TOPOLOGICAL DESIGN OF BIONIC STRUCTURES

INSPIRED BY NATURE

Developed at the Department of Structural Mechanics
of University of Granada

by

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Finding of equilibrium shape of structures

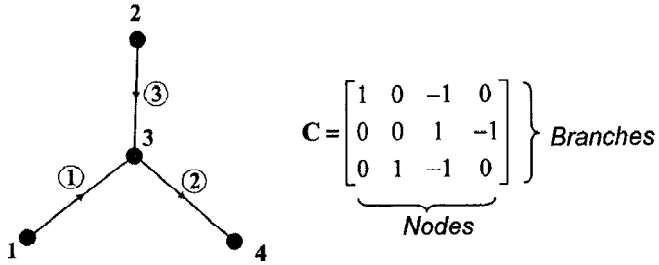
The process of form finding of shell structures was always a challenge for architects and engineers, and an issue of effective collaboration. Tools which allow finding an equilibrium shape of structure change a lot as time goes by.

Modified Force density method together with topological mapping is applied for form finding of compressed structures.

GAUDI software is a new form-finding tool based on constant values of the force:length ratios that give endless opportunities for creativity for architects and engineers. It allows finding an equilibrium shape of structure initially desired by an artist by iteratively changing input parameters.

With this tool, forces follow any well conceived form of structure. This new conception changes the traditional notion of “form follows forces” to “forces follow a well conceived form”.

Force-density method

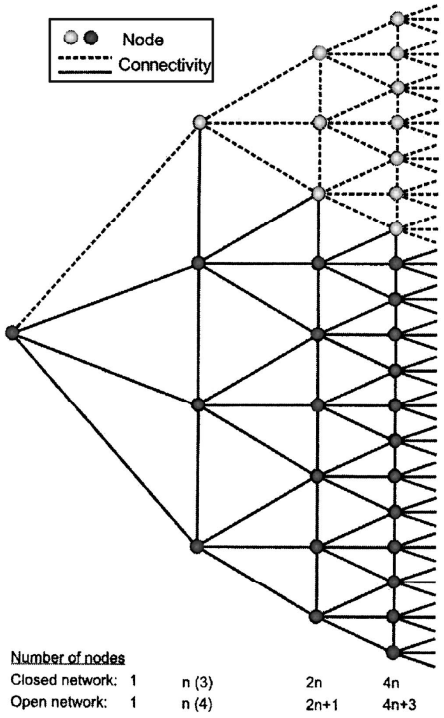


The force density method (FDM) was initially presented by Linkwitz and Schek. This method is based upon the force:length ratios, also named as force densities, which are defined for each branch of the net structure.

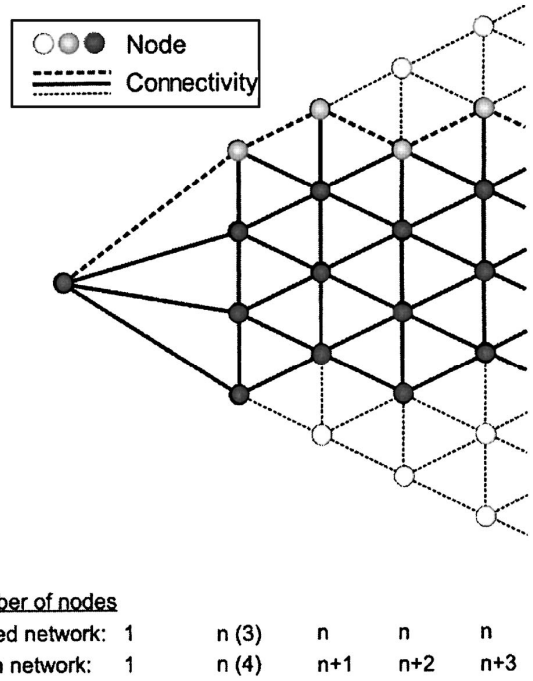
The starting point for the FDM is a pin-joint network consisting of cable or bar elements, in which some of the points are fixed and the others are free. The free points will have to find a position in the equilibrium configuration.

Topology Mapping

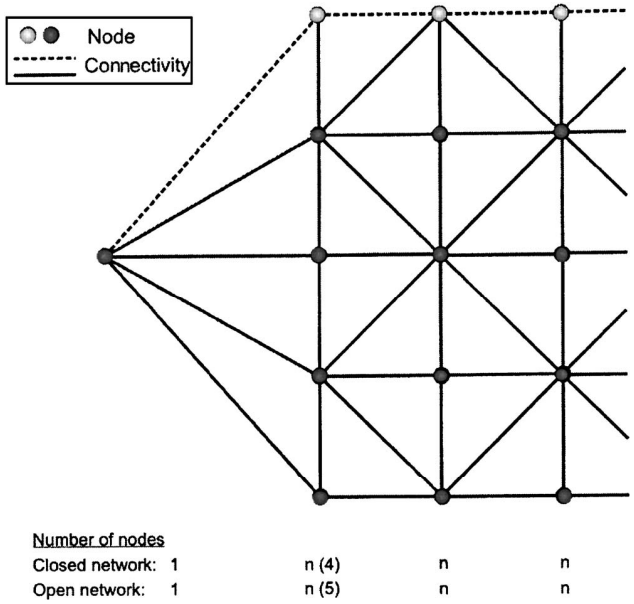
Topology mapping is based on the idea that no initial coordinates are needed for the FDM, rather the connectivity between the nodes. Taking advantage of this property a mapping is performed in topology. A topology graph may be used to obtain a network of nodes and connections, so the initial guess of the shape is no longer needed and the same topology graph can be used for several equilibrium shapes. We will call this procedure “topological mapping.” The main feature of the topological mapping is that with a few topological rules a mapping can be performed independently of the final geometric configuration, and becomes especially attractive when an initial guess of the equilibrium shape is difficult to find.



