Apply physics in design

Kangaroo physics

- Physics engine for interactive simulation, form-finding, optimisation and constraint solving.

- Mainly written by Daniel Piker

https://www.food4rhino.com/app/kangaroo-physics

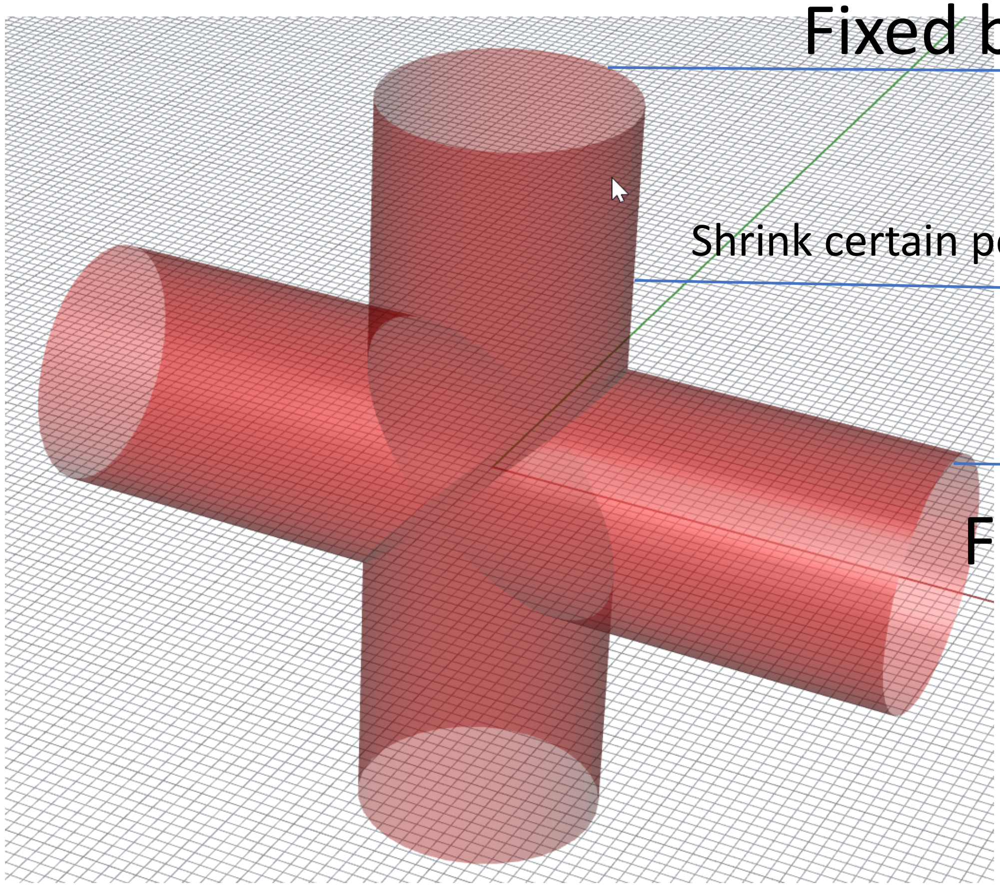
The idea of Kangaroo

10602_Rubber_Duck_v1_L3.obj

Define different types of goals

Minimize it using a solver

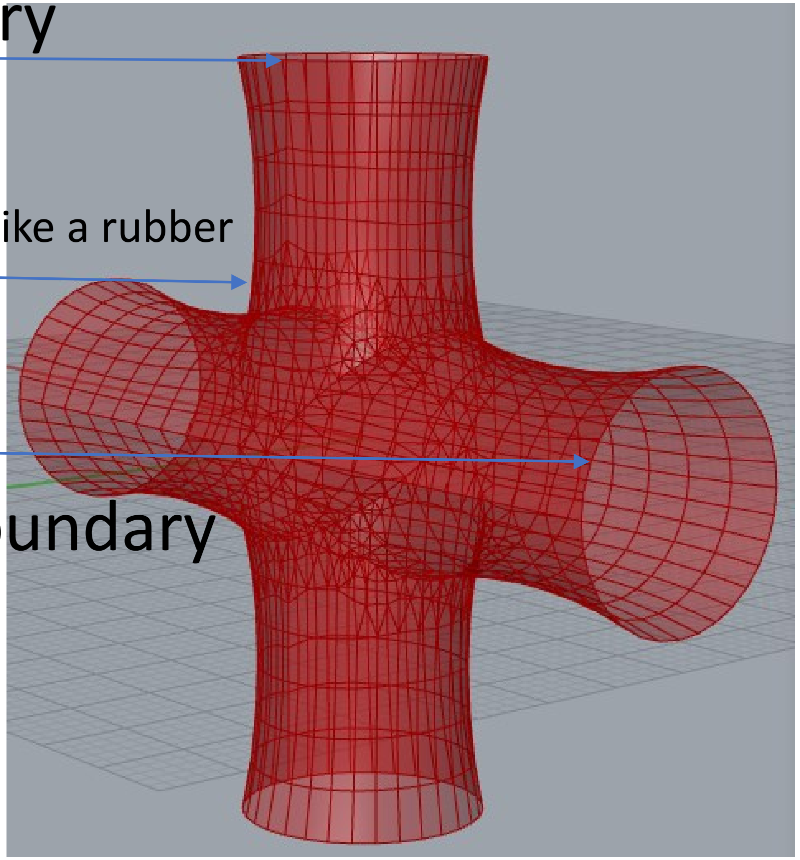
Case – Create an organic “cross” surface



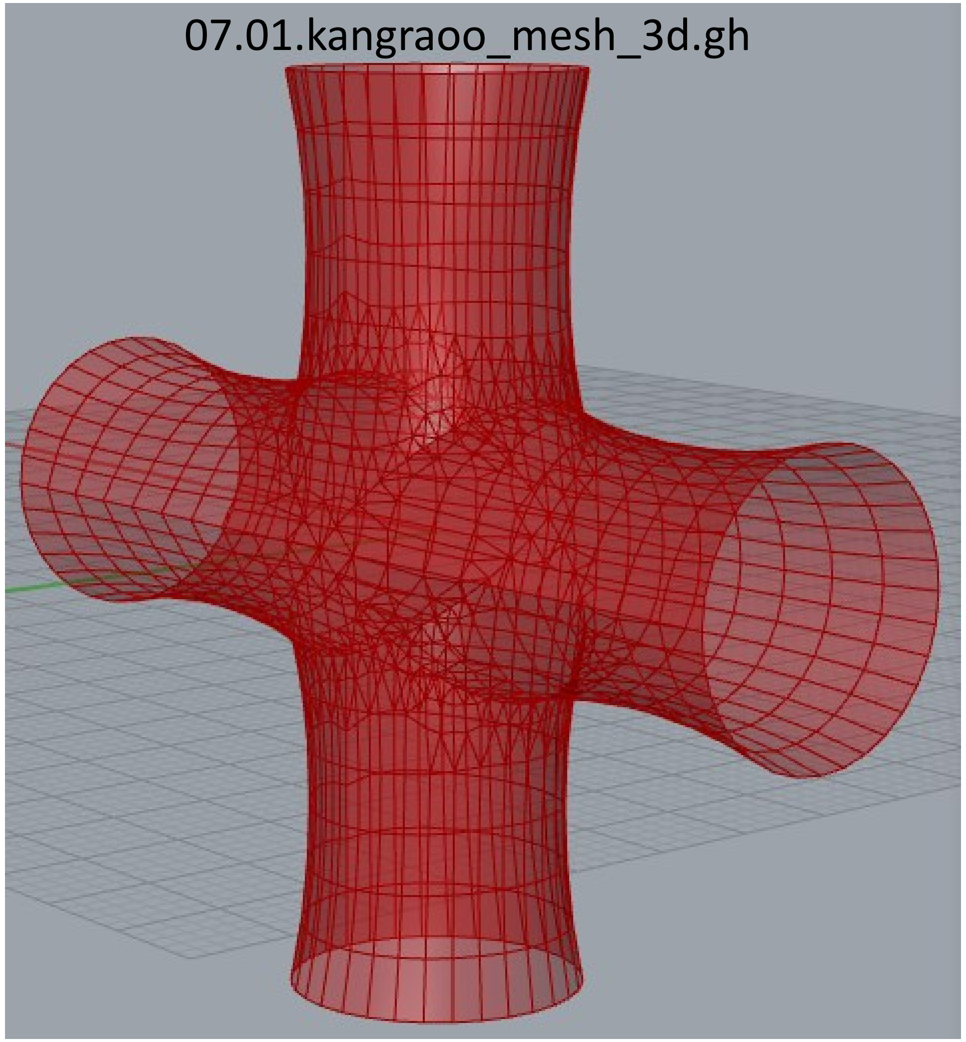
Fixed boundary

Shrink certain percentage like a rubber

Fixed boundary



Case – Create an organic “cross” surface



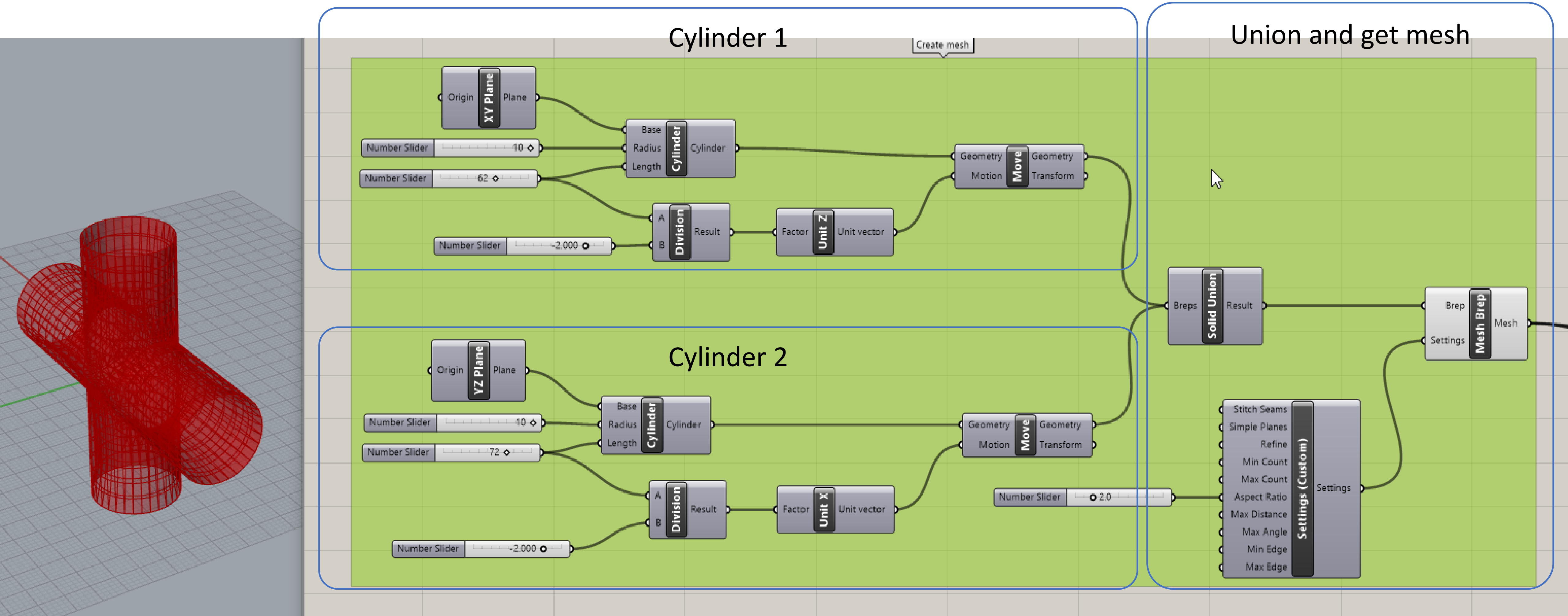
Create a surface with 2 cylindrical surface across

Subdivide the surface to many rectangular “cells”

Make all boundary vertices as anchors

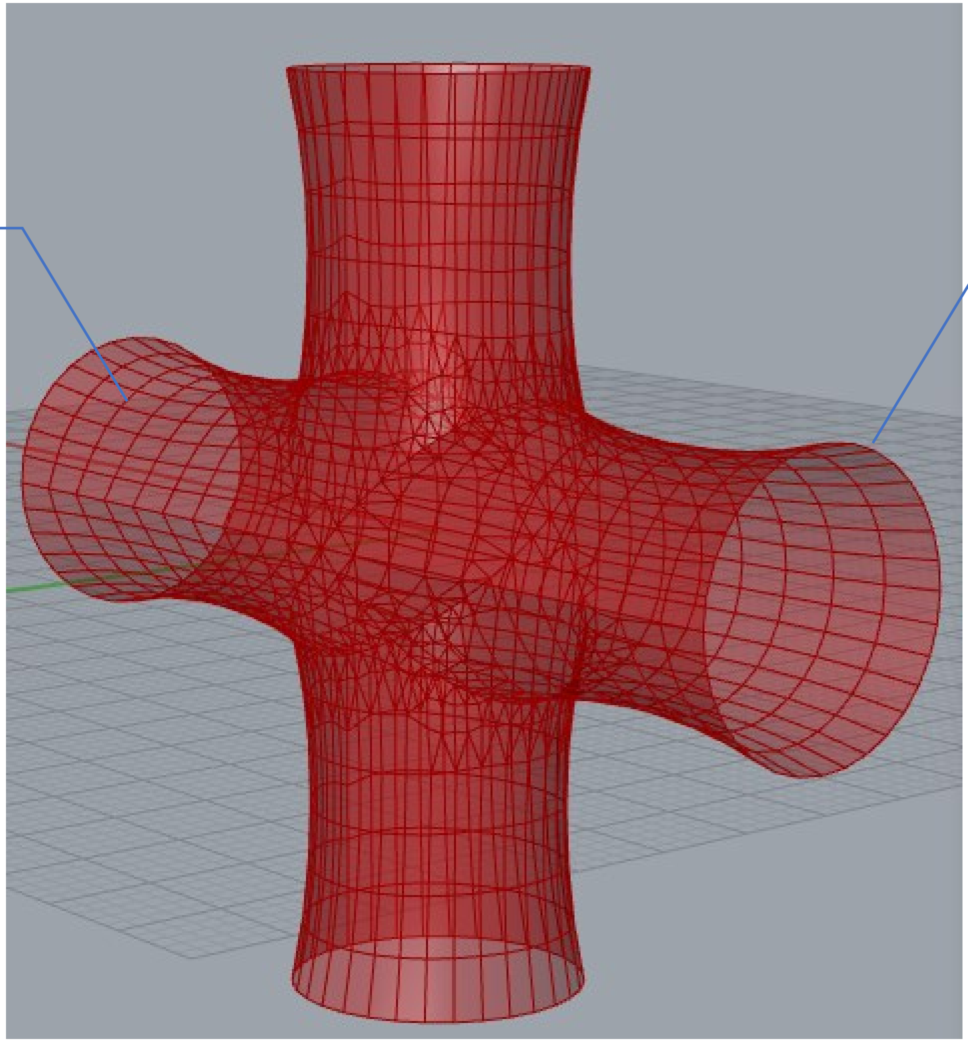
Target: Shrink the edge to 50% like a “rubber” tube

