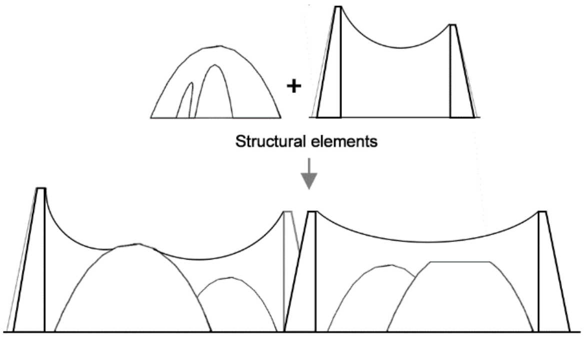
Form finding procedure has been divided into two parts

- **the compression only structures – domes**
- **the tent roof supported on anchor walls**



Pseudocode for form finding – Domes (Kangaroo 1)

Sketch the vision for the form and identify the elements of the form. In our case:

- domes
- arches which connect these domes
- doors and windows

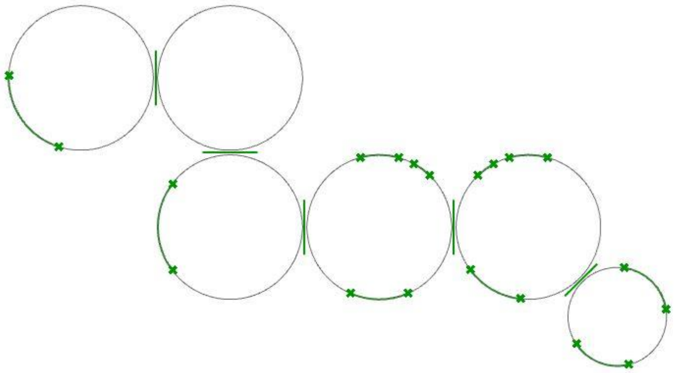
Identify the form finding procedure – dynamic relaxation using particle spring method.

Identify the software and its workability – Kangaroo 1 and weaverbird plugin for grasshopper

Identify the input, i.e. location of domes, connecting arches and sizes of openings for doors and windows.

Defining the characteristic of input (derived from the architectural plan)

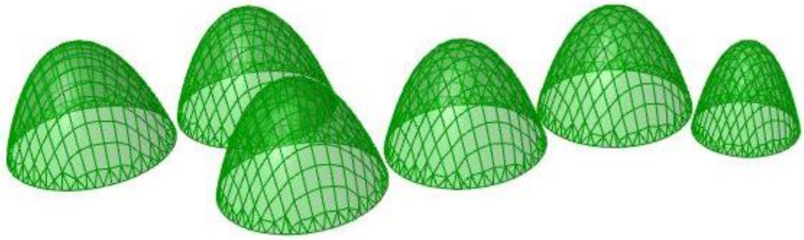
- Domes – center line of circles (curves)
- Arches- center line of the arch (line)
- Doors and windows- part of the circle that forms the doors and windows(arcs)



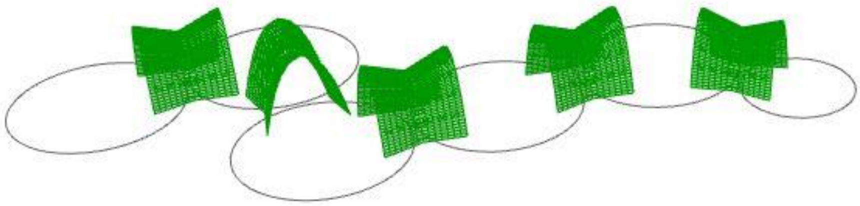
Dynamic relaxation for all the three parts are done separately to create the domes, connecting arches and openings

a) Domes:
   # create boundary surface from the circle
   # convert surface to mesh
   # deconstruct the mesh

identify the anchor points (naked vertices)
Convert the vertices into particles for application of unary forces, input the direction and the strength of force on the particles
mesh edges of the mesh using weaverbird, these edges are input into spring with a stiffness value.
input the unary forces and springs into the kangaroo engine force objects.
input the anchor points and original mesh into geometry of kangaroo engine.
set the simulation reset button and a timer
simulate to generate the domes