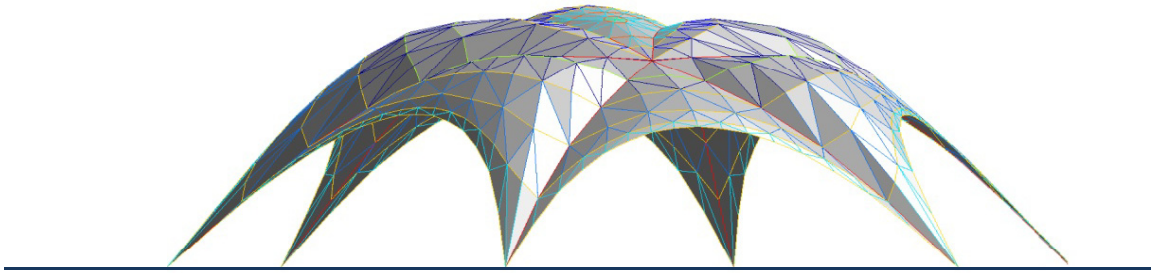
Topology of network Type A

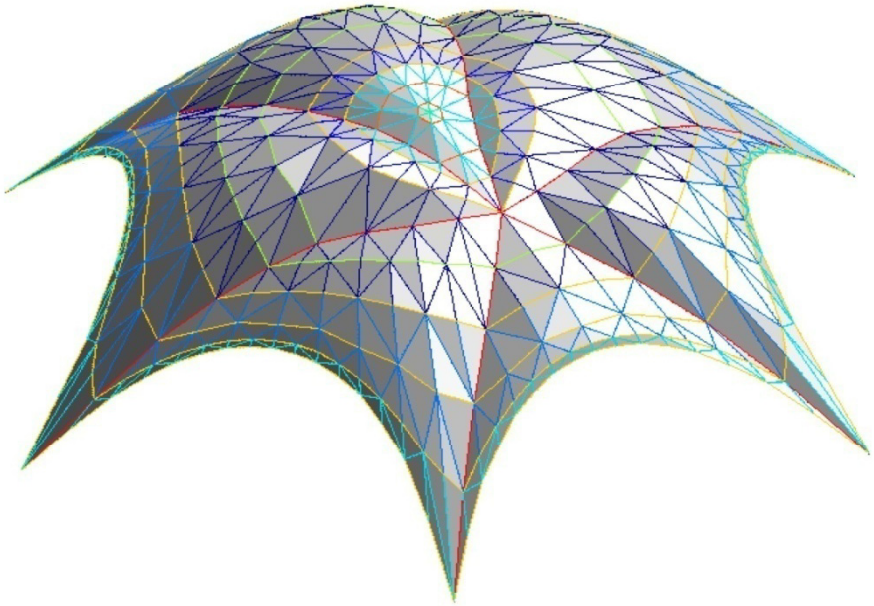


Topology of network Type B



Topology of network Type C





Input data	
Number of rings	10
Number of nodes in initial ring	6
Number of contour anchor points	6
Weight of the ribs (kN/m)	0,23
Self-weight (kN/m2)	1,0