The staring point



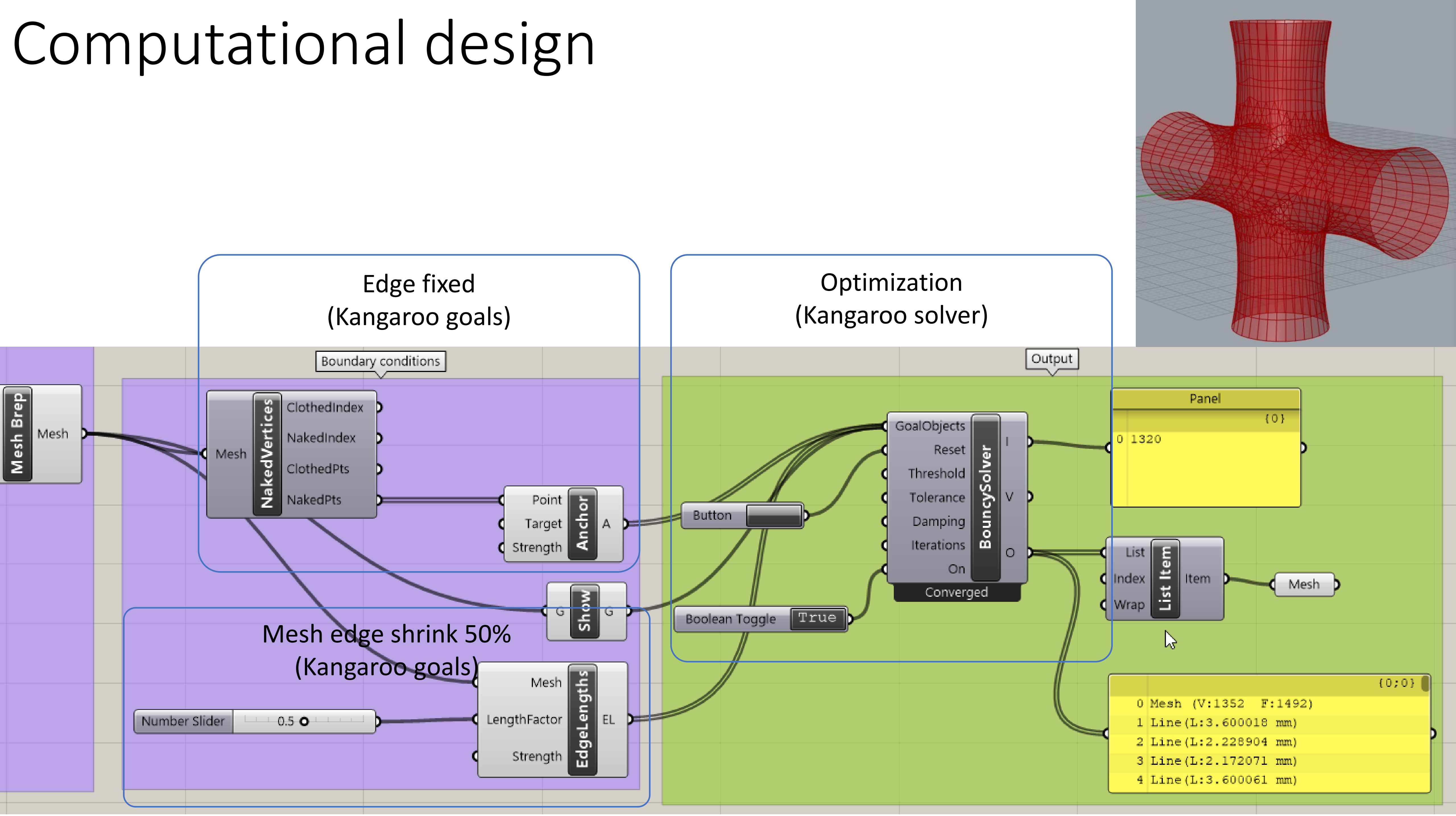
Boundary conditions

All cells will contract towards
0.5 edge length

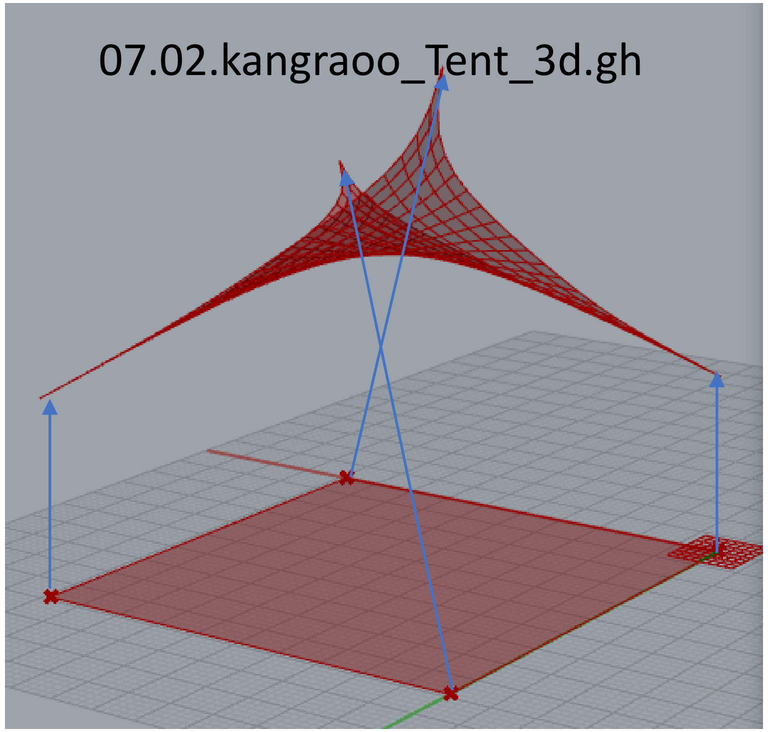


All naked boundaries are
fixed

Computational design



A similar case



Create a rectangular surface

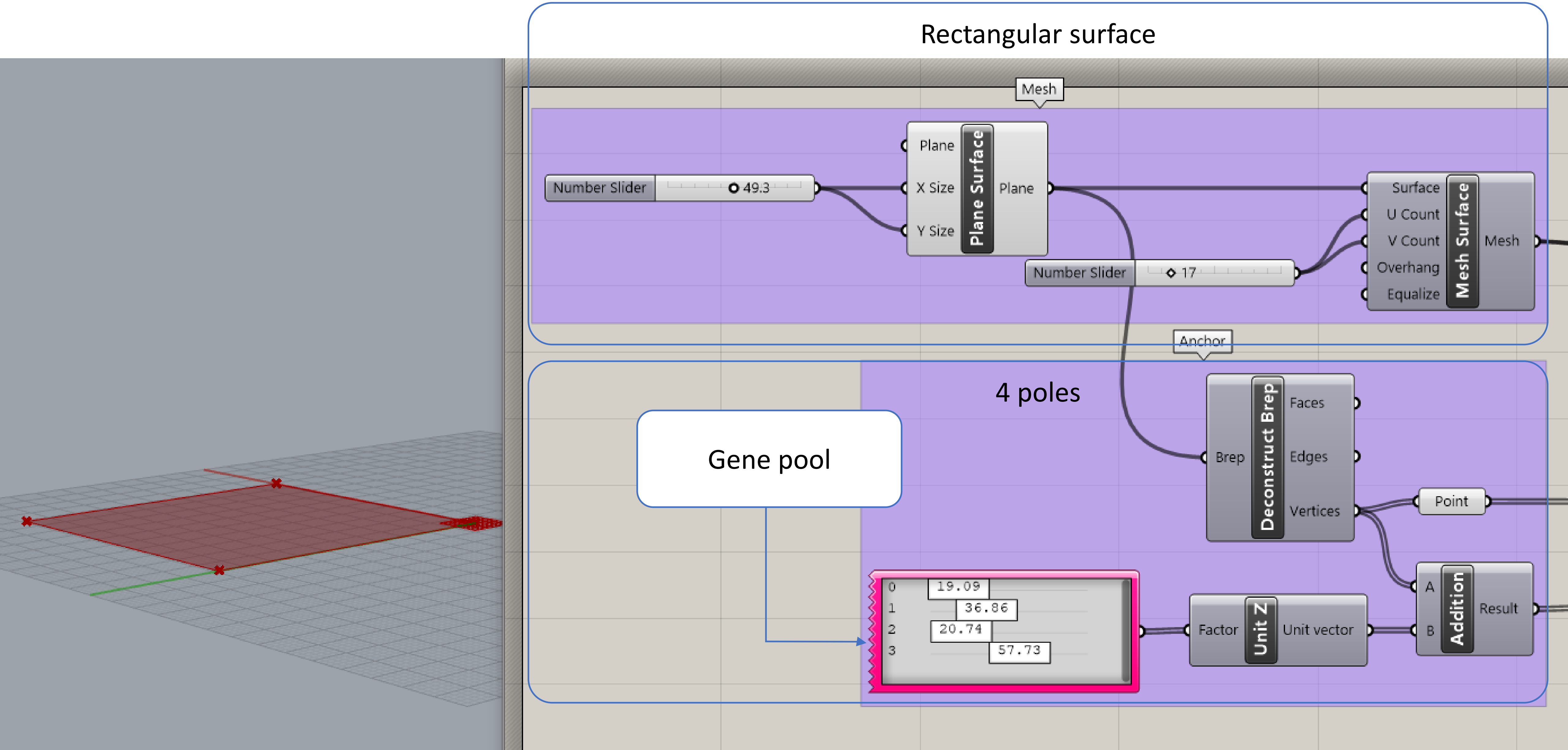
Subdivide it to many rectangular “cells”

