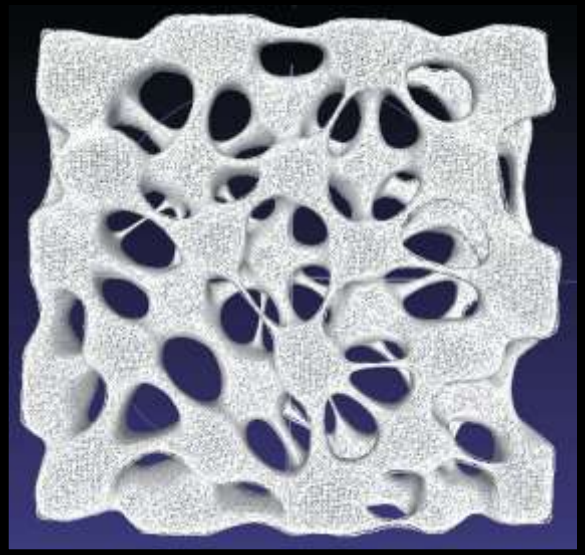
Eindhoven University of Technology [BICT]
Arno Pronk, Assistant Professor
Maurice Dominicus, PhD candidate

MODELING AND PRODUCING OPTIMAL OPEN CELL STRUCTURES FOR ARCHITECTURE

Optimal structures



Bone structure with script

Normal bone [Marching cubes algorithm][BMT]

Osteoporosis [Marching Cubes Algorithm][BMT]

Bone Algorithm

- Bone-algorithm

Point location

Voronoi algorithm

Scaling the Voronoi-cells with an uniform scale factor < 1

Explode the polyhedra to get surface information

Criteria loft surface

Criteria 1: SurfaceNormals surface anti-parallel.

criteria 2: Exact the same surfacearea.

criteria 3: Closest distance

Creating curves around surfaces. [borders]

Creating curves between the midpoints of surfacecentrodis.

Calculate the midpoint of the curves

Select all the curves and make a surface (rail method)

Joined all surfaces to get a continuous polysurface.

Deleted unused polysurfaces/lines/points

CT-Data to Mathematica and Meshlab

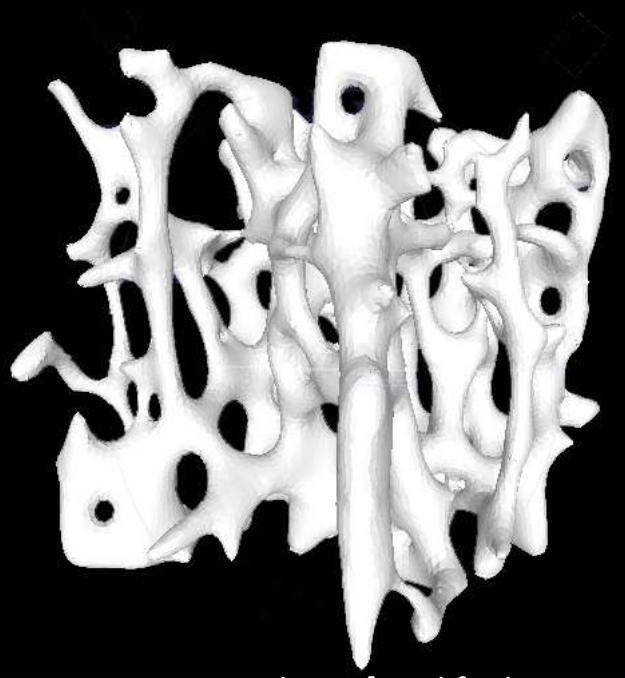
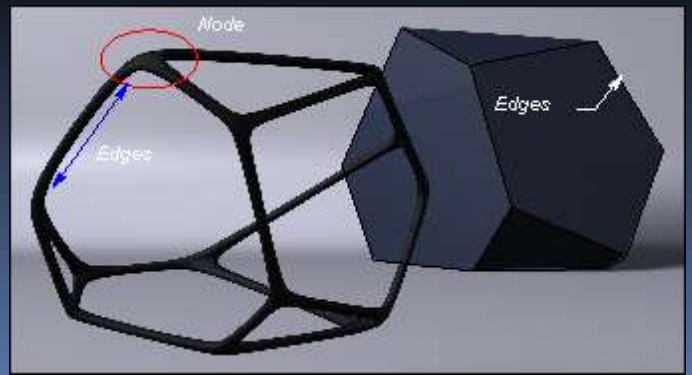