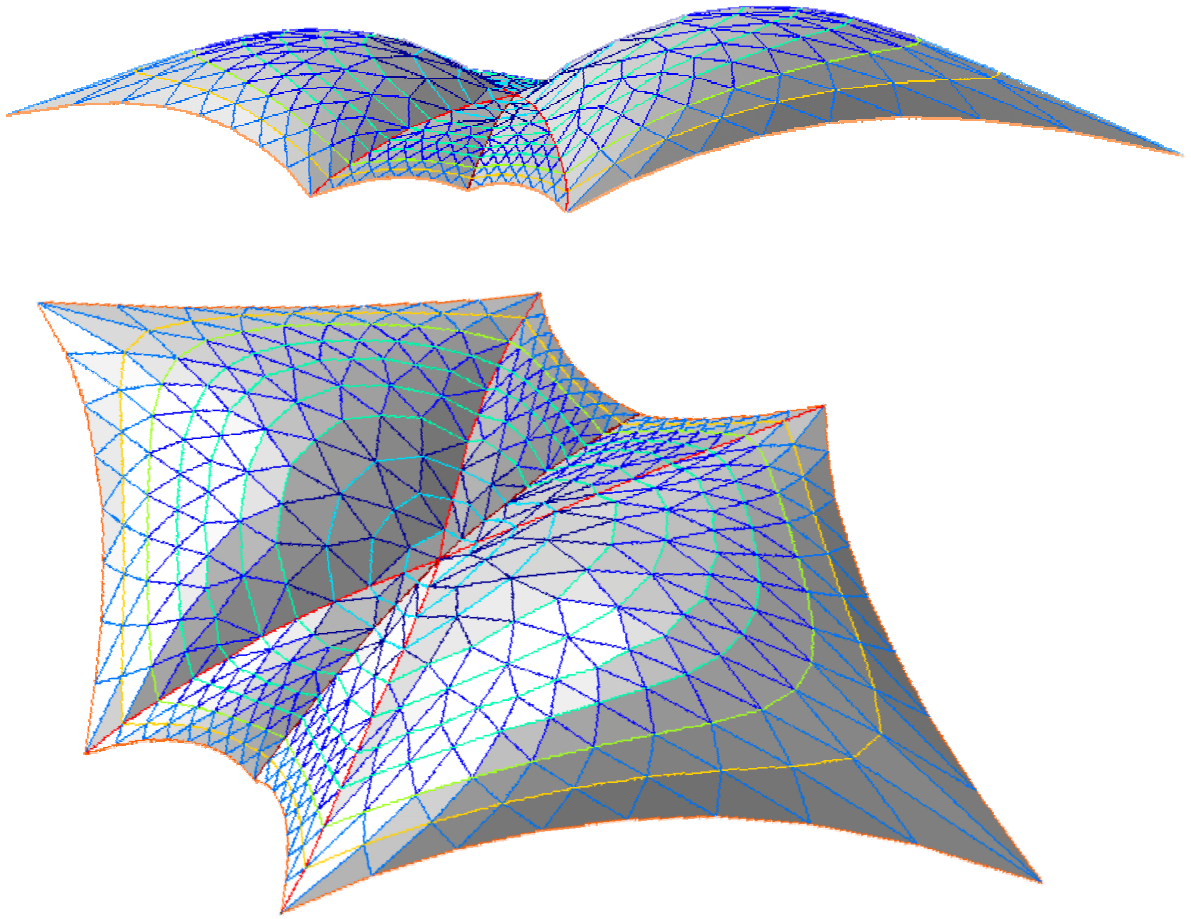
INSPIRED BY SEASHELL

Maximum height: 1,206 m

Material: masonry

Force:length coefficient	Coordinates of anchor points		
	X_i (m)	Y_i (m)	Z_i (m)
0.1	1,0	0,0	0,0
0.11	3,0	0,0	0,0
0.12	4,0	1,73	0,0
0.13	3,0	3,46	0,0
0.15	1,0	3,46	0,0
0.5	0,0	1,73	0,0
0.6			
0.7			
3			

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	A	C	C	A	C	C	A	C	C
Force:length coefficient of ring branches	0,7	0,7	0,6	0,6	0,5	0,5	0,6	0,5	0,6	0,6
Force:length coefficient of radial branches	0,15	0,13	0,13	0,11	0,1	0,1	0,1	0,1	0,1	0,12



Input data	
Number of rings	10
Number of nodes in initial ring	6
Number of contour anchor points	8
Weight of the ribs (kN/m)	1,41
Self-weight (kN/m2)	4,7

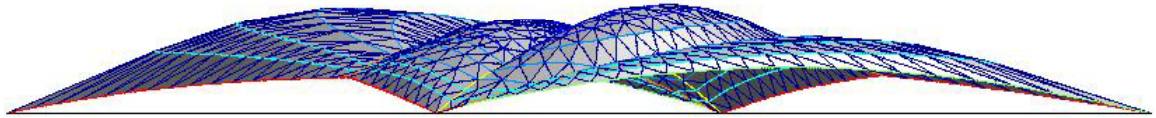
INSPIRED BY MANTA

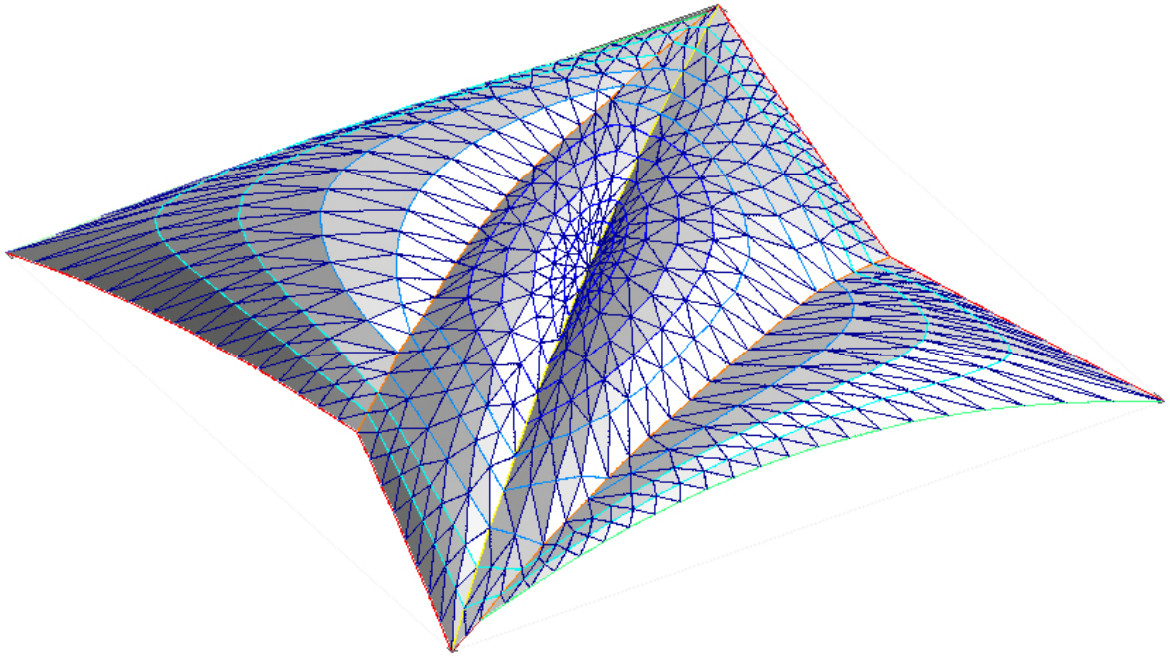
Maximum height : 1,616 m

Material: concrete

Force:length coefficient	Coordinates of anchor points		
	X_i (m)	Y_i (m)	Z_i (m)
3	2,0	7,0	0,0
4	7,5	2,2	0,0
5	9,2	3,2	0,0
7	11,0	2,2	0,0
8	15,7	4,7	0,0
10	12,0	10,0	0,0
15	10,2	9,5	0,0
50	9,0	11,0	0,0
200			
250			