Create 4 anchors in the 3D space

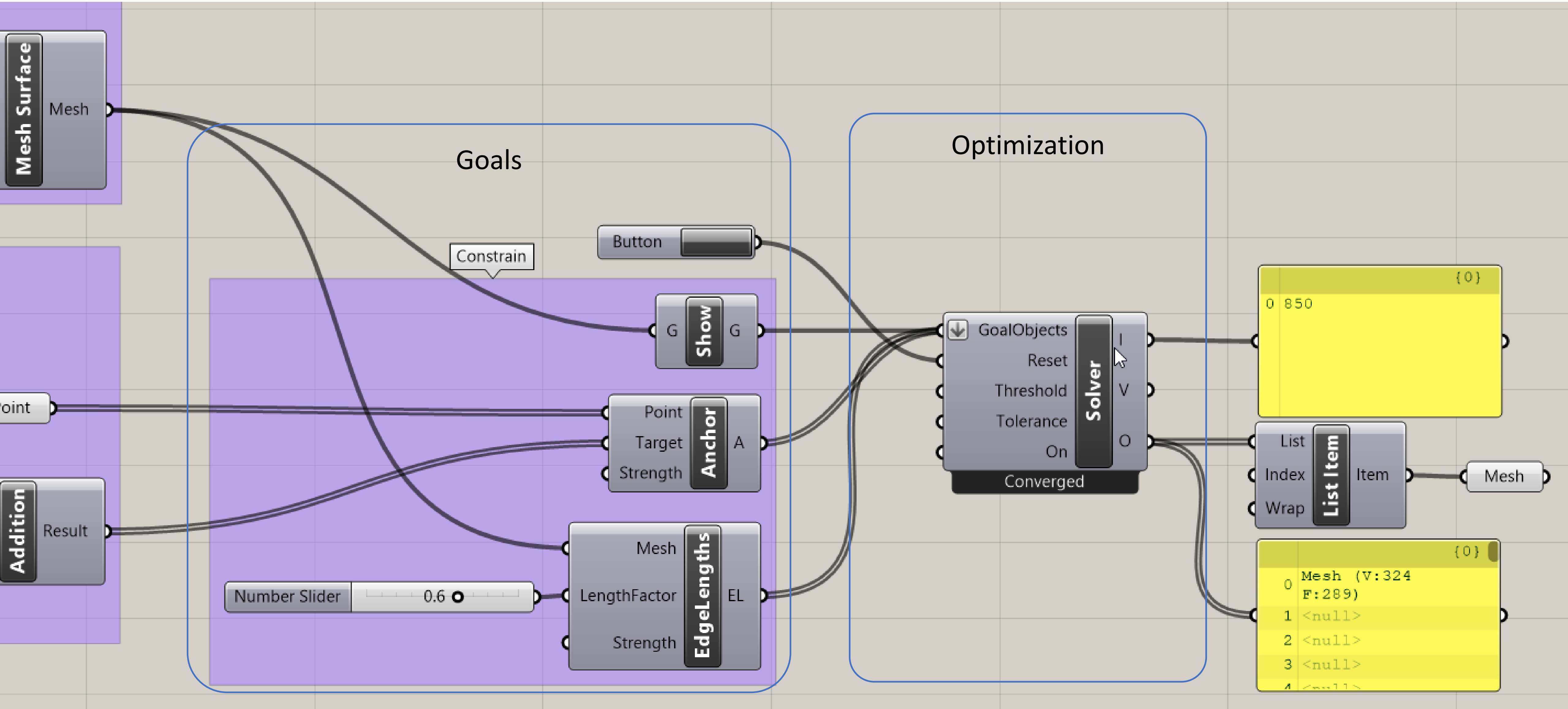
“Hang” surface on the 4 anchors

Target: Shrink the edge to 60% like a “rubber” sheet

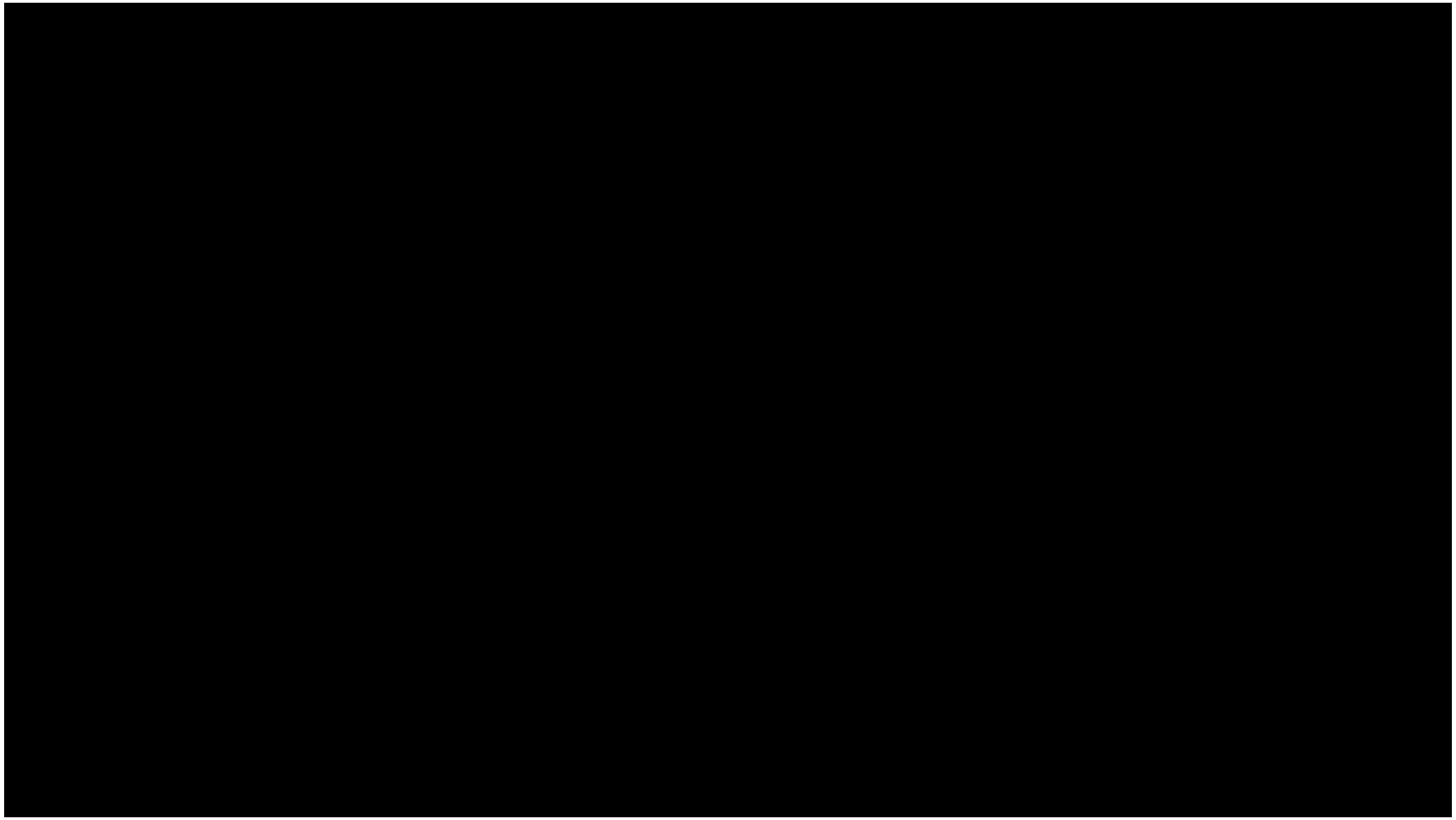
The starting point



Make a rubber tent



4D printing Programmable Textiles



The idea

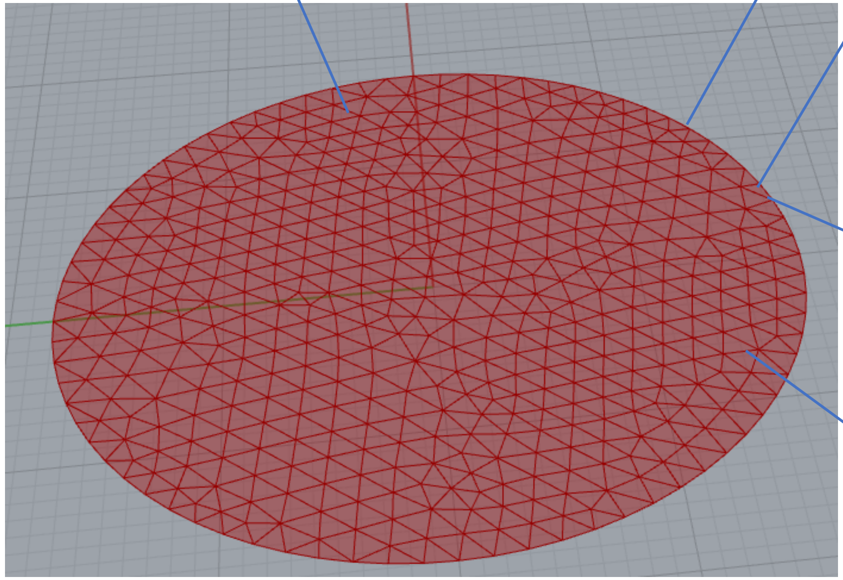
Define a disk mesh

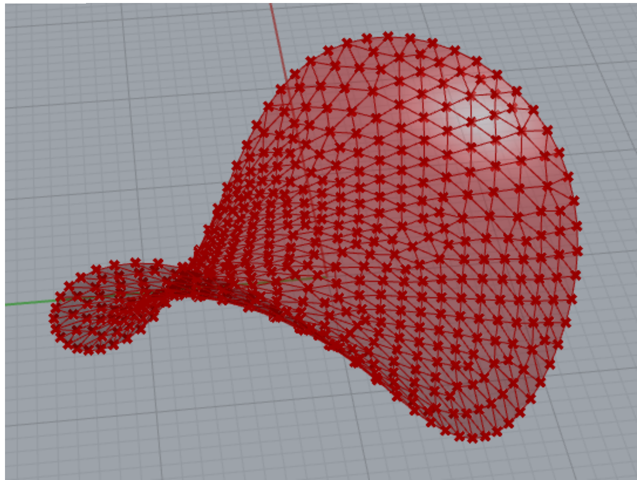
All naked boundaries are like Rod

Add a very small force on a vertex

Anchor another vertex

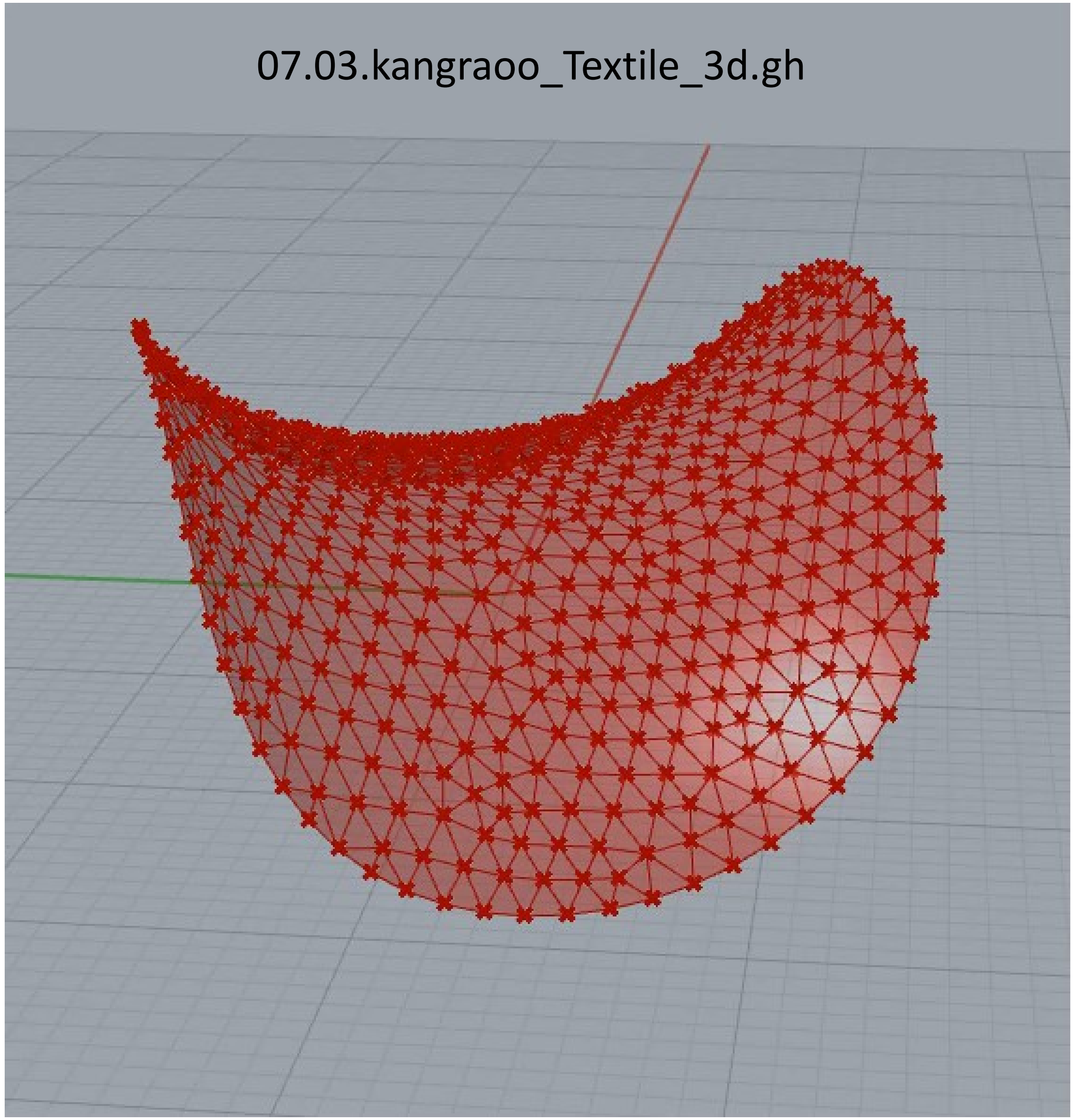
All edges shrink towards 0.5



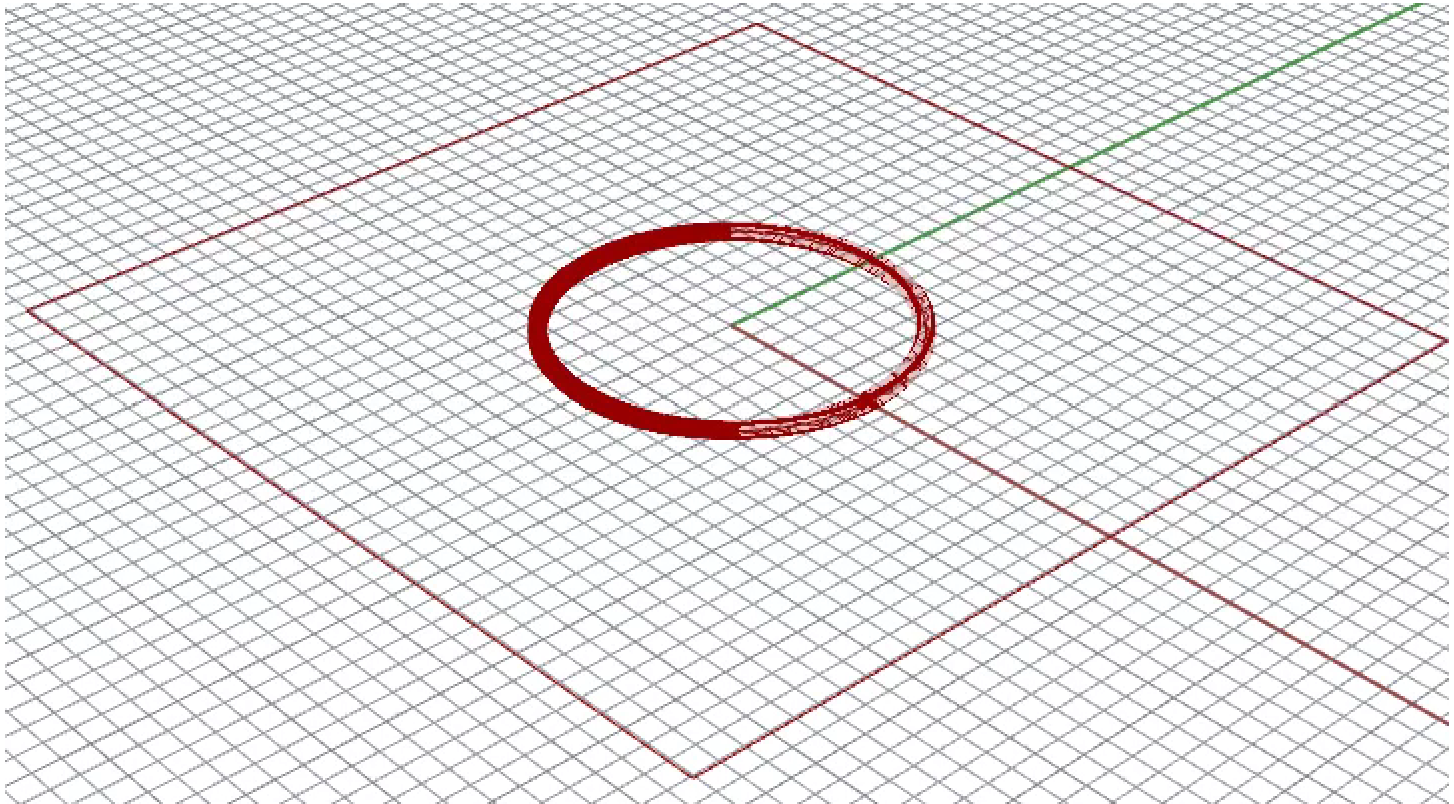


Courtesy and modified from Daniel Piker: https://discourse.mcneel.com/t/simulation-of-tensile-textiles-and-3d-printing/86357/2

The result

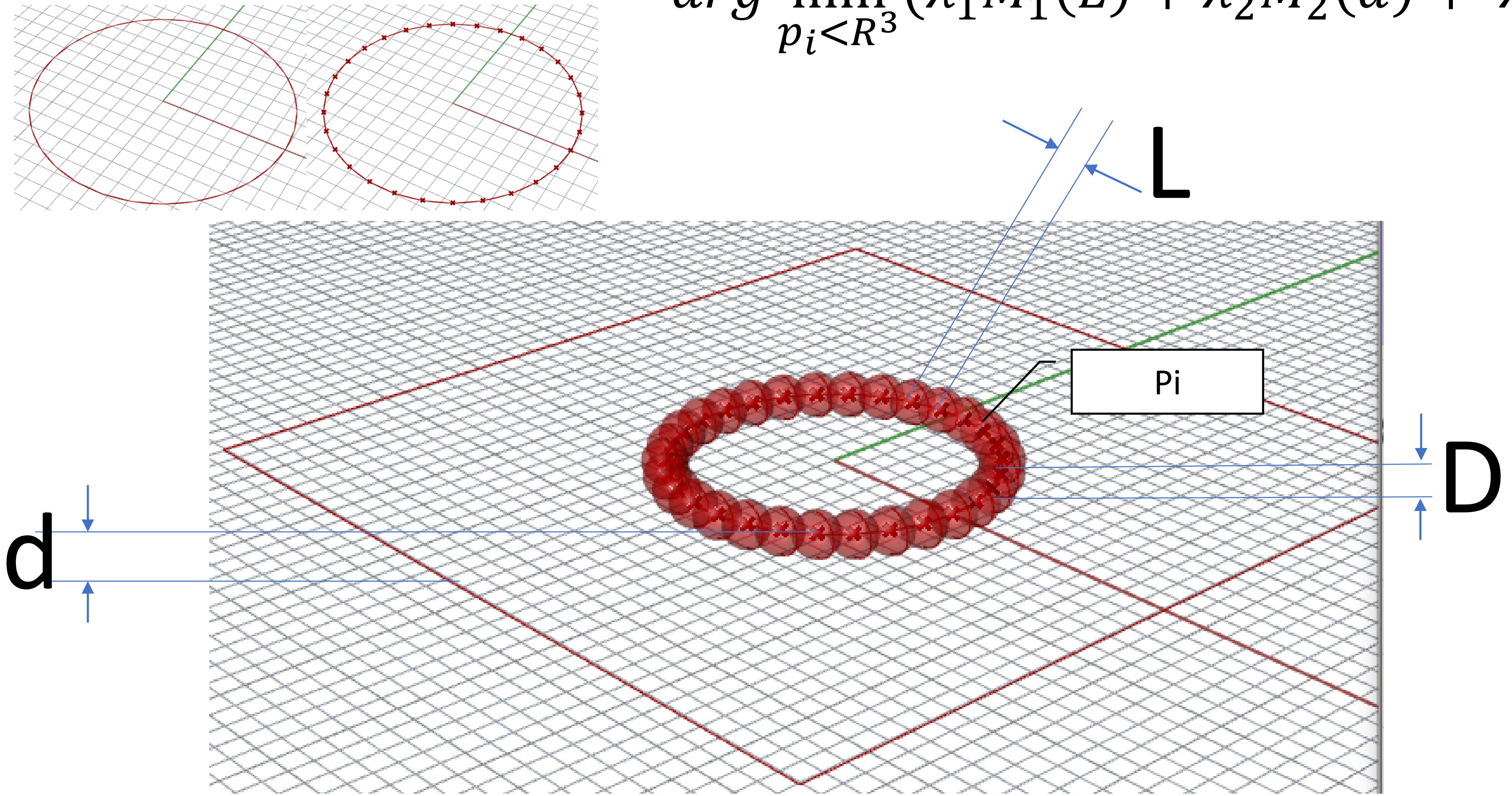


Line growth

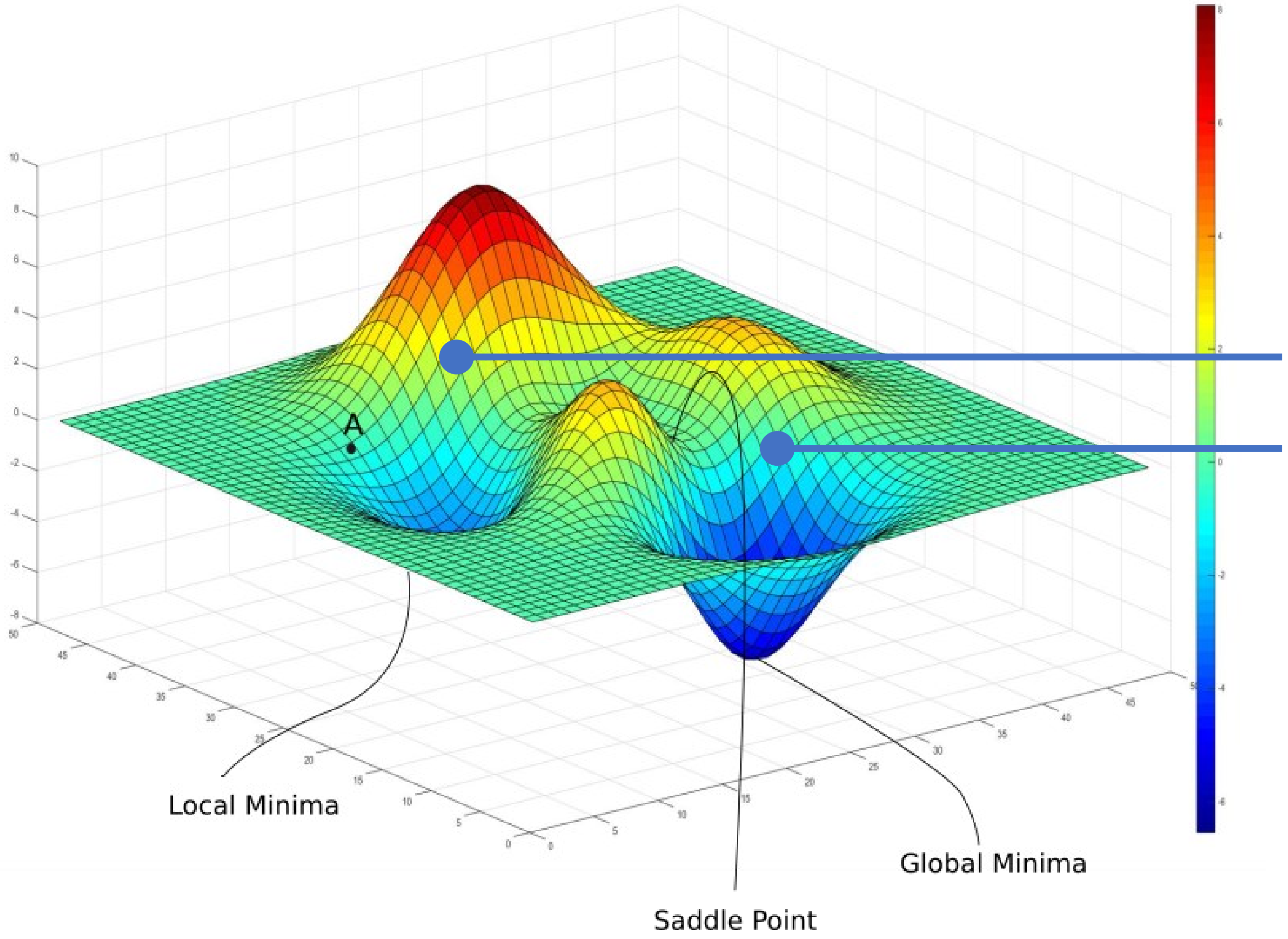


Line growth

$$arg \min_{p_i < R^3} (\lambda_1 M_1(L) + \lambda_2 M_2(d) + \lambda_3 M_3(D))$$