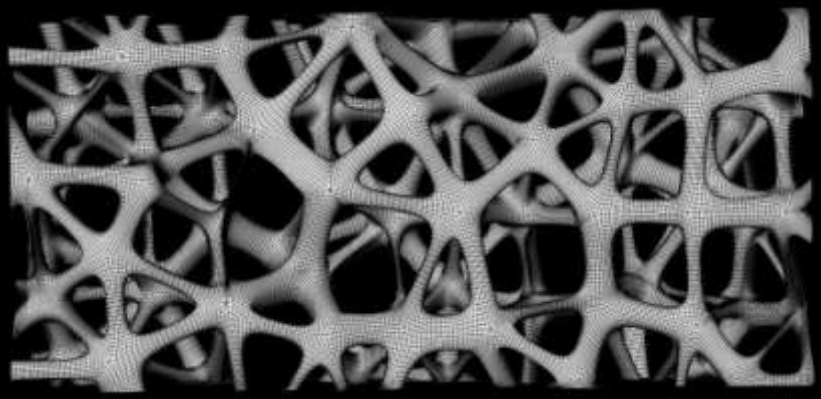
Image 1: Human bone [modified

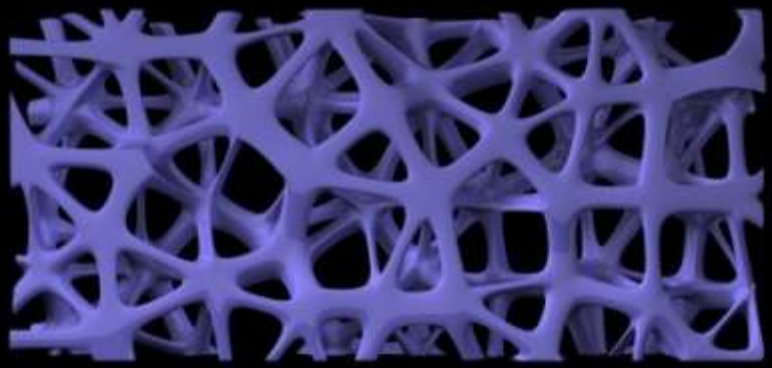
Image 2: Polyhedra with lattice modifier