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	B	A	B	A	B	B	B	B	B
Force:length coefficient of ring branches	7	7	7	8	8	8	8	10	15	50
Force:length coefficient of radial branches	3	3	3	3	4	4	4	4	5	5

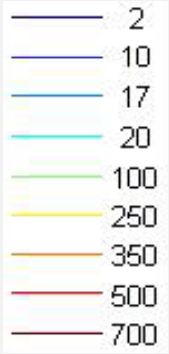




Input data	
Number of rings	12
Number of nodes in initial ring	12
Number of contour anchor points	4
Weight of the ribs (kN/m)	1,41
Self-weight (kN/m2)	4,7

INSPIRED BY A NIGHTMARE
Maximum height: 1,050 m
Material: concrete

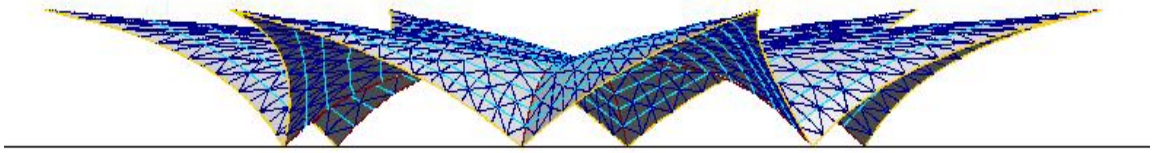
Force:length coefficient

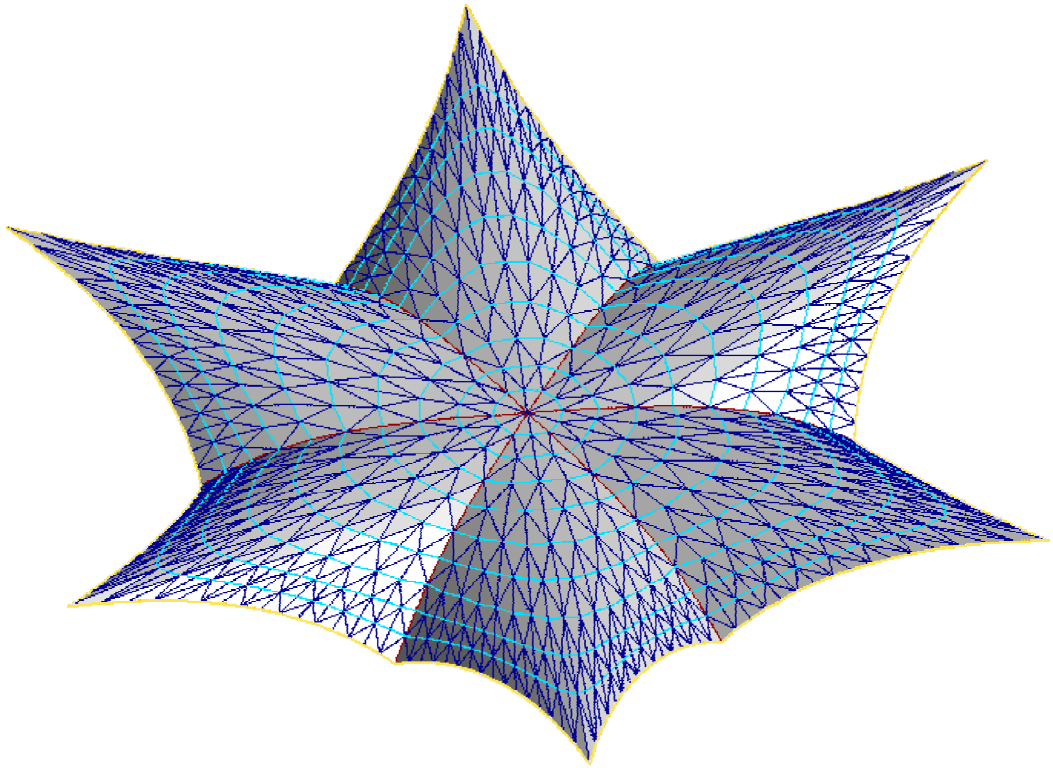


Coordinates of anchor points

X_i (m)	Y_i (m)	Z_i (m)
0,0	0,0	0,0
8,0	0,0	0,0
8,0	8,0	0,0
0,0	8,0	0,0

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10	Ring 11	Ring 12
Type of topology	A	C	B	C	A	C	B	B	A	B	B	B
Force:length coefficient of ring branches	10	10	10	10	10	10	17	17	17	20	20	100
Force:length coefficient of radial branches	2	2	2	2	2	2	2	2	2	2	2	2





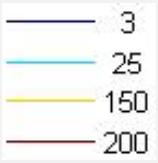
Input data	
Number of rings	10
Number of nodes in initial ring	6
Number of contour anchor points	12
Weight of the ribs (kN/m)	1,41
Self-weight (kN/m2)	4,7