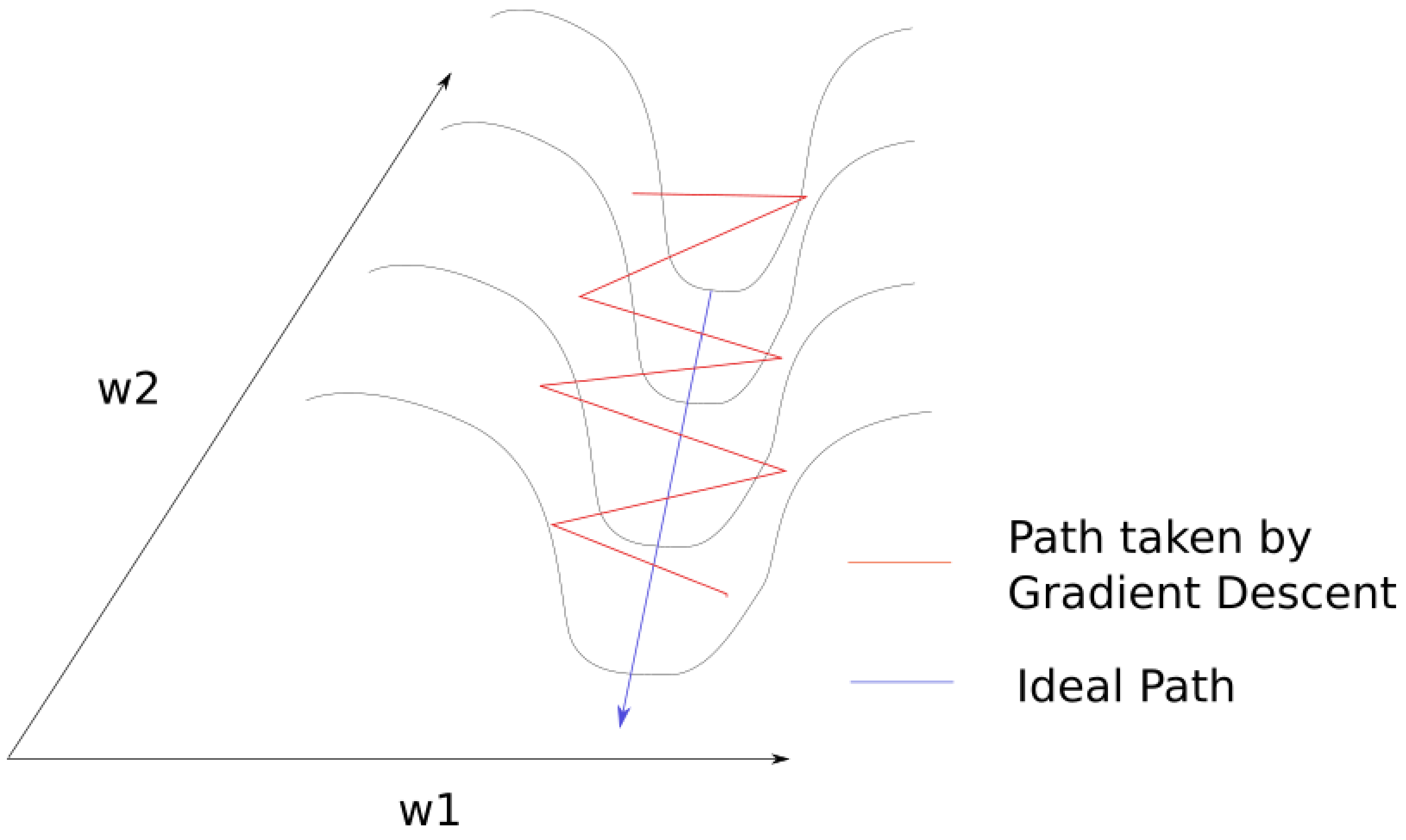
Optimization: Local and global minimum



Different starting point
may have different results

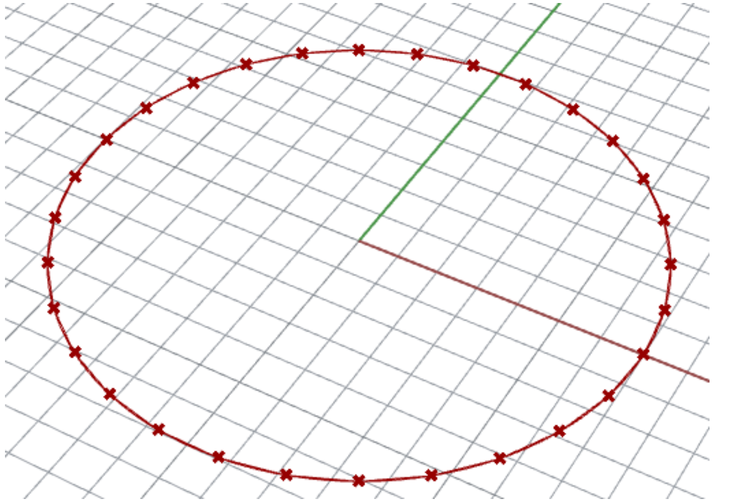
https://medium.com/ai%C2%B3-theory-practice-business/optimization-in-deep-learning-5a5d263172e

Optimization: Step length

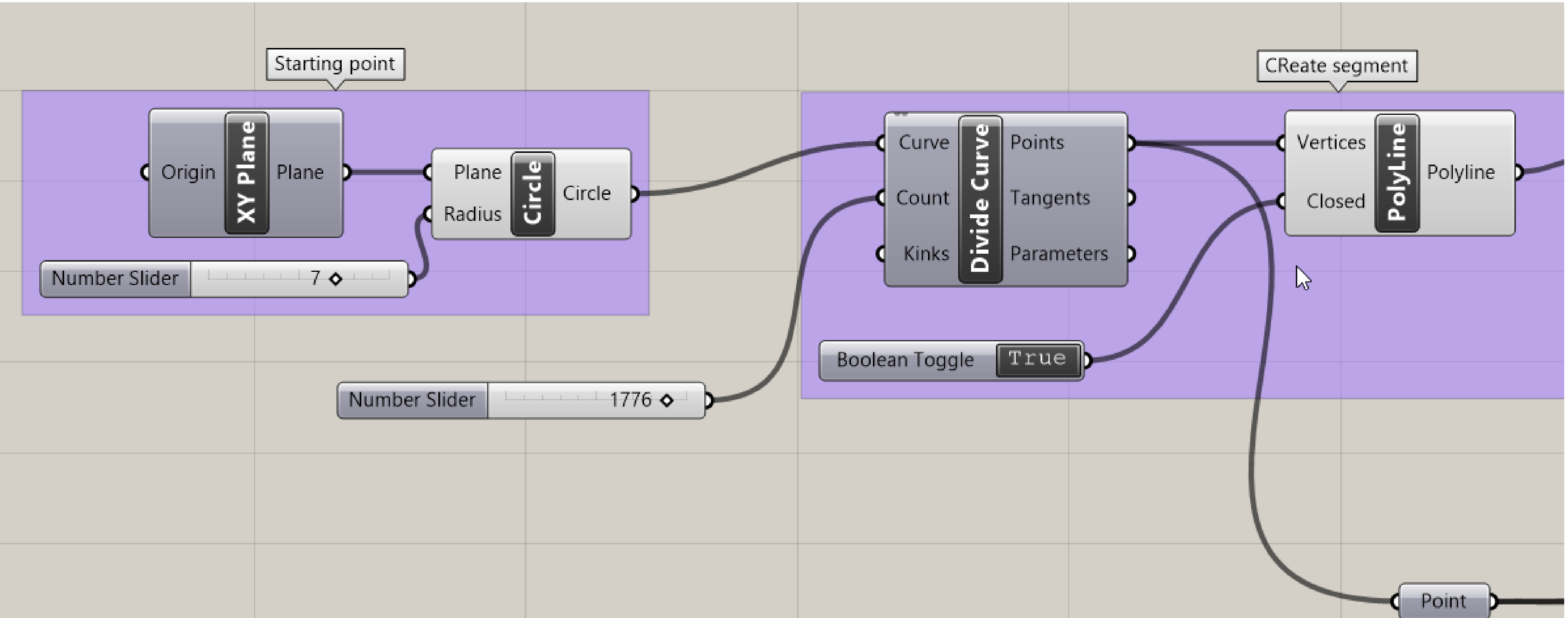


https://medium.com/ai%C2%B3-theory-practice-business/optimization-in-deep-learning-5a5d263172e

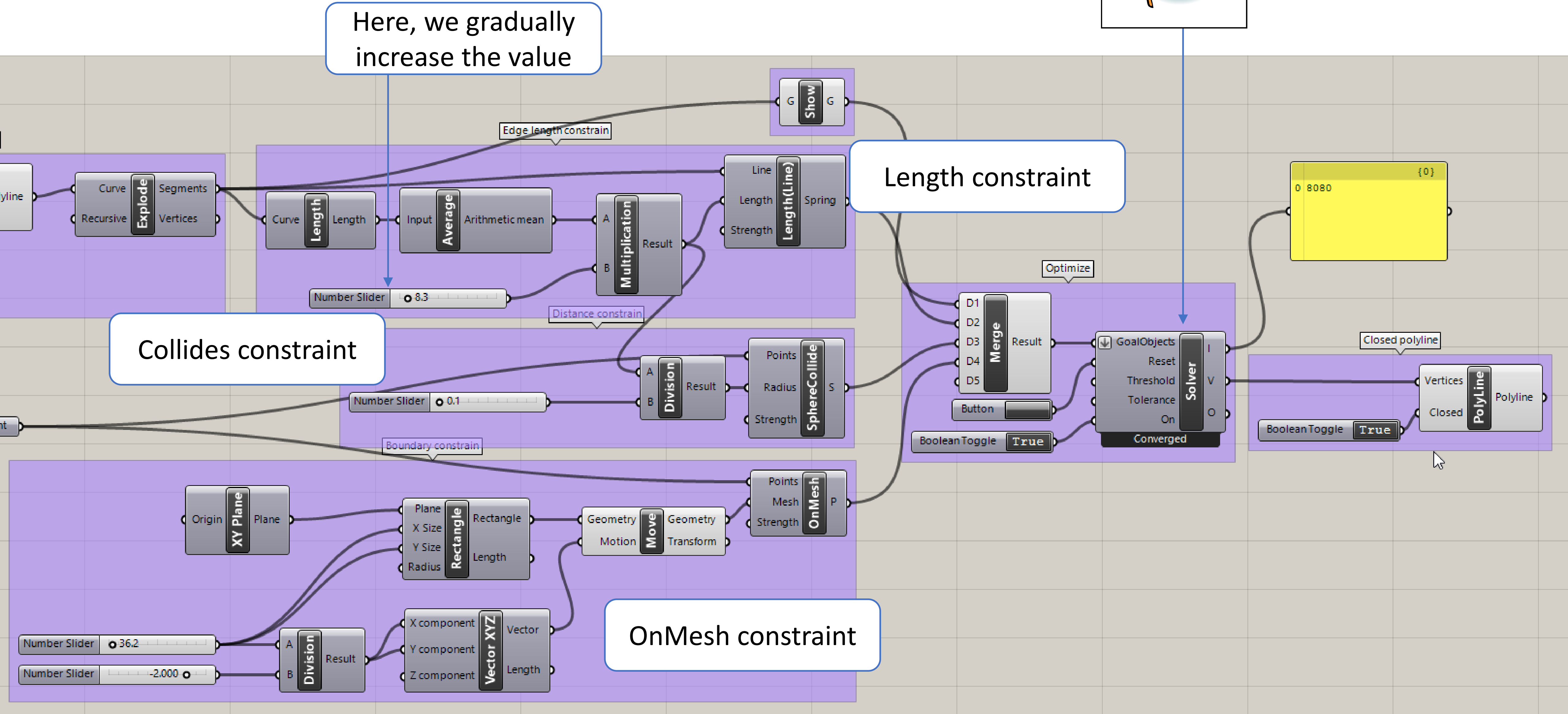
The starting point



07.04.kangraoo_grow_in_3d.gh

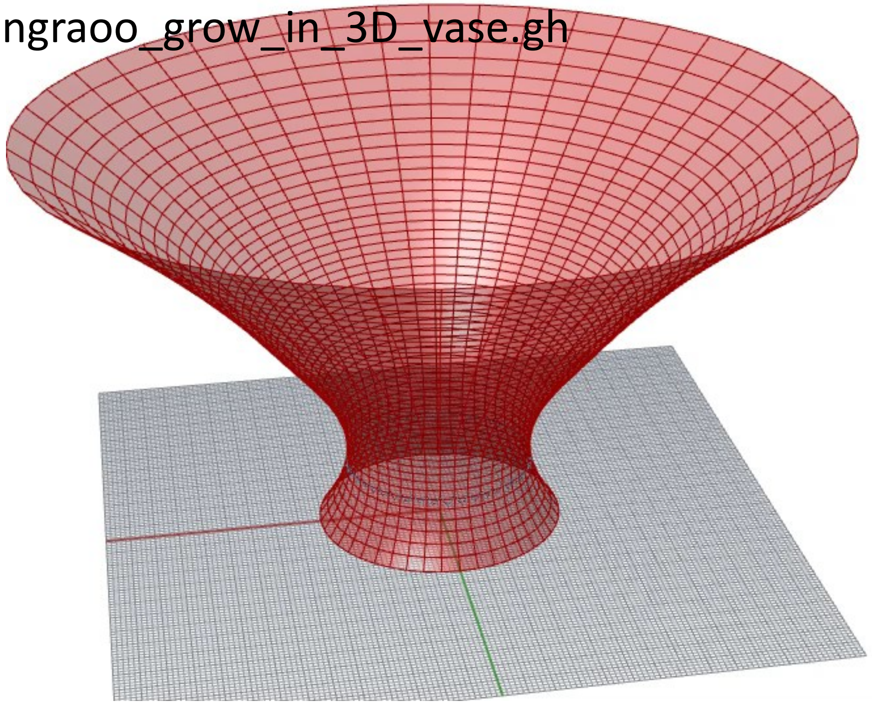


The optimization



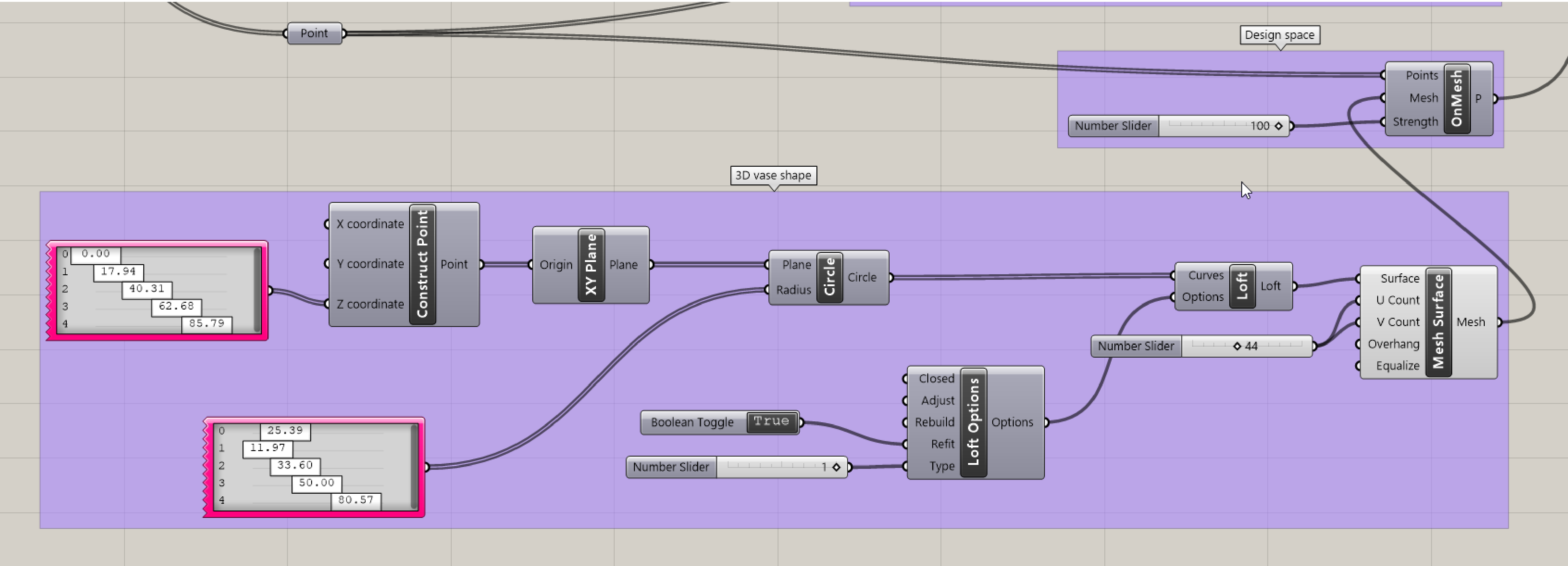
Line growth in 3D

07.04.kangraoo_grow_in_3D_vase.gh

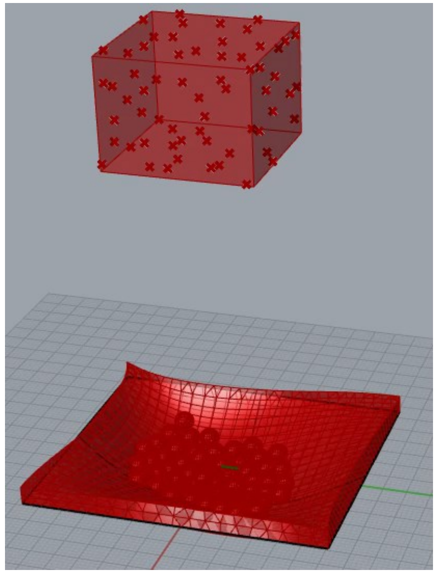


Add a surface constrain

07.04.kangraoo_grow_in_3D_vase.gh



Discreet simulation

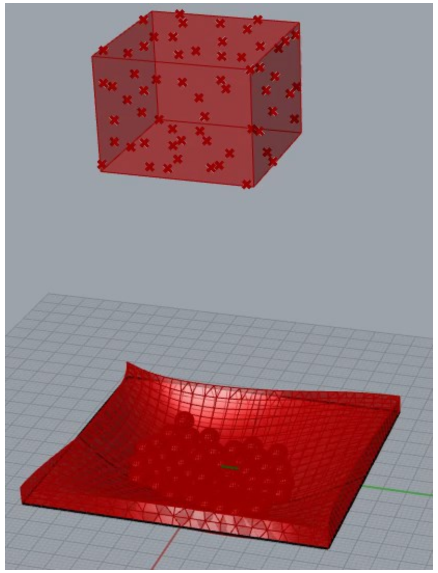


Based on https://www.youtube.com/watch?v=qe1OQ92NoqU

Idea

07.05.Bouncing_ball.3dm

07.05.Bouncing_ball.gh



Create a box, randomly put some points as the center of balls

Create a solid “basin”