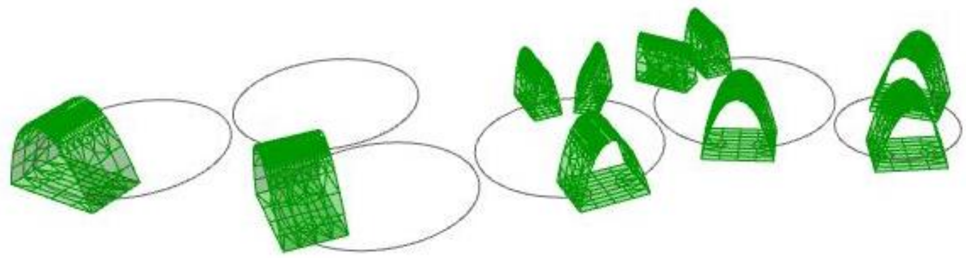


b) Arches:
#Divide the curve into 10 segments
shatter the segments
take the shattered segments as input for springs in kangaroo
identify the end points of the curve as anchor points
apply unary forces on the points of the divided curve
assemble all into the kangaroo engine and simulate
the generated catenary is the center line of the arch
move the catenary by 1.5m on either side of the center line
scale the moved catenary by a factor of 1.2
loft the three catenaries to generate a brep
convert the brep to mesh and smoothen using weaverbird Laplacian smoothening



c) Openings- doors and windows:
the location of the doors and windows are identified in the plan
the different sizes are filtered on the basis of their length
the center point of the arch is identified based on the groups of sizes
standardization of the sizes of the openings based on these groups
draw circles with the half radius of opening sizes
draw lines using the intersecting points of circles and arcs
Use this new line for generating a catenary arch
#Divide the line into 10 segments
shatter the segments
take the shattered segments as input for springs in kangaroo
identify the end points of the line as anchor points

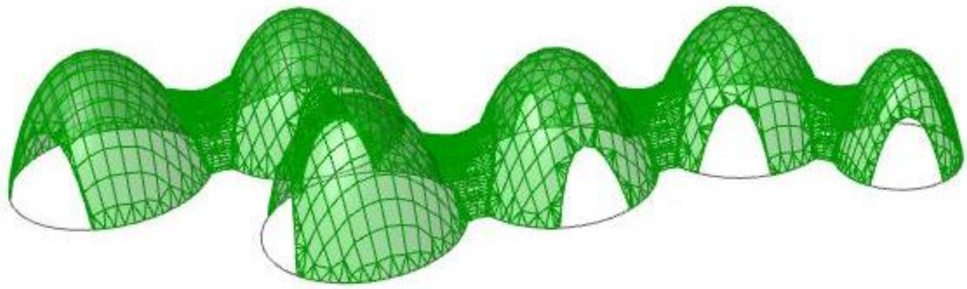
    # apply unary forces on the points of the divided line
    # assemble all into the kangaroo engine and simulate
    # the generated catenary is the opening shape
    # extrude this opening towards the outside of the centerline of the dome
    # trim the surface of the generated dome using this extrusion to create the openings



trim the surface of the domes using the lofted mesh for the doors and windows to create the opening