INSPIRED BY FLOWER

Maximum height : 1,500 m

Material: concrete

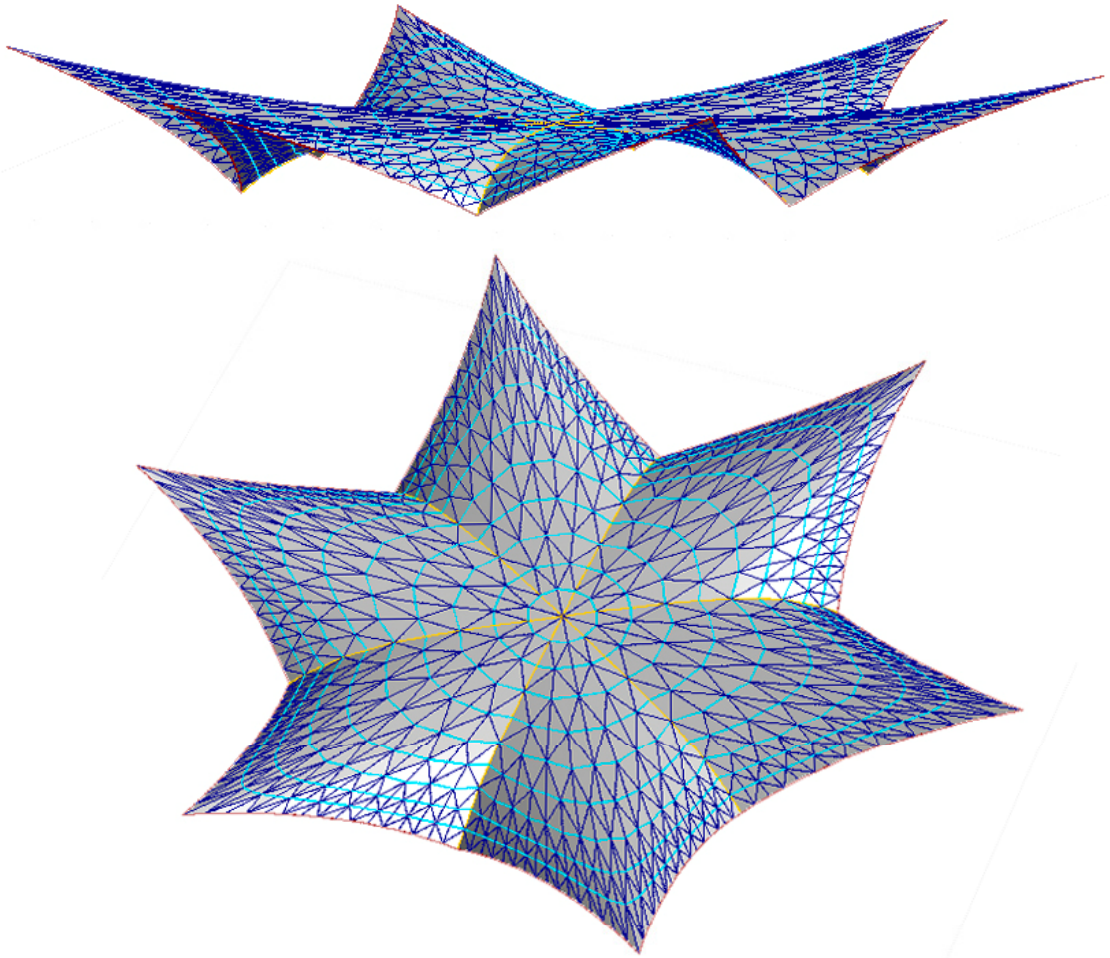
Force:length coefficient



Coordinates of anchor points

X_i (m)	Y_i (m)	Z_i (m)
3,5	9,0	0,0
0,0	7,0	-1,5
3,5	5,0	0,0
3,5	1,0	-1,5
7,0	3,0	0,0
10,5	1,0	-1,5
10,5	5,0	0,0
14,0	7,0	-1,5
10,5	9,0	0,0
10,5	13,0	-1,5
7,0	11,0	0,0
3,5	13,0	-1,5

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	B	B	B	A	B	B	B	B	B
Force :length coefficient of ring branches	25	25	25	25	25	25	25	25	25	150
Force:length coefficient of radial branches	3	3	3	3	3	3	3	3	3	3



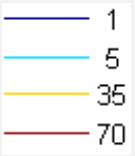
Input data	
Number of rings	10
Number of nodes in initial ring	6
Number of contour anchor points	12
Weight of the ribs (kN/m)	0.50
Self-weight (kN/m2)	0.70