Give each point a diameter as a ball

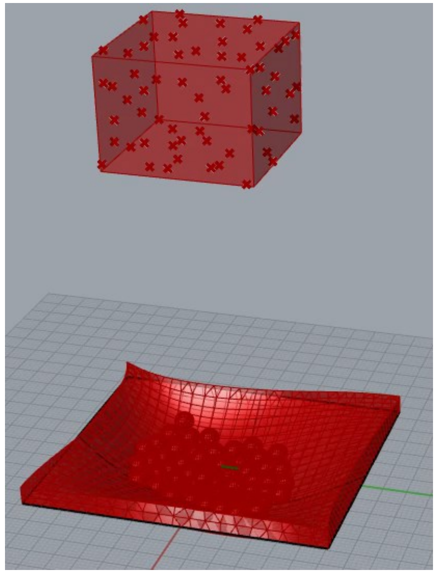
Define ball – ball collide conditions

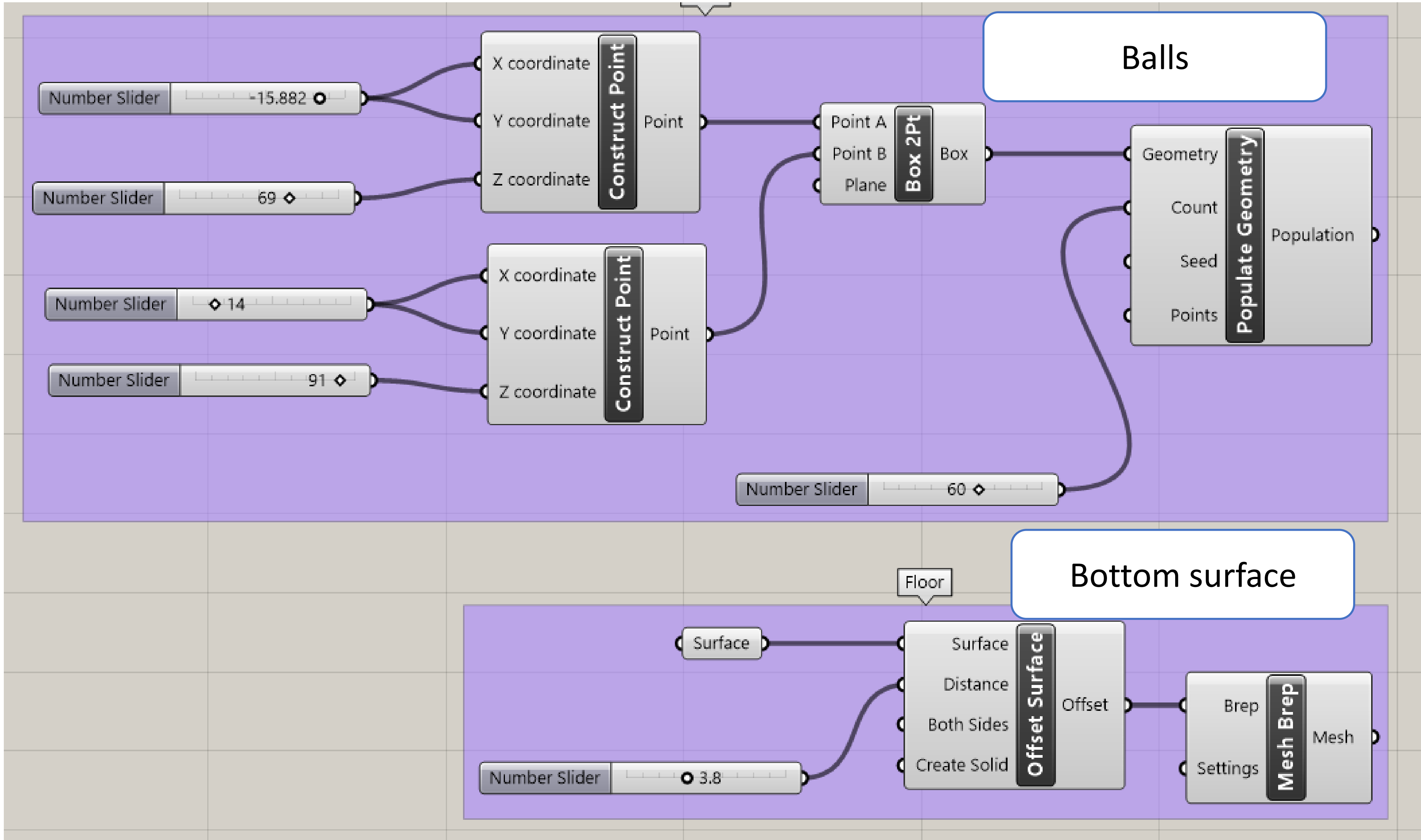
Define ball- basin surface collide conditions

Assignment grivation

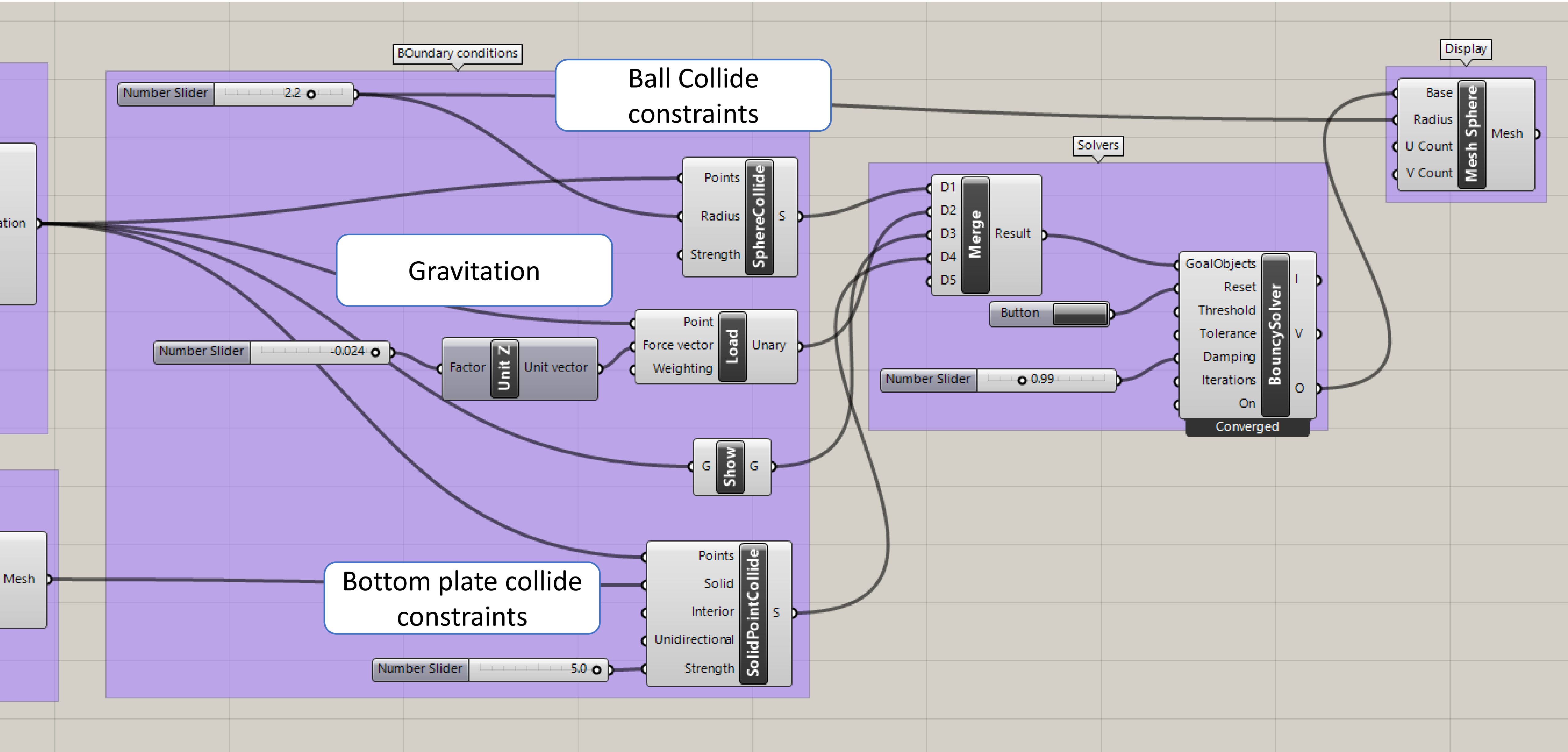
Target: motion stopped

Setup




Balls
Number Slider
-15.882
Number Slider
69
Number Slider
14
Number Slider
91
X coordinate
Y coordinate
Z coordinate
Construct Point
Point
Point A
Point B
Plane
Box 2Pt
Box
Geometry
Count
Seed
Points
Populate Geometry
Population
Number Slider
60
Floor
Bottom surface
Surface
Surface
Distance
Both Sides
Create Solid
Offset Surface
Offset
Brep
Settings
Mesh Brep
Mesh
Number Slider
3.8

Our approach

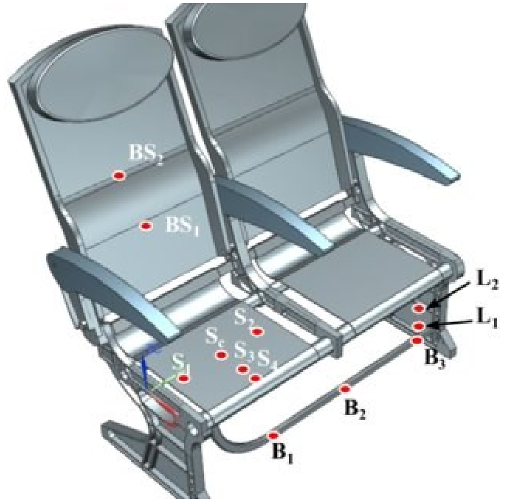


Data-driven design

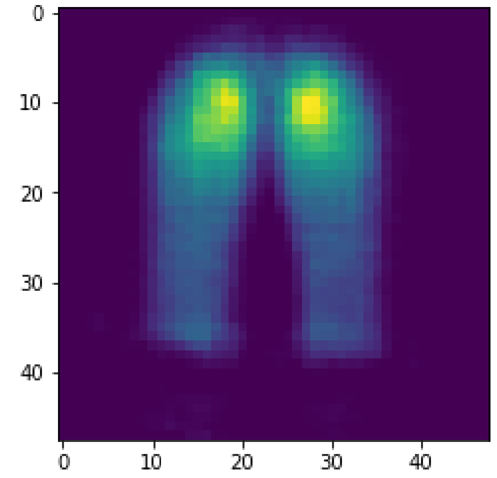
Using data in design

- Syntenic data
- Directly use data
- Data derived boundary conditions
- …

Case study: Using seat pressure map in seat design



https://www.researchgate.net/profile/Marwan_Hassan3

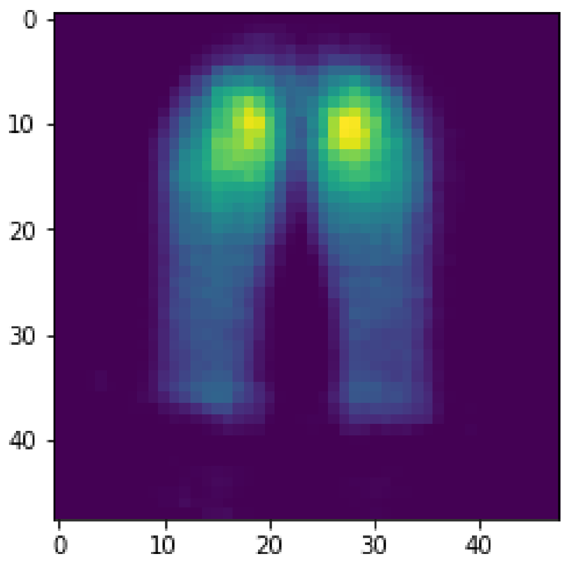


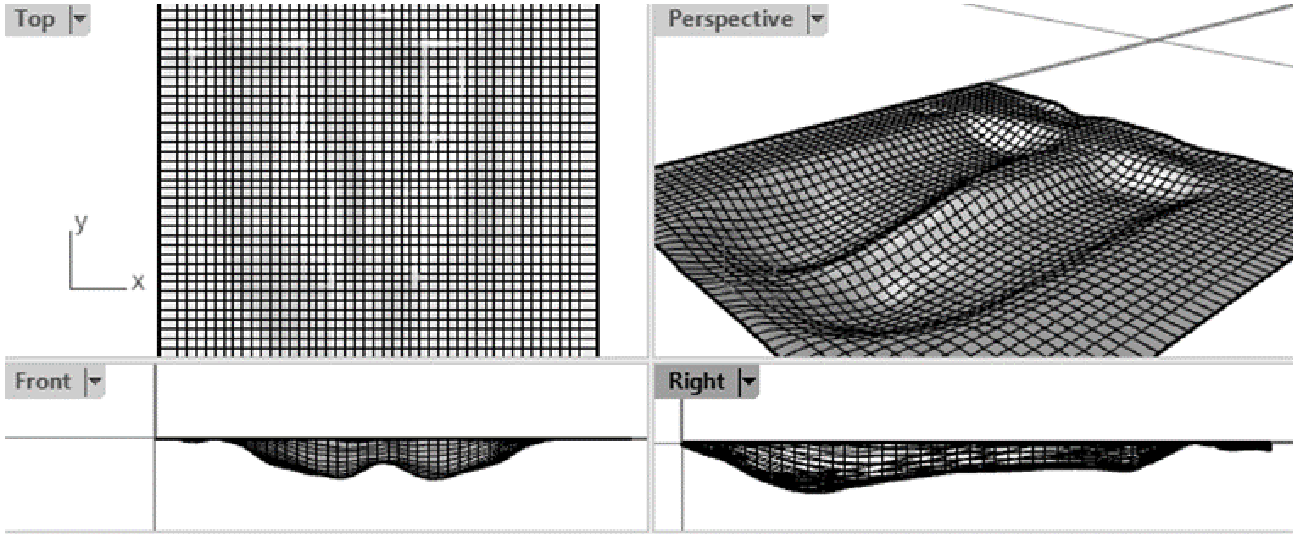
https://www.walmart.ca/en/ip/Cushion-Pad-Chronic-Rebound-Sofa-Beautiful-Hip-Memory-Foam-Car-Seat-Cushion-Office-Aircraft-Long-distance-Travel-Chair-Thickened-High-Cushion/734IKOW86ULE

https://www.octaspringtechnology.com/aerospace/

Designing a shaped seat-pan cushion to improve postural (dis)comfort reducing pressure distribution and increasing contact area at the interface, Iolanda Fiorilloa, Yu Song, Peter Vink, Alessandro Naddeo, submitted to ICED 2021

