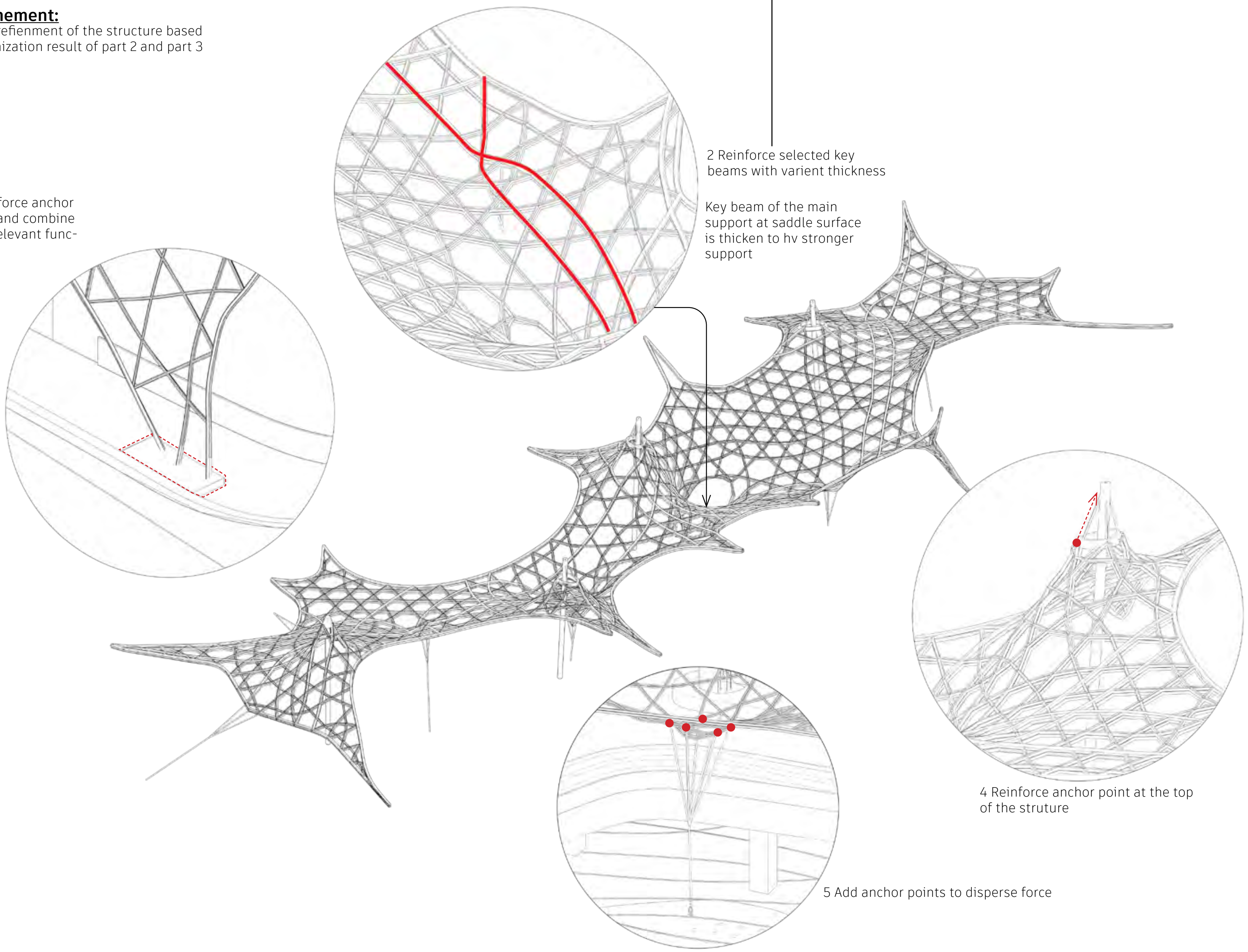
Mesh refinement:

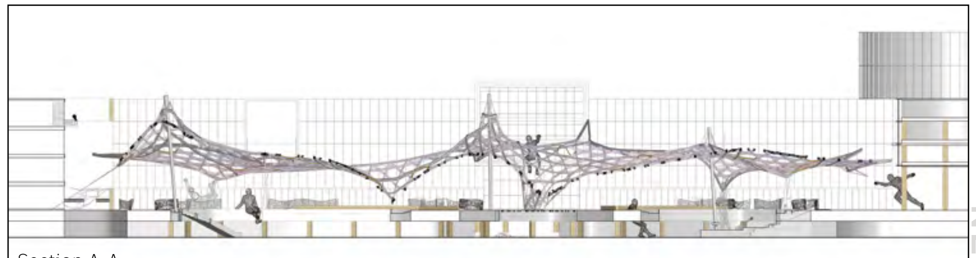
Original:



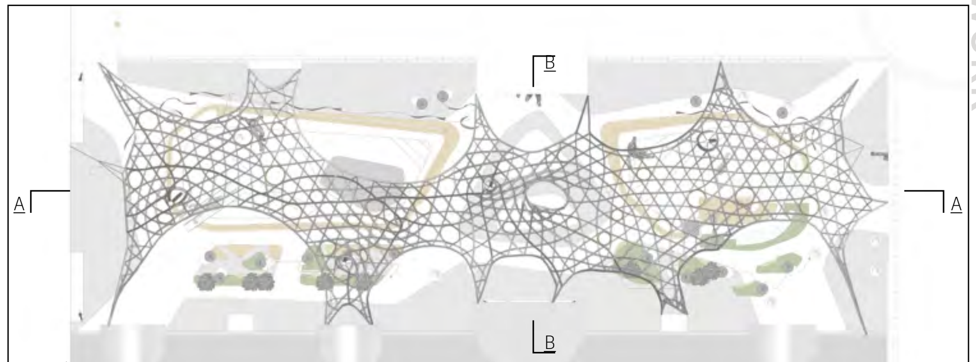
Final refinement:

Go through refinement of the structure based on the optimization result of part 2 and part 3

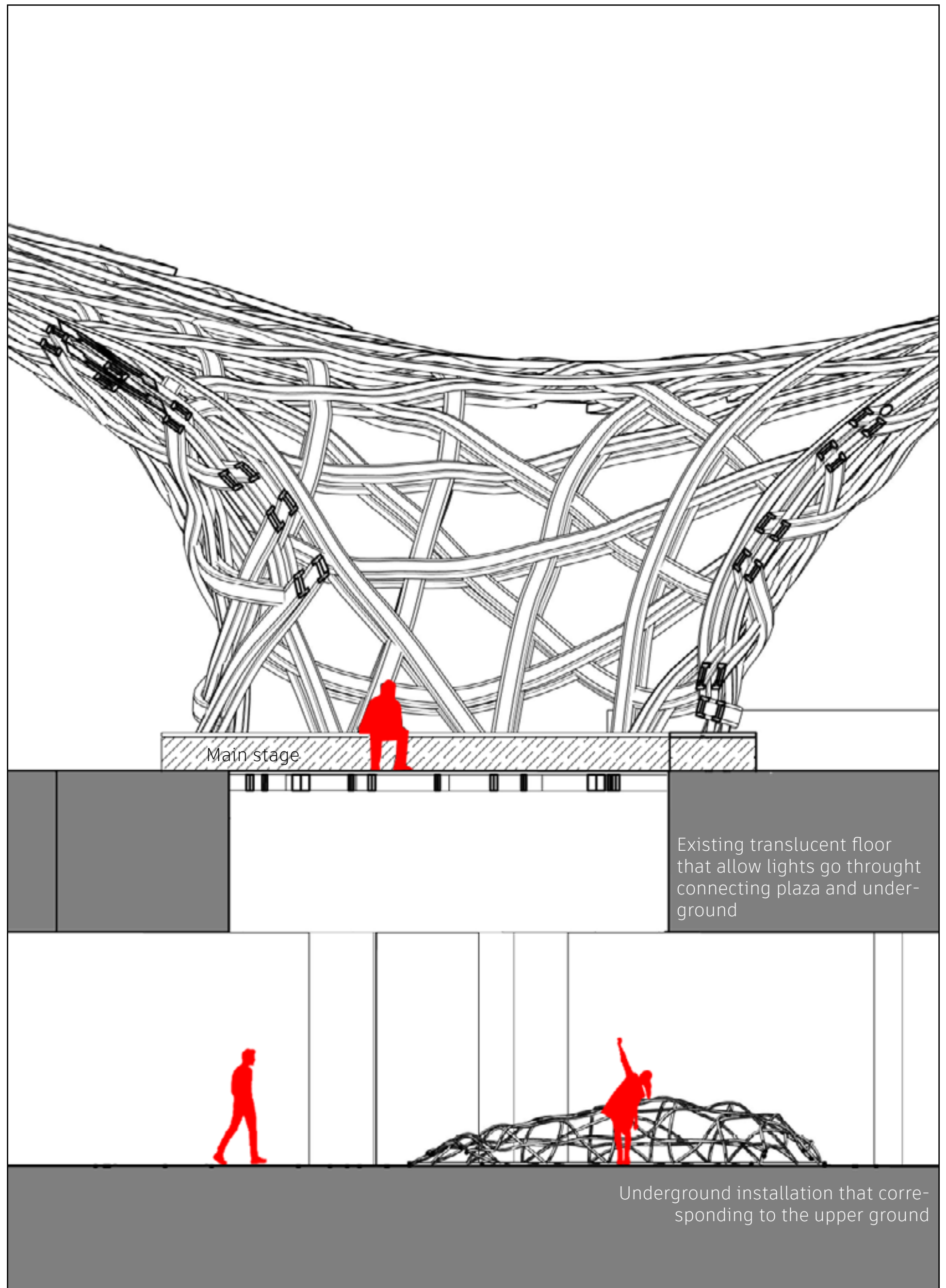




Section A-A



Top view



Section B-B

NETWORK