INSPIRED BY FLOWER

Maximum height : 1,500 m

Material: steel and glass

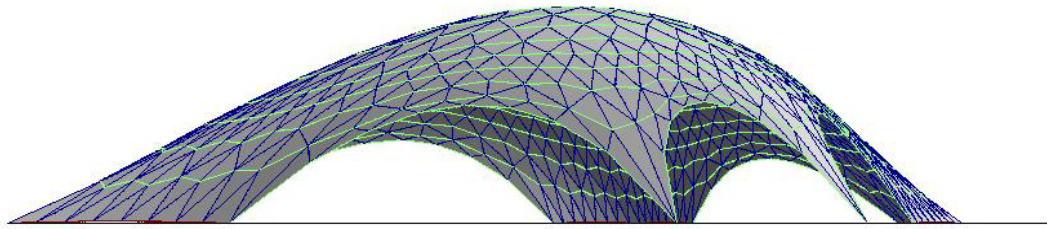
Force:length coefficient

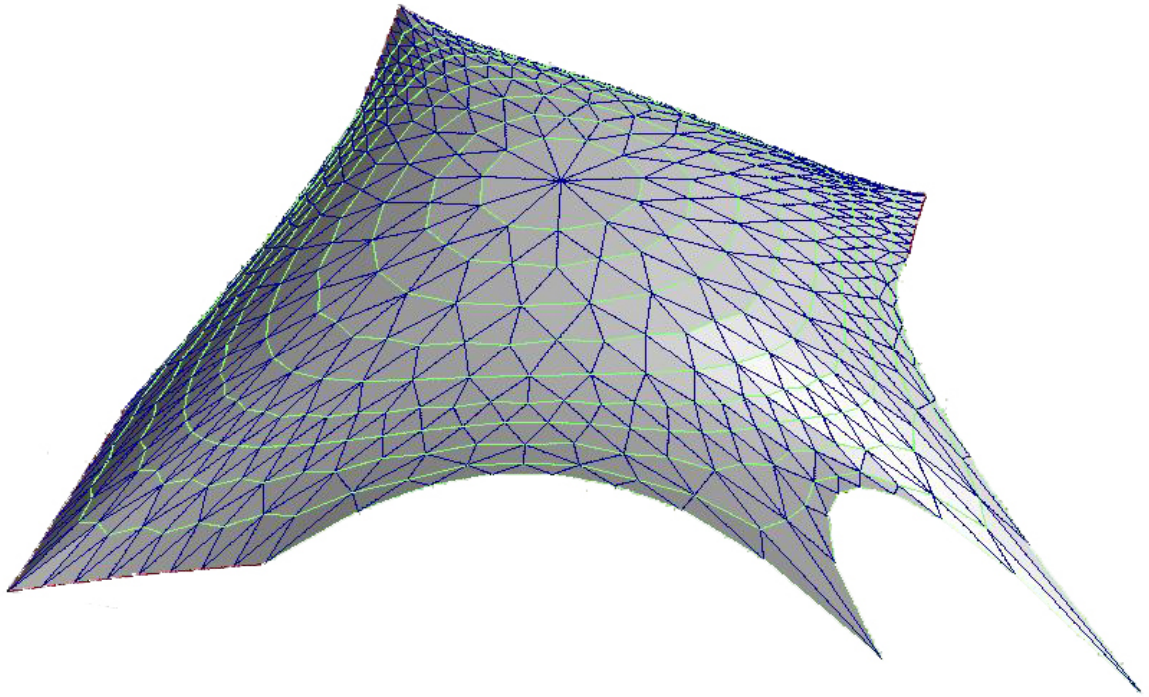


Coordinates of anchor points

X_i (m)	Y_i (m)	Z_i (m)
3,5	9,0	0,0
0,0	7,0	-1,5
3,5	5,0	0,0
3,5	1,0	-1,5
7,0	3,0	0,0
10,5	1,0	-1,5
10,5	5,0	0,0
14,0	7,0	-1,5
10,5	9,0	0,0
10,5	13,0	-1,5
7,0	11,0	0,0
3,5	13,0	-1,5

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	B	B	B	A	B	B	B	B	B
Force:length coefficient of ring branches	5	5	5	5	5	5	5	5	5	70
Force:length coefficient of radial branches	1	1	1	1	1	1	1	1	1	1





Input data	
Number of rings	10
Number of nodes in initial ring	11
Number of contour anchor points	11
Weight of the ribs (kN/m)	1,41
Self-weight (kN/m2)	4,7