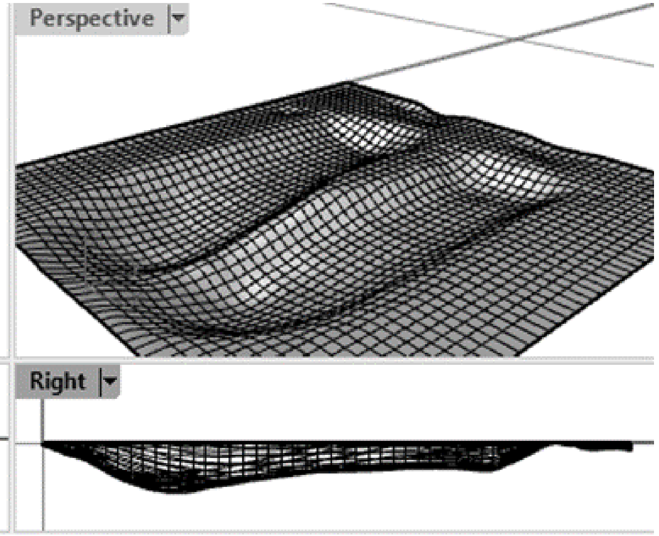
Using data to drive a design

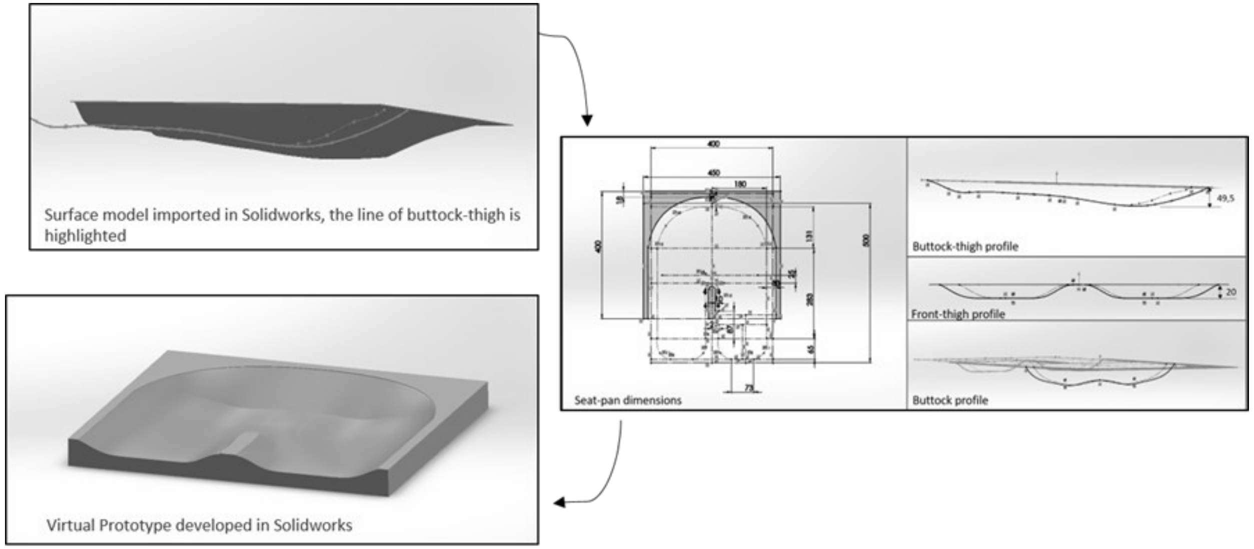




Designing a shaped seat-pan cushion to improve postural (dis)comfort reducing pressure distribution and increasing contact area at the interface, Iolanda Fiorilloa, Yu Song, Peter Vink, Alessandro Naddeo

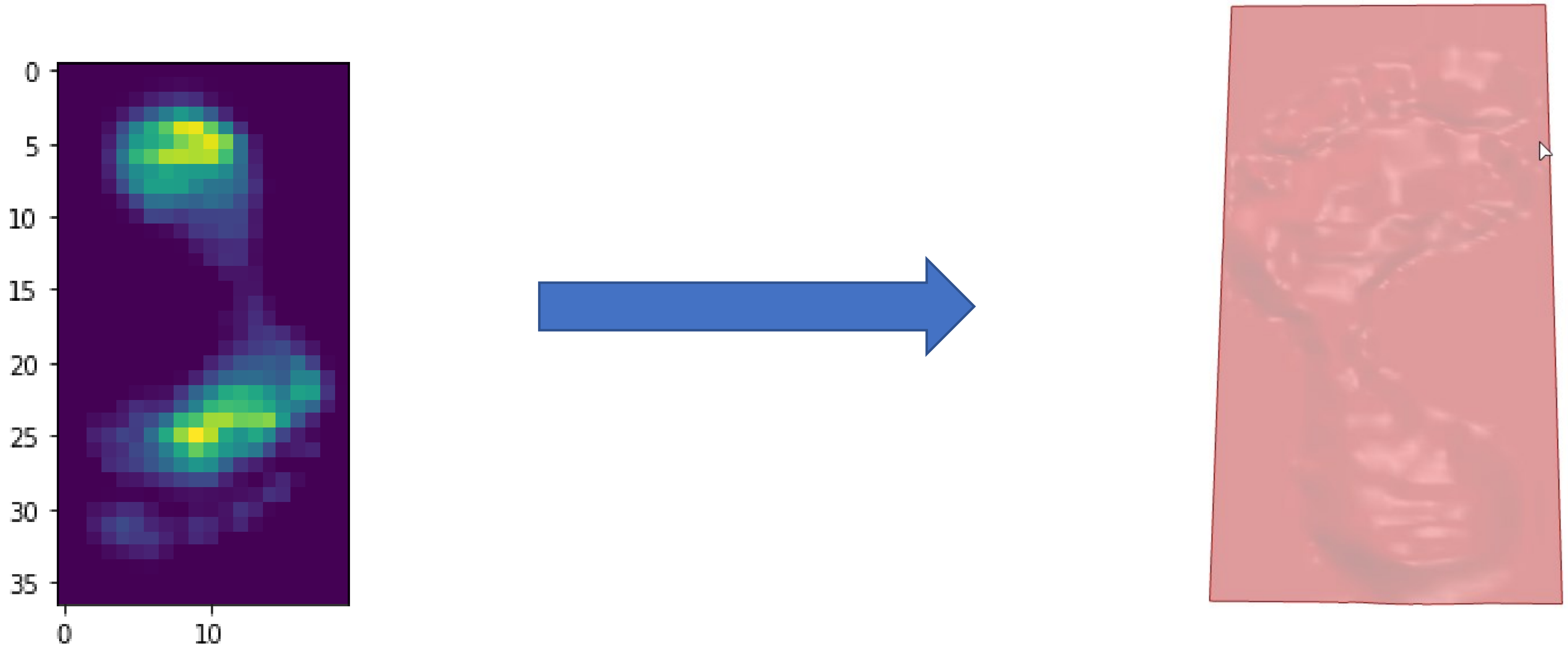
The cushion





Designing a shaped seat-pan cushion to improve postural (dis)comfort reducing pressure distribution and increasing contact area at the interface, Iolanda Fiorilloa, Yu Song, Peter Vink, Alessandro Naddeo

Example: Foot pressure



Data – CSV format (37 *20)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	26	65	129	176	130	50	0	0	0	0	0	0	0	0	0	
3	0	0	0	0	47	213	602	907	1117	961	333	82	8.3	0	0	0	0	0	0	0	
4	0	0	0	73	497	1231	2143	###	###	###	2124	784	59	0	0	0	0	0	0	0	
5	0	0	0	340	1636	3214	###	###	###	7100	###	###	975	0	0	0	0	0	0	0	
6	0	0	0	624	2212	###	###	###	###	###	###	###	###	439	0	0	0	0	0	0	
7	0	0	0	871	###	4721	###	###	6516	###	###	###	###	602	0	0	0	0	0	0	
8	0	0	0	683	###	3571	###	###	4105	###	###	###	###	758	0	0	0	0	0	0	
9	0	0	0	386	1663	###	4143	4139	###	3319	###	###	###	1007	76	0	0	0	0	0	
10	0	0	0	54	471	1507	2661	###	2514	###	###	###	1727	745	0	0	0	0	0	0	
11	0	0	0	0	81	405	1491	1450	1219	1482	1472	1497	1514	474	0	0	0	0	0	0	
12	0	0	0	0	0	0	84	186	519	1147	1247	1491	1417	499	0	0	0	0	0	0	
13	0	0	0	0	0	0	0	0	47	462	763	932	970	236	0	0	0	0	0	0	
14	0	0	0	0	0	0	0	0	0	95	676	999	948	214	0	0	0	0	0	0	
15	0	0	0	0	0	0	0	0	0	0	0	402	410	355	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	0	0	0	376	390	0	0	0	0	0	0	
17	0	0	0	0	0	0	0	0	0	0	0	0	401	796	208	0	0	0	0	0	
18	0	0	0	0	0	0	0	0	0	0	0	254	459	968	472	0	0	0	0	0	
19	0	0	0	0	0	0	0	0	0	0	0	170	486	1063	1184	910	366	0	0	0	
20	0	0	0	0	0	0	0	0	0	0	0	464	962	1308	1464	1652	1010	423	0	0	
21	0	0	0	0	0	0	0	0	0	0	694	1261	1883	2018	2165	1961	###	1380	103	0	
22	0	0	0	0	0	0	0	0	101	673	1584	2351	###	###	###	2171	3271	###	808	0	
23	0	0	0	0	0	121	204	275	1119	###	###	###	###	###	###	###	4184	###	1096	29	
24	0	0	0	0	404	928	776	941	2021	3231	###	###	###	###	###	3471	###	###	552	0	
25	0	0	242	398	587	1373	1666	###	###	5217	###	###	5715	###	###	###	1944	742	0	0	
26	0	0	656	973	1477	1336	2615	###	6157	7321	###	4416	###	###	###	1497	599	153	6.7	0	
27	0	0	355	776	981	1585	###	3129	###	###	4781	###	3451	###	1595	448	583	730	0	0	
28	0	0	0	877	1097	1398	1903	###	###	###	###	###	1112	654	212	0	0	0	0	0	
29	0	0	0	0	389	433	767	1105	1433	1644	1657	729	231	45	357	770	213	0	0	0	
30	0	0	0	37	61	64	4.1	163	267	337	282	230	297	396	1006	846	0	0	0	0	
31	0	0	315	541	888	871	357	41	13	266	248	389	1030	704	98	0	0	0	0	0	
32	0	26	548	1250	1646	1363	768	527	427	944	787	354	757	192	0	0	0	0	0	0	
33	0	0	280	879	1393	1211	1224	717	344	849	610	0	0	0	0	0	0	0	0	0	
34	0	0	0	200	396	608	730	296	0	0	0	0	0	0	0	0	0	0	0	0	
35	0	0	0	0	0	38	59	0	0	0	0	0	0	0	0	0	0	0	0	0	
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
38																					

Comma separated values with a return

```
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0¶
0,0,0,0,0,26.3501,65.3585,129.167,176.184,129.942,49.6001,0,0,0,0,0,0,0,0,0¶
0,0,0,0,46.5001,213.384,601.918,907.01,1116.52,961.002,332.992,82.4085,8.26668,0,0,0,0,0,0,0¶
0,0,0,72.5918,496.518,1231.22,2142.88,3084.76,3891.54,3327.86,2124.02,784.302,59.4168,0,0,0,0,0,0,0¶
0,0,0,340.226,1636.29,3213.93,4488.55,5475.9,6943.76,7099.79,5588.54,3300.21,975.21,0,0,0,0,0,0,0¶
0,0,0,624.393,2212.37,3922.02,4399.68,4847.63,5838.09,6425.54,6997.75,5897.5,2658.51,438.909,0,0,0,0,0,0¶
0,0,0,870.585,2835.73,4720.53,5396.59,6424.76,6516.21,6408.23,6502.52,5072.9,2651.8,601.66,0,0,0,0,0,0¶
0,0,0,683.035,2355.75,3571.21,3935.2,4357.06,4104.92,4007.02,3992.81,3478.47,2486.2,757.952,0,0,0,0,0,0¶
0,0,0,386.467,1662.89,3204.89,4142.9,4139.28,4094.07,3318.56,2828.76,2749.96,2347.48,1006.73,76.4668,0,0,0,0,0¶
0,0,0,53.9918,470.943,1506.6,2661.36,2722.32,2513.59,2337.66,2579.72,2383.39,1726.7,745.293,0,0,0,0,0,0¶
0,0,0,0,80.6002,405.067,1491.36,1449.51,1218.56,1481.8,1472.24,1497.04,1514.09,473.784,0,0,0,0,0,0¶
0,0,0,0,0,0,83.9585,186,519.251,1146.74,1246.98,1490.84,1416.96,499.101,0,0,0,0,0,0¶
0,0,0,0,0,0,0,0,47.2751,462.418,762.602,932.327,969.527,236.117,0,0,0,0,0,0¶
0,0,0,0,0,0,0,0,0,94.8085,675.543,998.719,948.344,214.417,0,0,0,0,0,0¶
0,0,0,0,0,0,0,0,0,0,0,401.967,409.717,354.692,0,0,0,0,0,0¶
0,0,0,0,0,0,0,0,0,0,0,0,376.392,389.567,0,0,0,0,0,0¶
0,0,0,0,0,0,0,0,0,0,0,0,401.192,796.185,208.217,0,0,0,0,0¶
0,0,0,0,0,0,0,0,0,0,0,253.942,458.543,968.235,471.976,0,0,0,0,0¶
0,0,0,0,0,0,0,0,0,0,0,170.242,485.668,1062.79,1183.94,909.852,366.059,0,0,0¶
```

Python parse the data

```python
    for x in f1:
        print (x)
        #remove "\n" i.e. return in the graph
        temp = x.rstrip()
        print (temp)
        #split text by comma ","
        line_value = temp.split(',')
        print(line_value)
        #append this line to the list
        text.append(line_value)
```

An extra “return” here

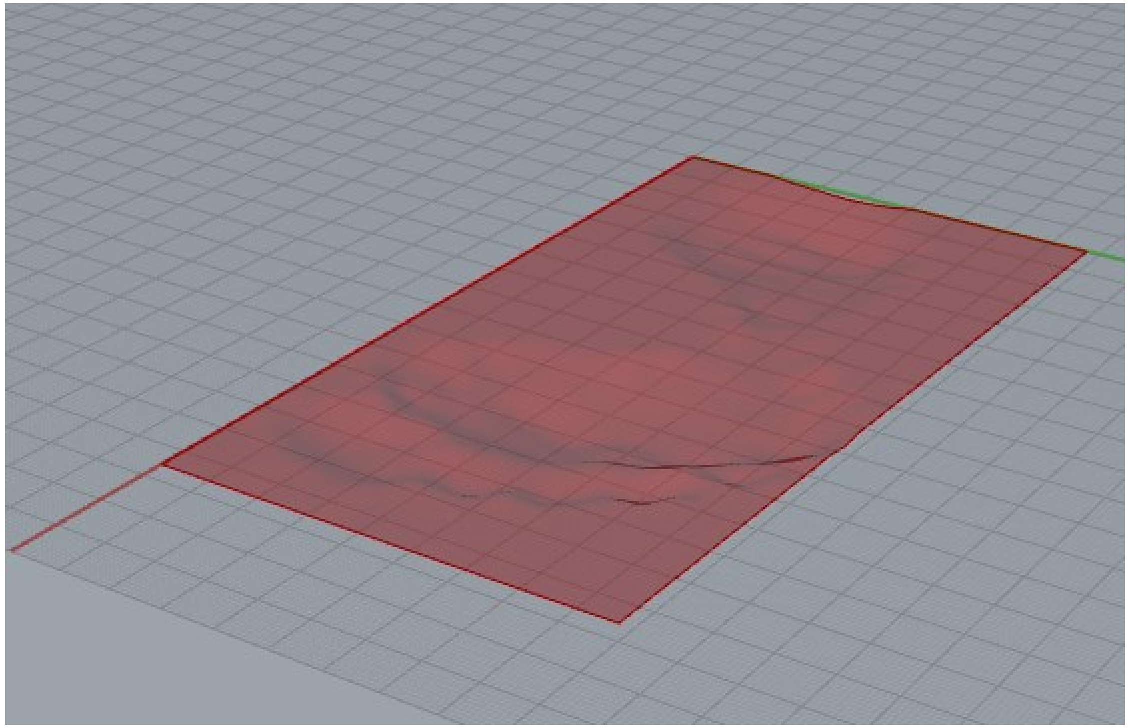
```
0,0,0,72.5918,496.518,1231.22,2142.88,3084.76,3891.54,3327.86,2124.02,784.302,59.4168,0,0,0,0,0,0,0

0,0,0,72.5918,496.518,1231.22,2142.88,3084.76,3891.54,3327.86,2124.02,784.302,59.4168,0,0,0,0,0,0,0
['0', '0', '0', '72.5918', '496.518', '1231.22', '2142.88', '3084.76', '3891.54', '3327.86', '2124.02', '784.302', '59.4168', '0', '0', '0', '0', '0', '0', '0']
```