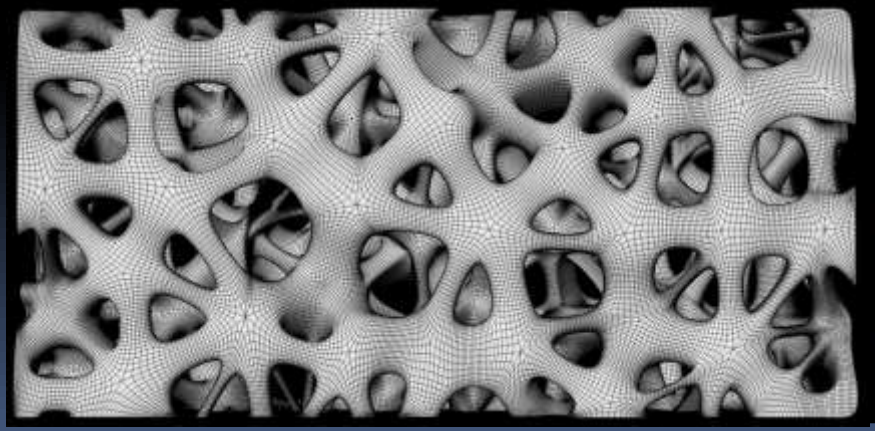


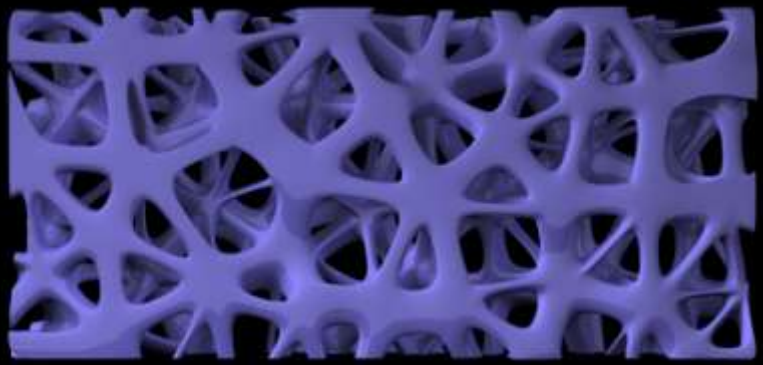
Bone algorithm

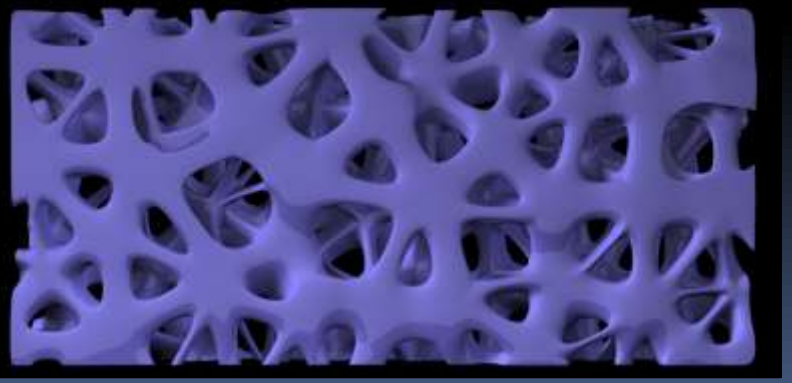
Bone algorithm. We can generate an open or closed structure.











Production process

Image 3: Production process of bone structure with membranes and concrete.

Production process

Image 4: Production process of bone structure with membranes and concrete.

Modeling optimal structures

- Modeling bone with:

- Shortest path algorithms [Dijkstra et al]
- Space filling algorithms
- Voronoi algorithm
- Delaunay Algorithm