trim the arches using the domes and trim the domes using the arches

merge the arches with the domes to get the final form as output



Pseudocode for form finding – tent roof

Anchor walls

Draw a circle, its center representing the position of the anchor wall

Use the circles as curve input for the grasshopper script

    # Create diameter lines with the possibility for extension

    # Divide the lines by the structural required length of the wall

    # Dispatch the new start/end points in relation to the quantity of circles

    # Create axis line with the new points – Control length

    # Offset curve (axis line) two times by half of the required width, one negative and one positive

    # Split the new curves with original circle

    # Extract both intersection points

    # Shatter circle with intersection points

Connect curves: shattered circle, split offset curves

Create missing end curve, by extracting endpoints – Bottom Wall Layout Finished

Join, close and fillet curves by desire

Copy bottom layout to desired height – Top Wall Layout

Filter and dispatch desired endpoint as scale origin

Scale top layout by desired factor

Divide layout curve by desired number of anchor points

Loft top and bottom layout to generate anchor wall

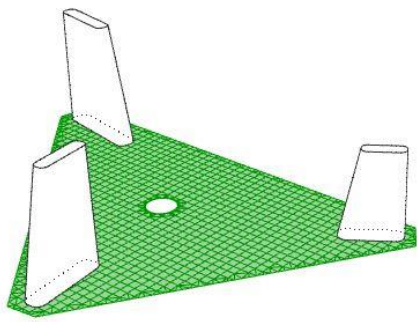
Create different sized sets of anchor walls by copying and adjusting the script.

Script can be connected by the output loft with the script for layering bricks on continuous curves, as well as with the tent roof simulation script, where the loft is used as collision object. The script can also be connected by the anchor points with the tent roof simulation.

 # Tent roof simulation (Kangaroo 2)

Draw the boundary of tent in Rhino as per the location of anchor walls and the curves for the location of holes on the fabric.

reference these continuous curves into grasshopper as input for surface generation

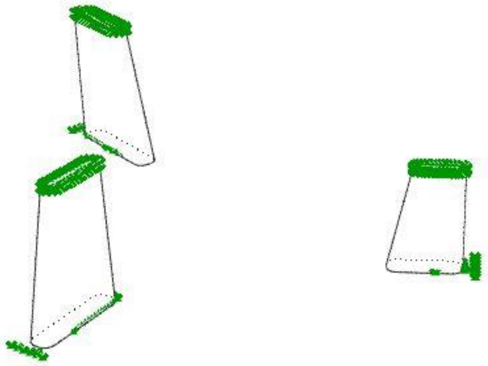


convert surface to mesh

deconstruct mesh

#create anchor points at multiple levels:

redraw the lines between minimum distance of vertices (of original curve input) to generate the anchor lines
divide this line into points as anchor points on the ground
top surface (convert to mesh) of the anchor wall is projected on the surface of the tent
#convert the projected mesh into points and find the closest points on the tent mesh from the projected mesh
#set these closest points as anchor points and original points on the surface (vertices of deconstructed brep) as the target points.
#attach the two sets of anchor points into the goal objects of kangaroo physics



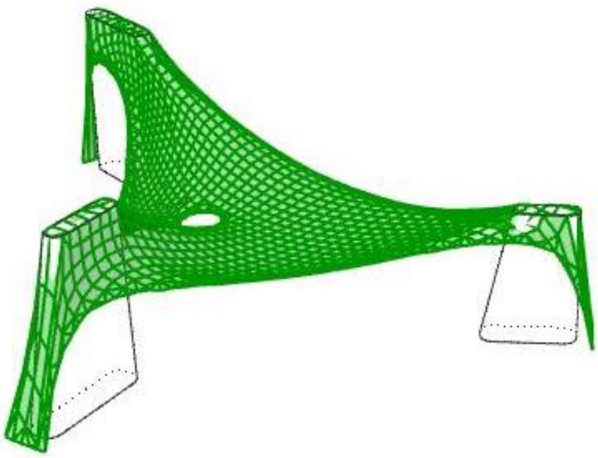
Convert the vertices of deconstructed mesh into particles for vertex loads, input the strength of force on the particles

Convert the mesh into springs using the mesh length component, specify the strength and the length factor

#input the vertex loads and mesh lengths into the goal objects

set the simulation reset button

goal output the required tensile tent shade



The output of this basic forming is connected to karamba for FEA. Since the model is parametric, the opening sizes and the heights have been adjusted in the script for different groups to generate the optimal structural solution.