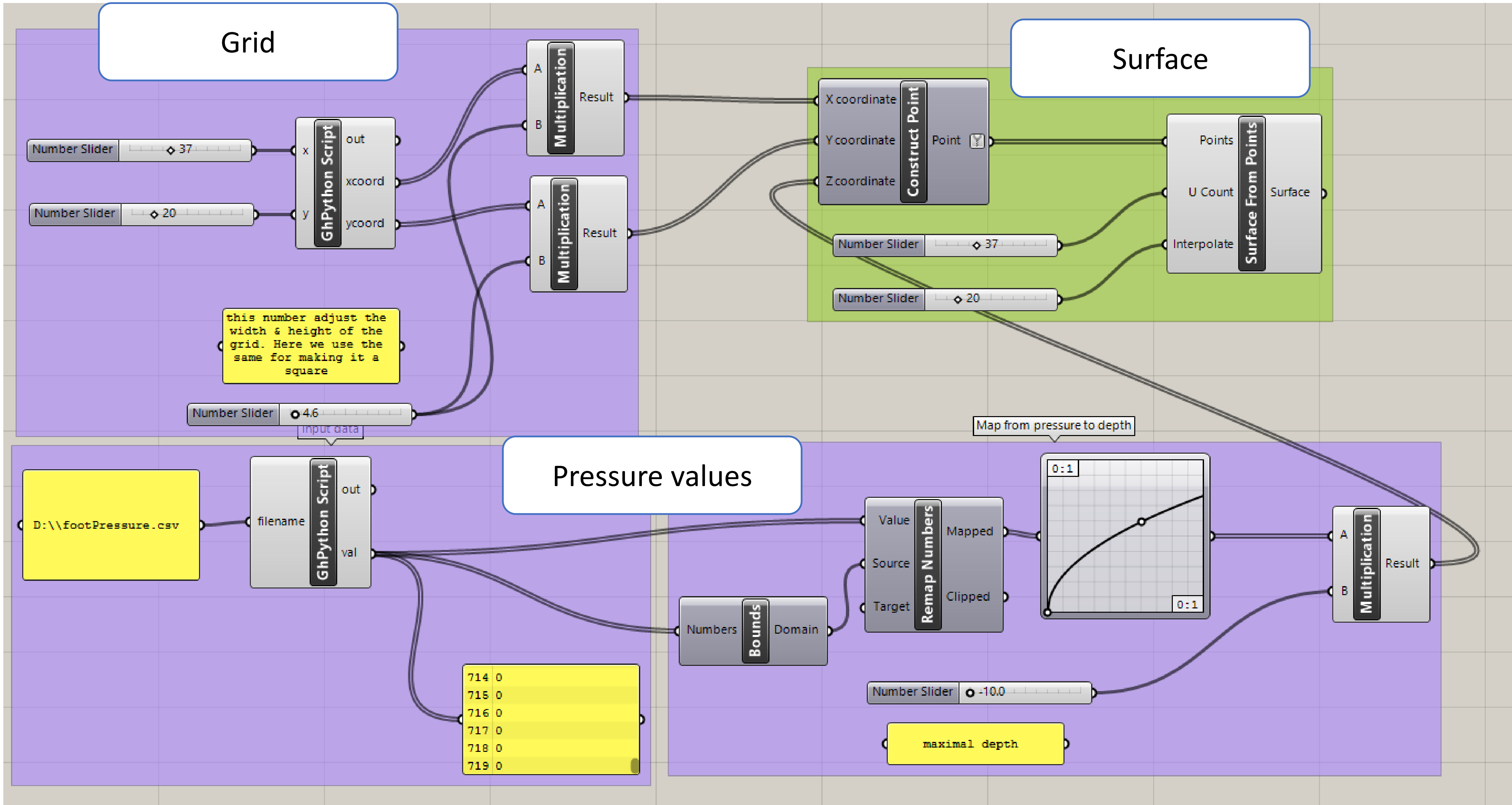
The idea of construction

- 37 * 20 (740) pressure measurement
- Create 37 * 20 (740) -- X coordinates
- Create 37 * 20 (740) -- Y coordinates
- Use X and Y as a grid (* a coefficient A)
- Use Z as depth (* a coefficient B)

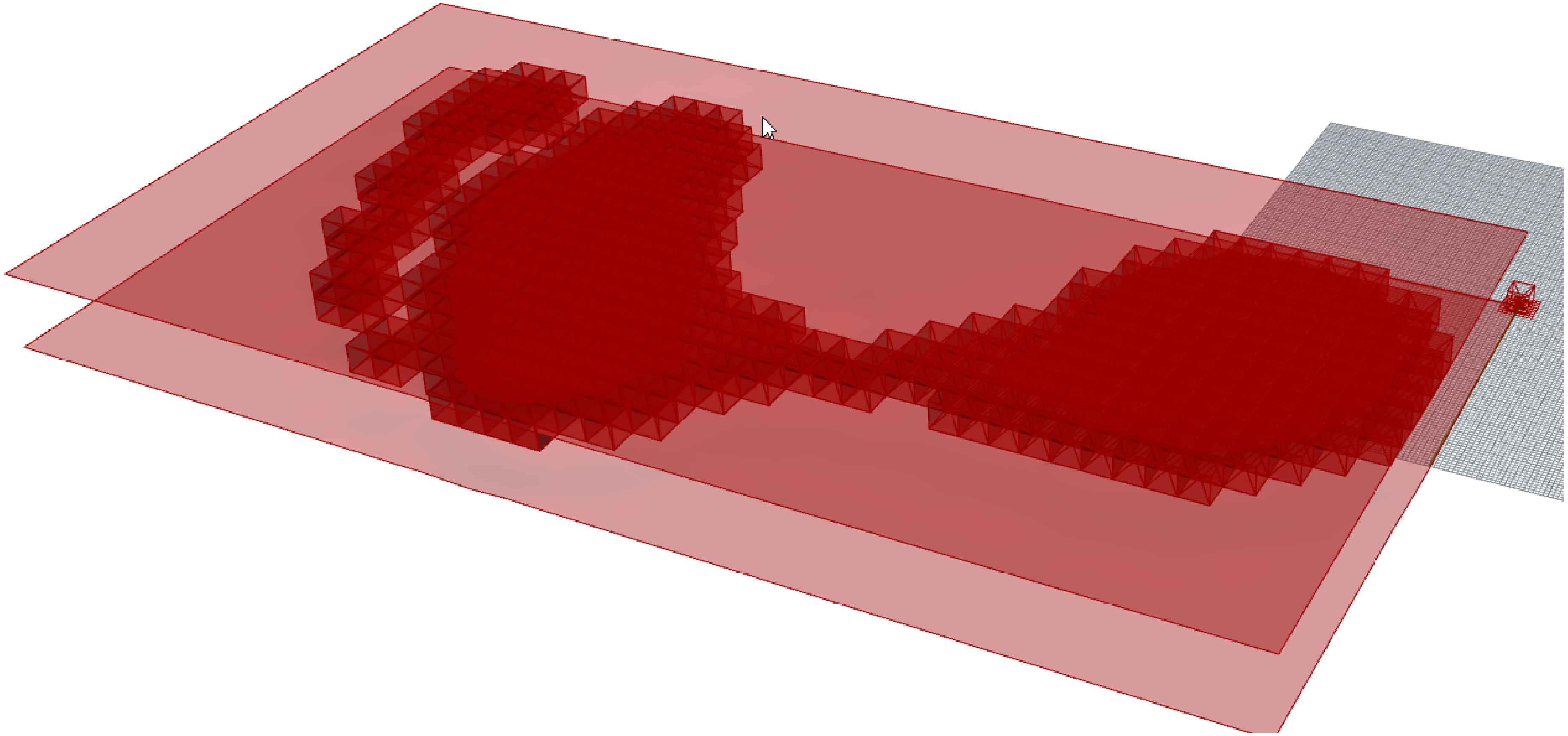
08.01.Data_driven_foot.gh



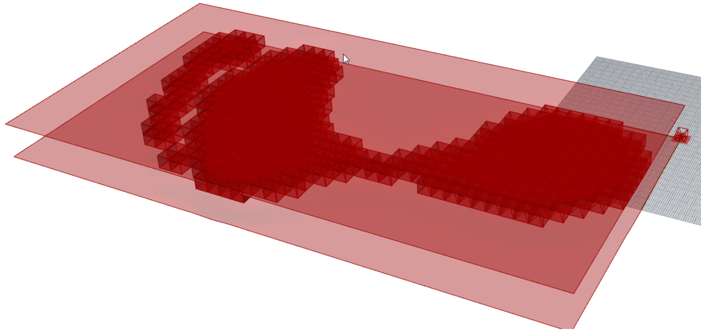
Construction



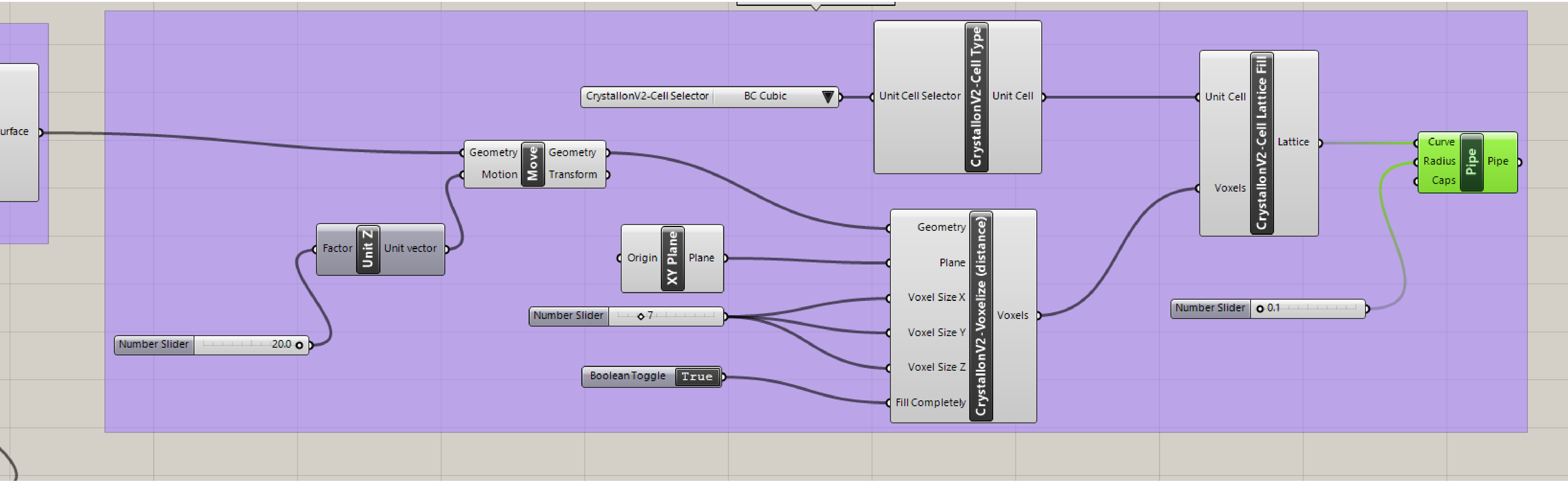
Workshop: Can you add the lattice between this surface and a flat plane?



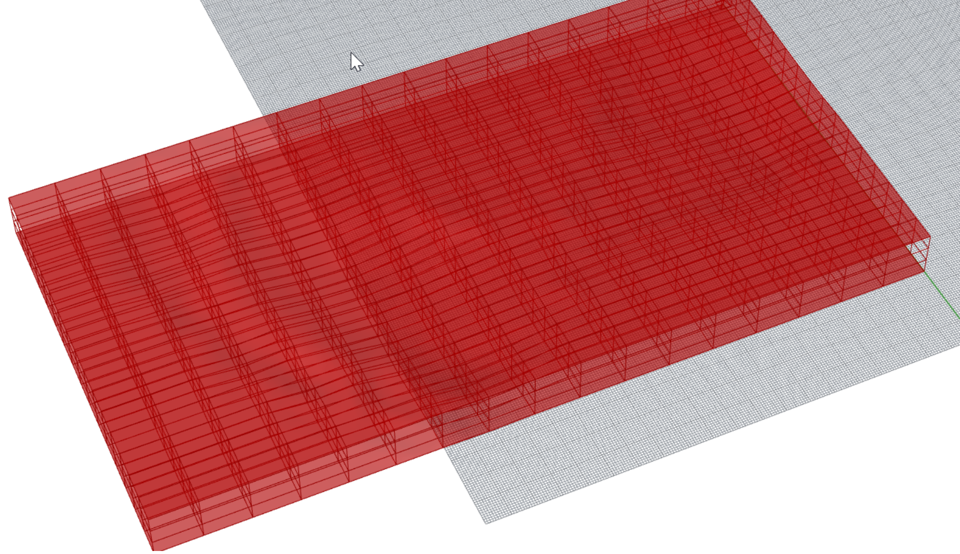
Add lattice - method 1



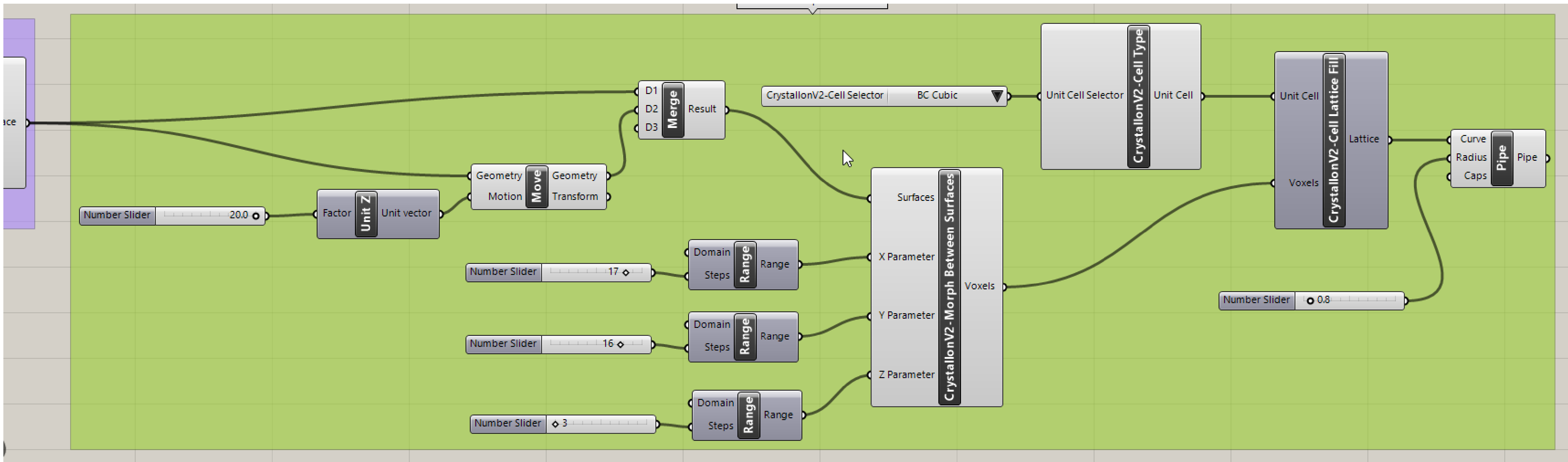
08.02.Data_driven_foot_lattice_method_1.gh



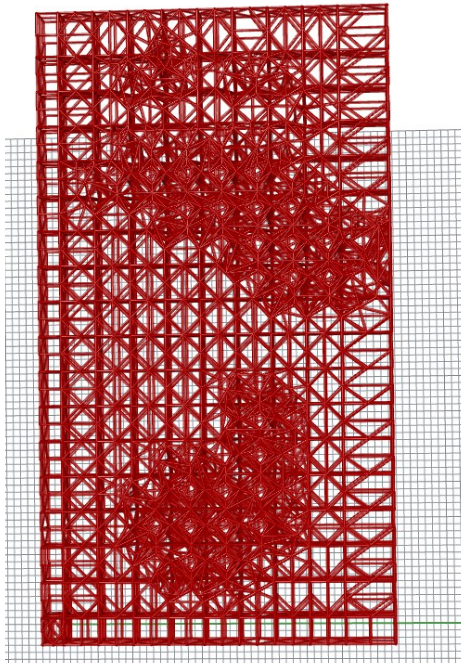
Add lattice - method 2



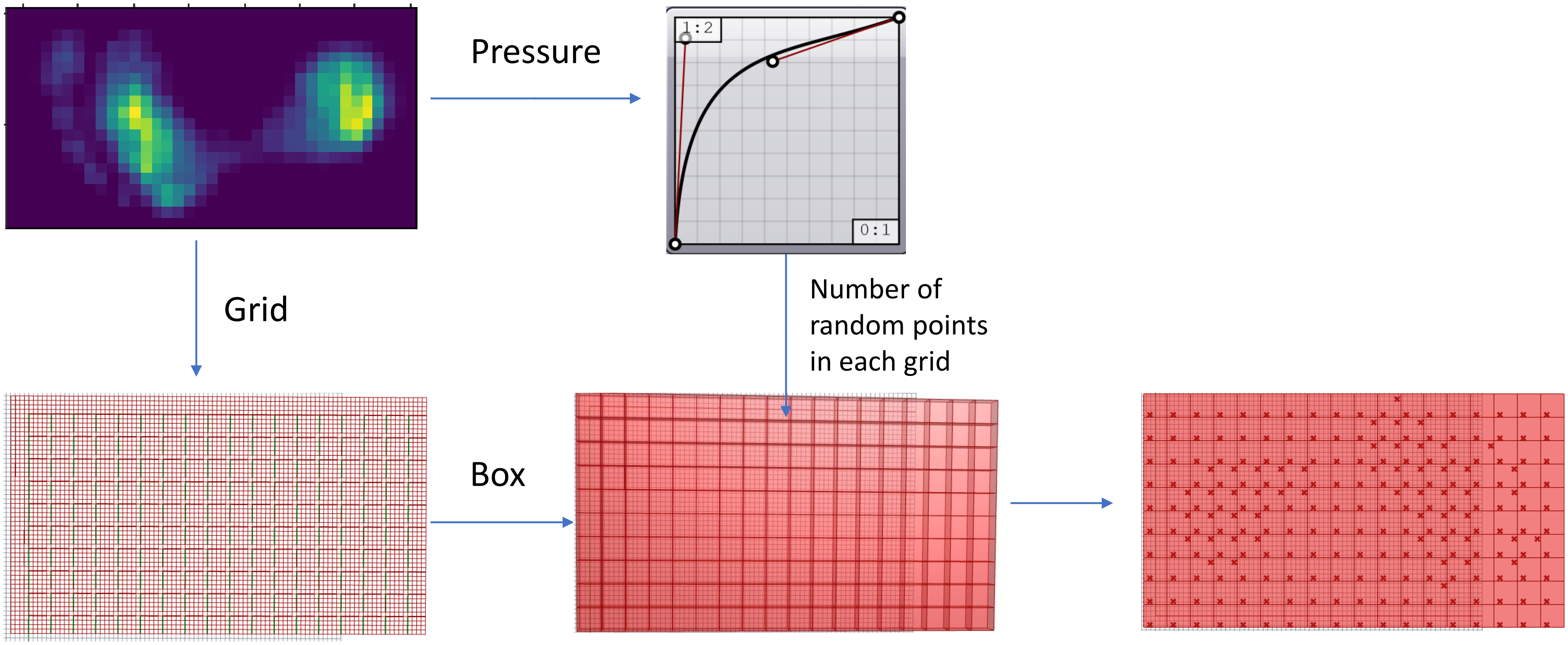
08.02.Data_driven_foot_lattice_method_2.gh