- Research to evolution of bone

Molding optimal structures

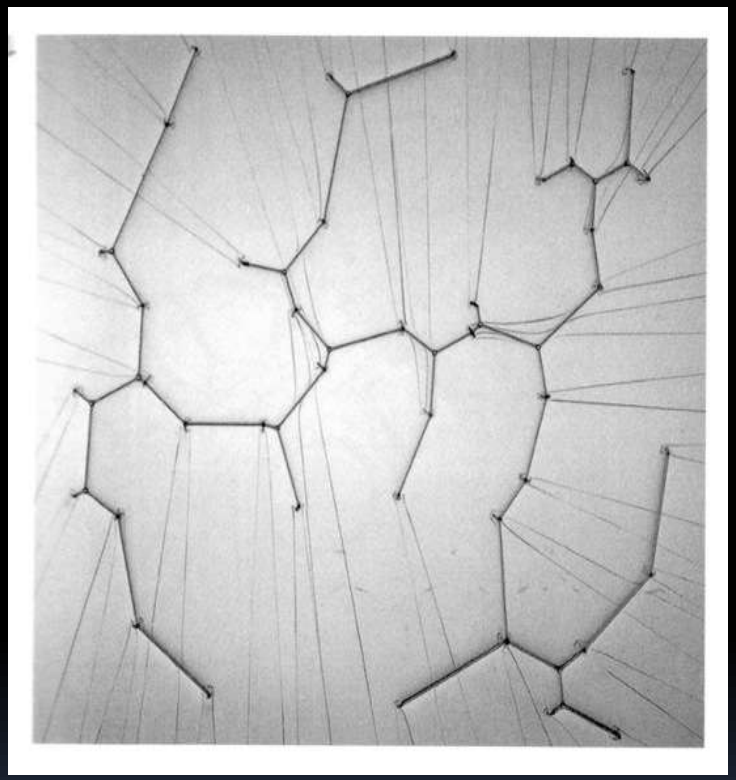


Image 5: Experiment by Frei Otto, Minimal path

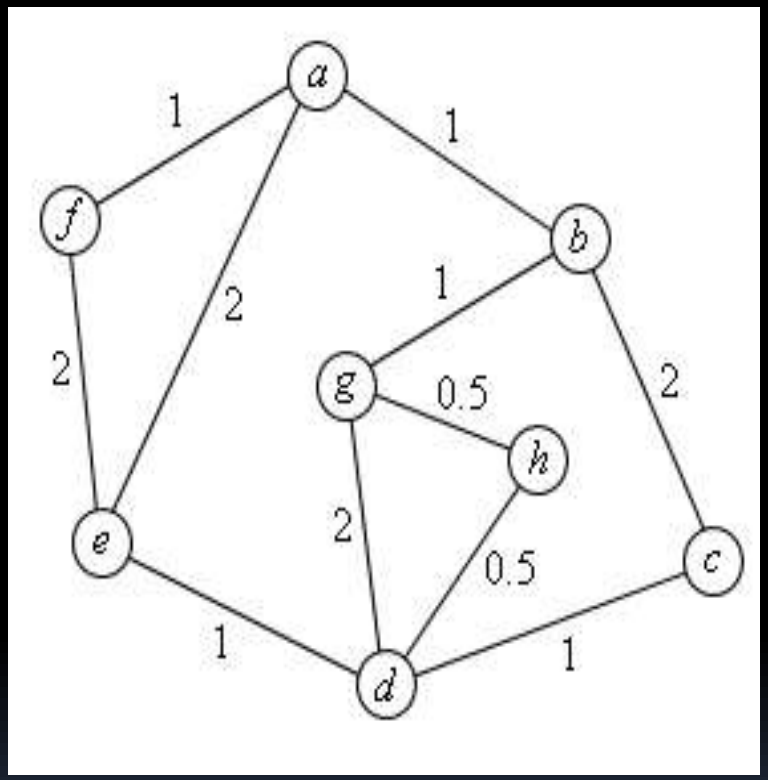
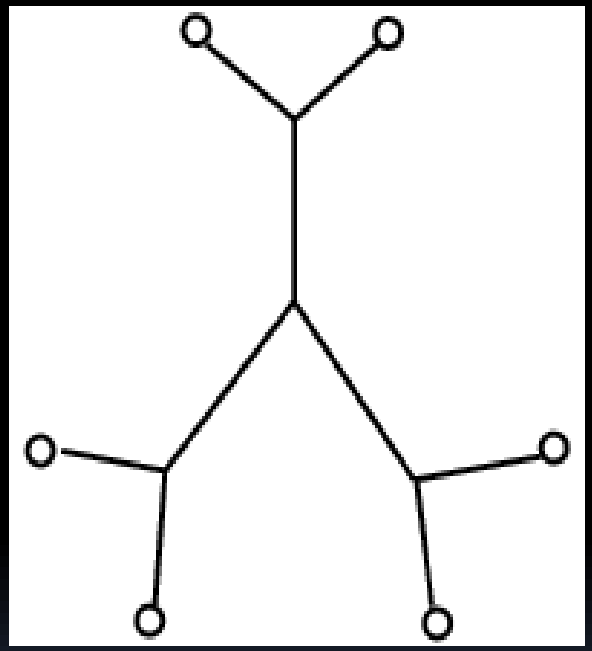


Image 6: Dijkstra's algorithm, Shortes path

Optimal structures



A graph G=(V,E), A subset of vertices T ∈ V

The steiner tree of a pair of vertices is simply the shortest path between them.

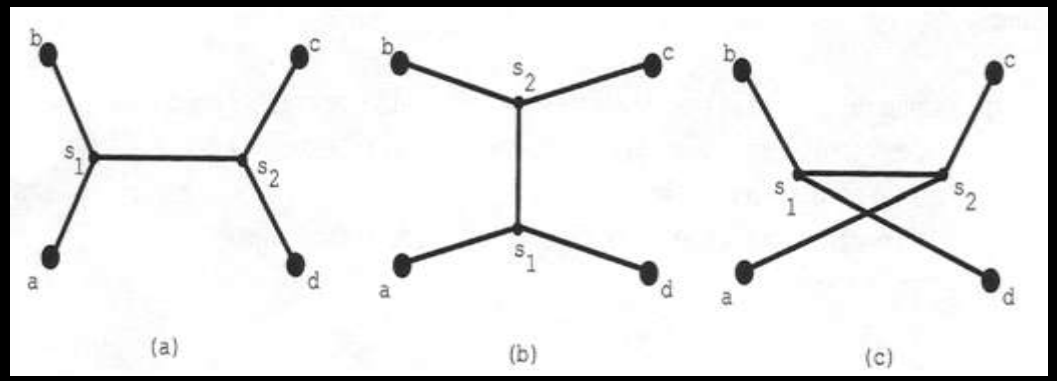


Image 6: Steiner tree [spanningstree]