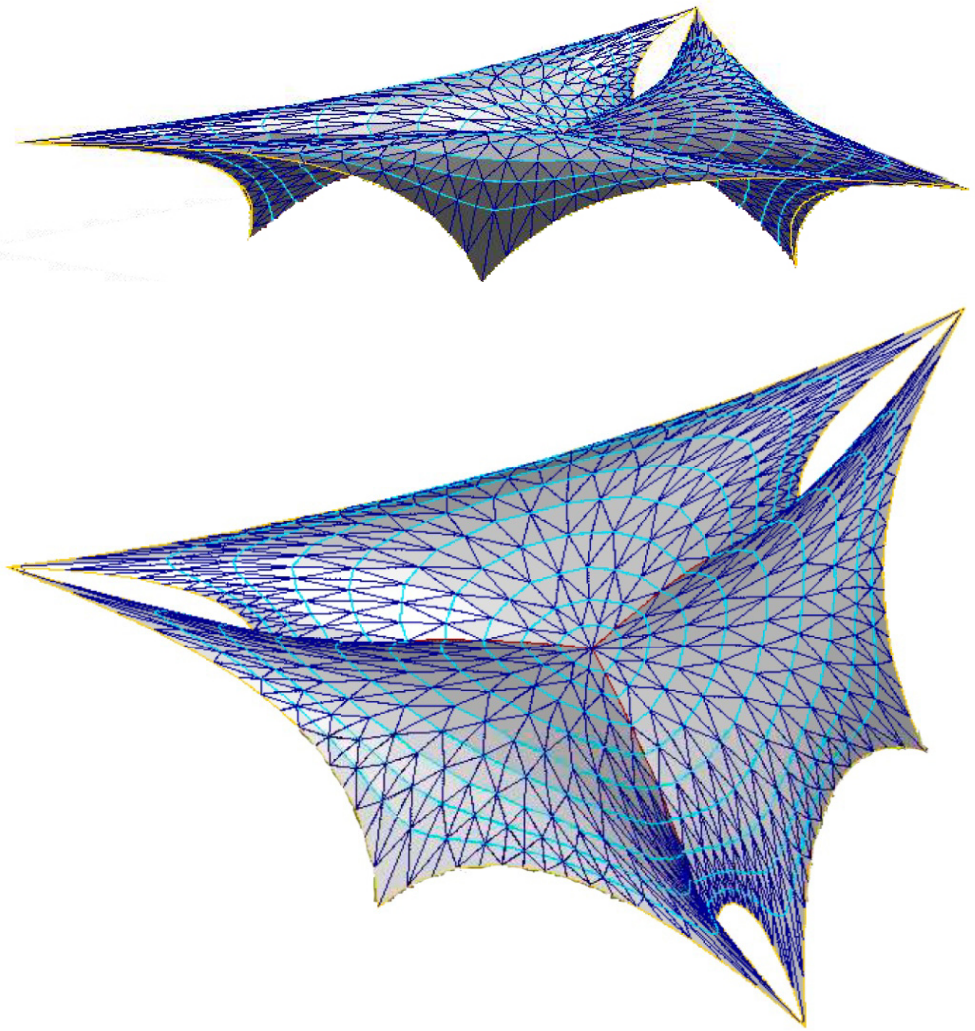
INSPIRED BY DINOSAUR

Maximum height: 2.806 m

Material: concrete

Force:length coefficient	Coordinates of anchor points		
	X_i (m)	Y_i (m)	Z_i (m)
5	3,0	4,0	0,0
10	2,3	1,0	0,0
1500	5,0	2,0	0,0
	12,0	1,0	0,0
	14,0	3,0	0,0
	11,0	8,0	0,0
	11,0	9,0	0,0
	10,0	9,0	0,0
	6,0	10,0	0,0
	4,7	10,6	0,0
	4,6	9,0	0,0

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	B	A	B	A	B	B	C	B	B
Force:length coefficient of ring branches	10	10	10	10	10	10	10	10	10	10
Force:length coefficient of radial branches	5	5	5	5	5	5	5	5	5	5



Input data	
Number of rings	10
Number of nodes in initial ring	6
Number of contour anchor points	12
Weight of the ribs (kN/m)	1,41
Self-weight (kN/m2)	4,7

INSPIRED BY FLOWER

Maximum height : 1,620 m

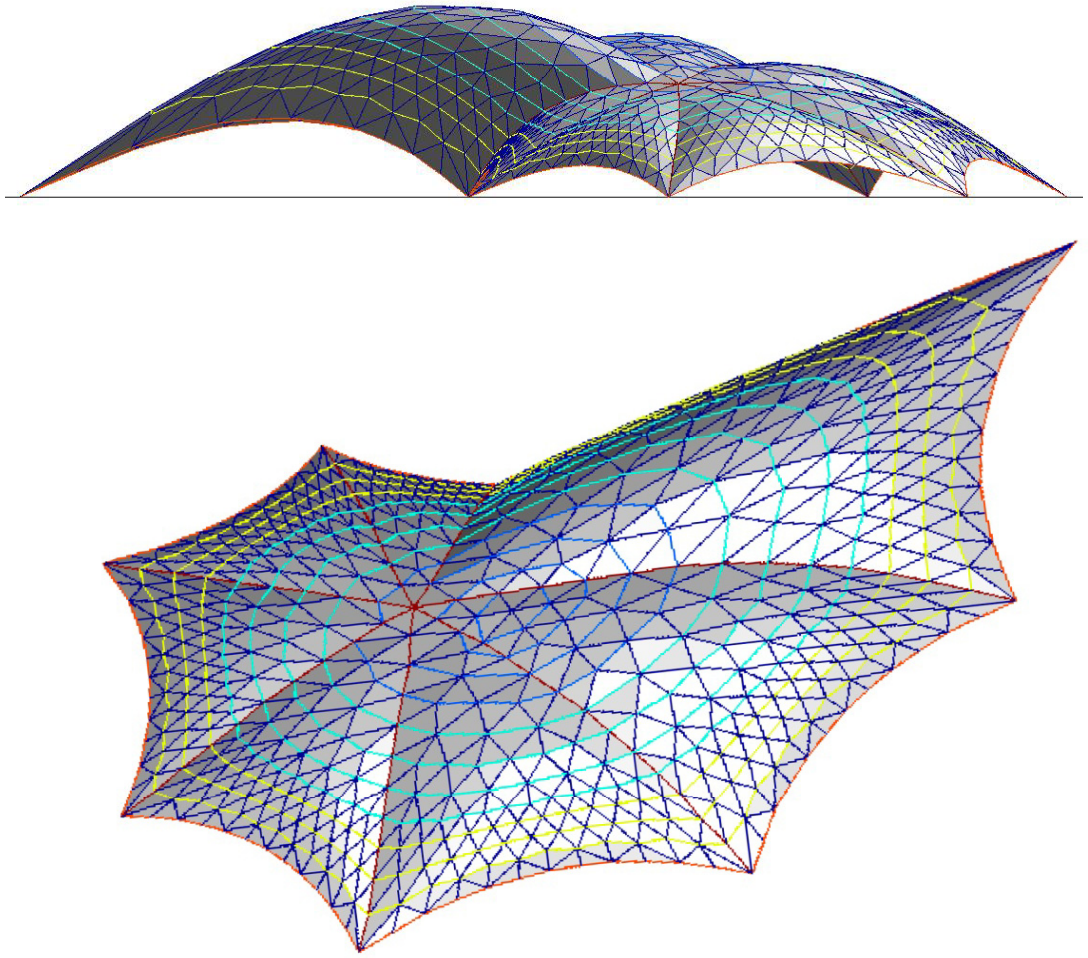
Material: concrete

Force : length coefficient

Coordinates of anchor points

X_i (m)	Y_i (m)	Z_i (m)
3,5	9,0	0,0
1,0	10,5	-1,5
3,5	5,0	0,0
7,0	0,0	-1,5
7,0	3,0	0,0
7,0	0,0	-1,5
10,5	5,0	0,0
13,0	10,5	-1,5
10,5	9,0	0,0
13,0	10,5	-1,5
7,0	11,0	0,0
1,0	10,5	-1,5