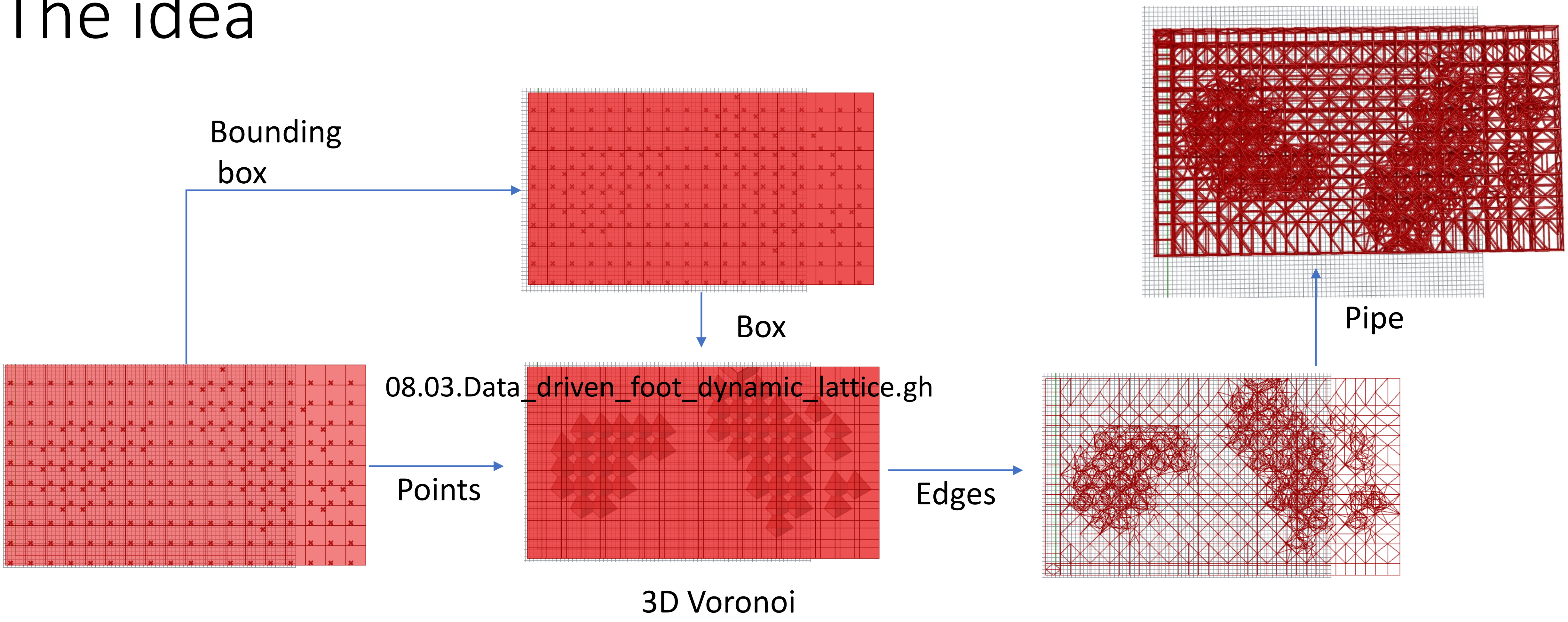
Using data to control 3D lattice



The idea



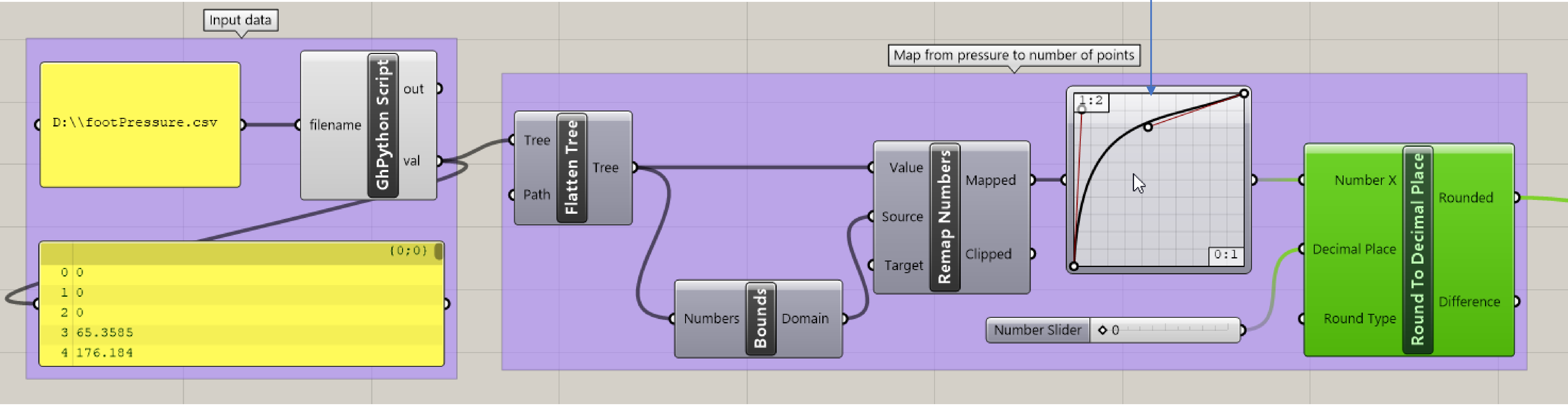
The idea


Bounding box
Box
08.03.Data_driven_foot_dynamic_lattice.gh
Points
3D Voronoi
Edges
Pipe

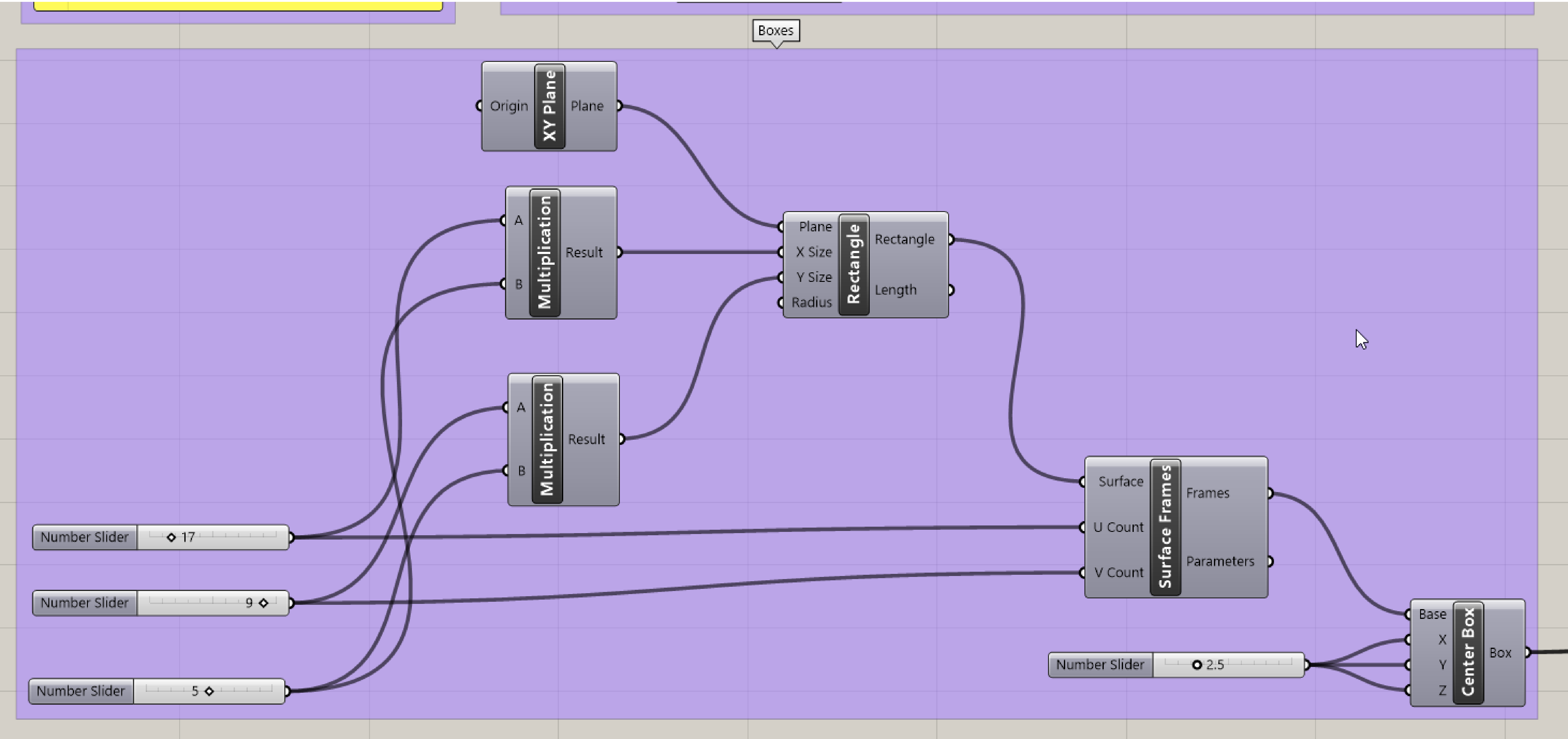
Change pressure value to “numbers of points”

Mapping

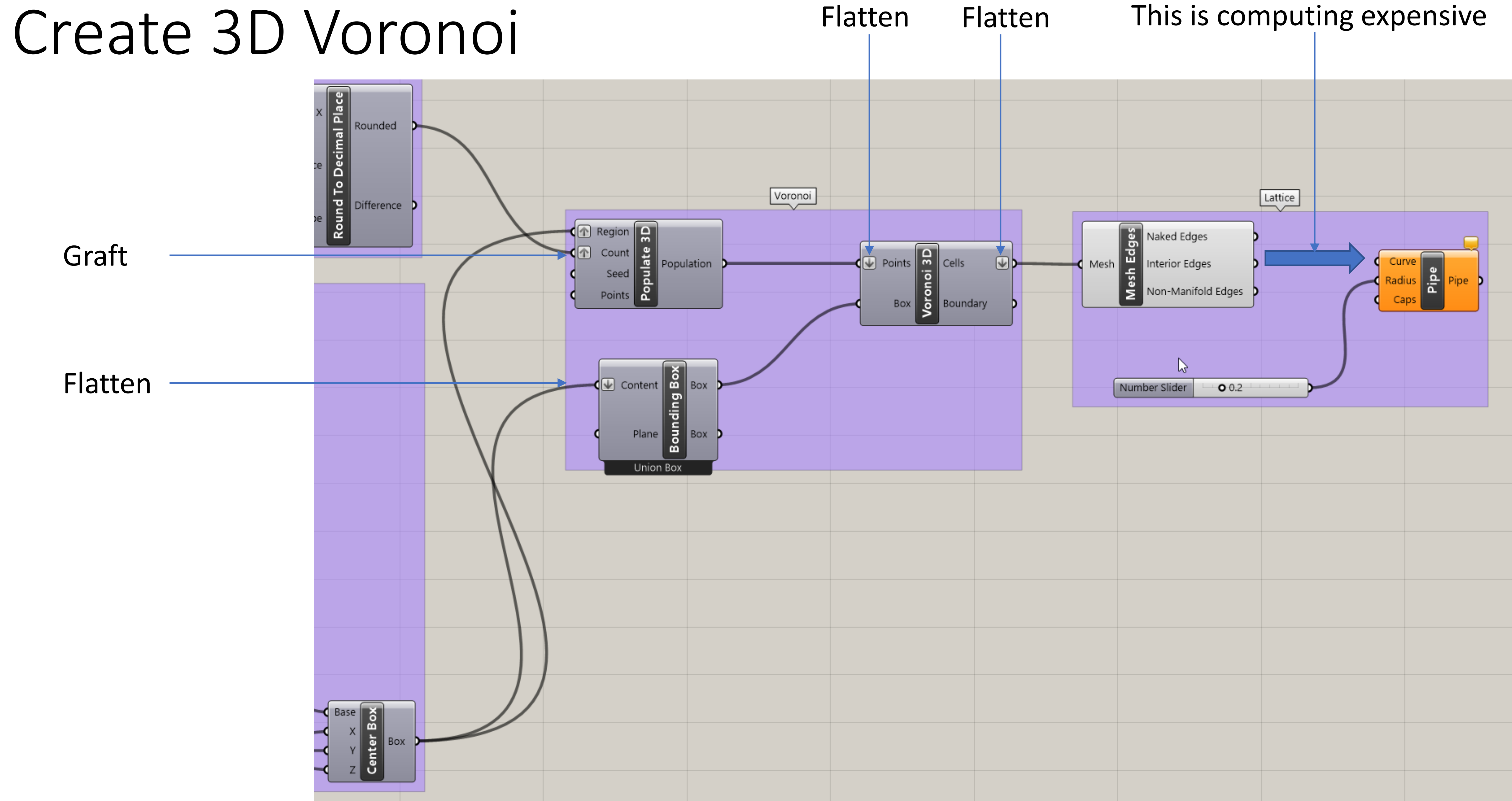
08.03.Data_driven_foot_dynamic_lattice.gh



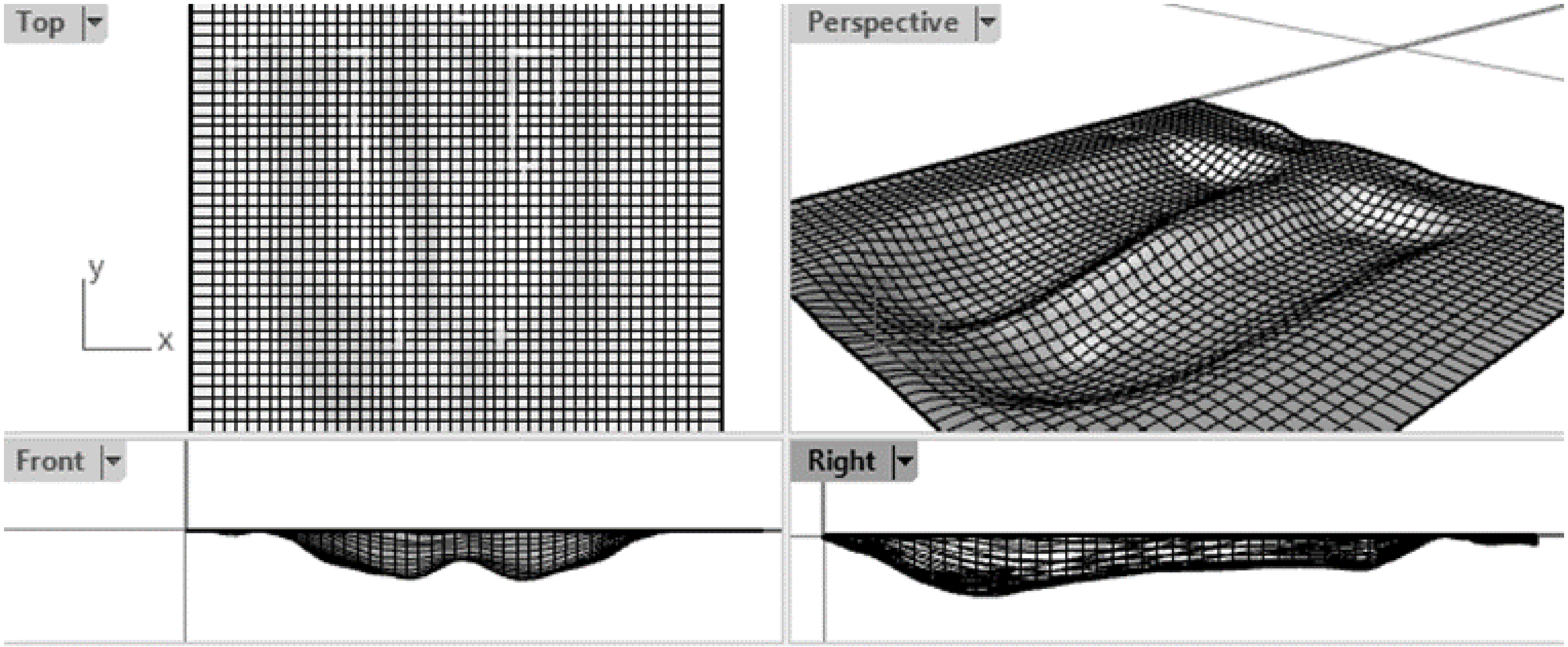
Create 18 * 10 grid (size 5)



Create 3D Voronoi



Can you do it with a 48 by 48 cushion?



Thanks