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	C	A	1	3	1	3	1	1	1
Force:length coefficient of ring branches	25	25	25	25	25	25	25	25	25	50
Force:length coefficient of radial branches	3	3	3	3	3	3	3	3	3	3



Input data	
Number of rings	12
Number of nodes in initial ring	6
Number of contour anchor points	8
Weight of the ribs (kN/m)	1,41
Self-weight (kN/m2)	4,7

INSPIRED BY NAUTILUS SHELL

Maximum height : 14,275 m

Material: concrete

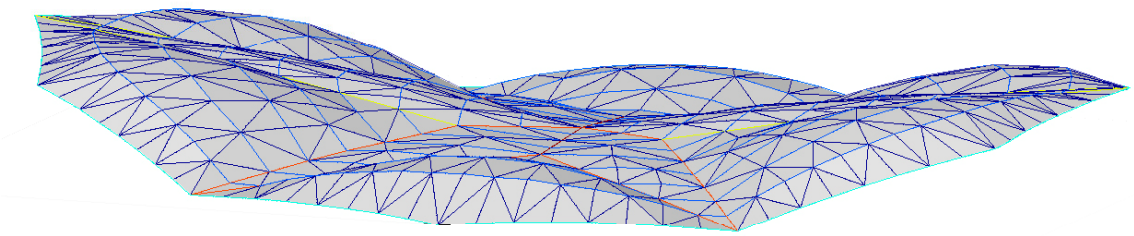
Force : length coefficient

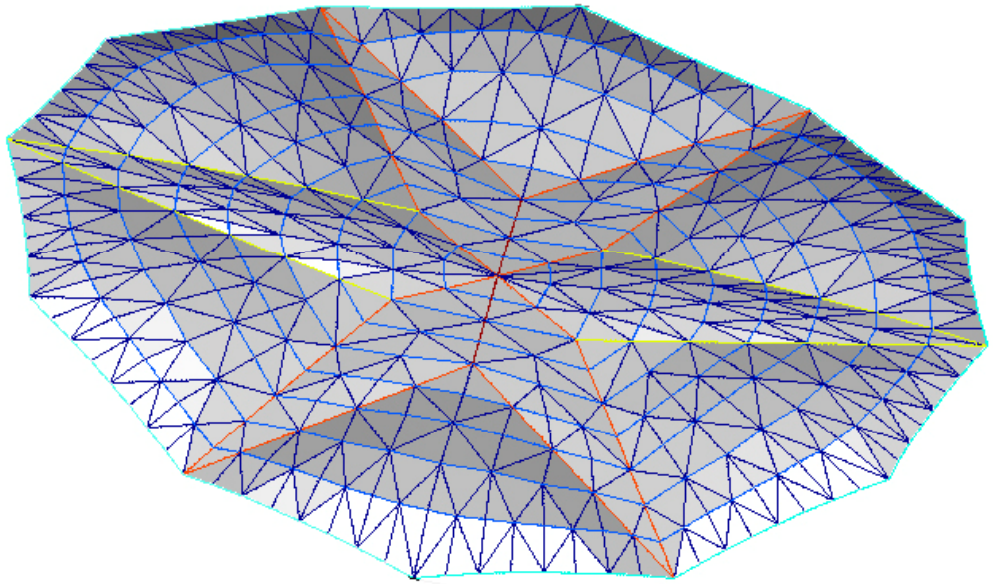
20
30
35
40
350
500

Coordinates of anchor points

X_i (m)	Y_i (m)	Z_i (m)
10,0	40,0	0,0
0,0	30,0	0,0
0,0	10,0	0,0
20,0	0,0	0,0
40,0	10,0	0,0
50,0	40,0	0,0
40,0	70,0	0,0
15,0	90,0	0,0

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10	Ring 11	Ring 12
Type of topology	A	B	A	B	A	B	A	B	B	B	C	C
Force:length coefficient of ring branches	30	30	30	30	35	35	35	35	40	40	40	350
Force:length coefficient of radial branches	20	20	20	20	20	20	20	20	20	20	20	20





Input data	
Number of rings	9
Number of nodes in initial ring	6
Number of contour anchor points	12
Weight of the ribs (kN/m)	0.50
Self-weight (kN/m2)	0.70

Maximum height: 1,500 m
Material: steel and glass

Force:length coefficient	Coordinates of anchor points		
0.2	X_i (m)	Y_i (m)	Z_i (m)
2	3,5	9,0	0,0
30	0,0	7,0	-1,5
50	3,5	5,0	0,0
100	3,5	1,0	-1,5
300	7,0	3,0	0,0
	10,5	1,0	-1,5
	10,5	5,0	0,0
	14,0	7,0	-1,5
	10,5	9,0	0,0
	10,5	13,0	-1,5
	7,0	11,0	0,0
	3,5	13,0	-1,5

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9
Type of topology	C	A	C	A	C	C	A	C	C
Force:length coefficient of ring branches	2	2	2	2	2	2	2	2	30
Force:length coefficient of radial branches	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2

Contacts

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