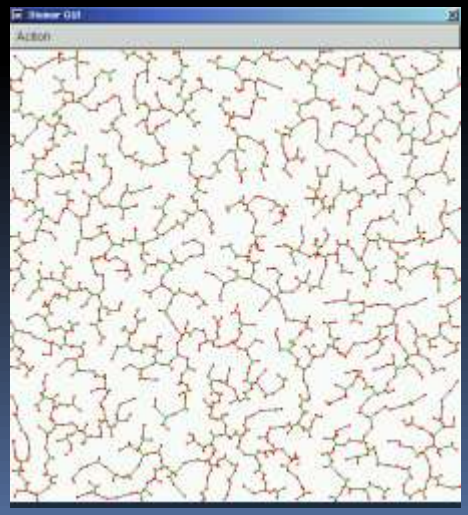
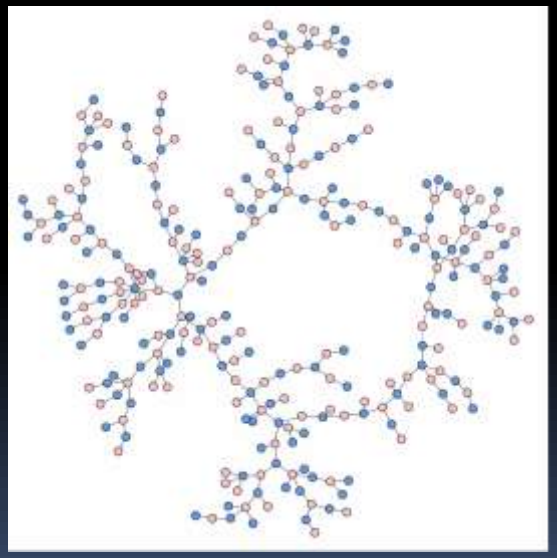


Image 7: Steiner tree, Wolfram

Shortest path algorithm

Steiner + dijkstra etc.

A spanning tree of a graph G=(V,E) is a subset of edges from E forming a tree connecting all vertices of V. For edge-weighted graphs, we are particulary interested in the minimum spanning tree – the spanning tree whose sum of edge weights is as small as possible.



Shortest path;
A path is a sequence of edges connecting two vertices.

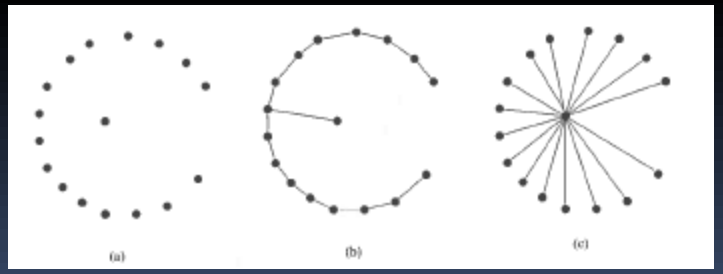
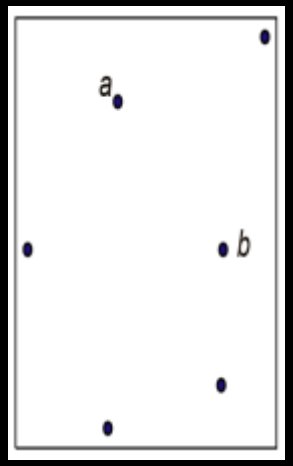
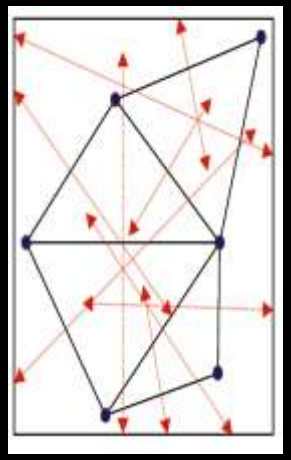
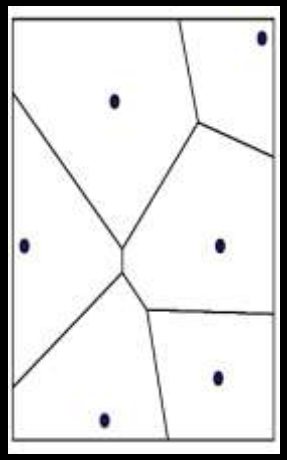


Image 6: Spanningstree

Optimal structures







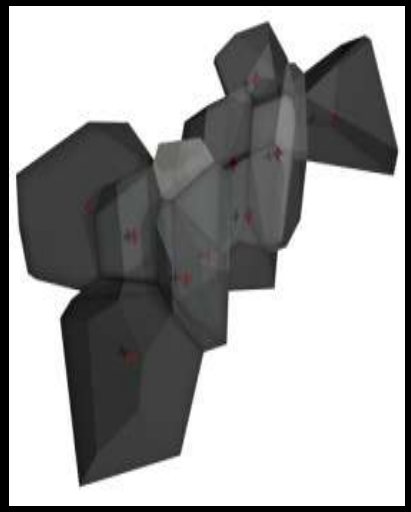
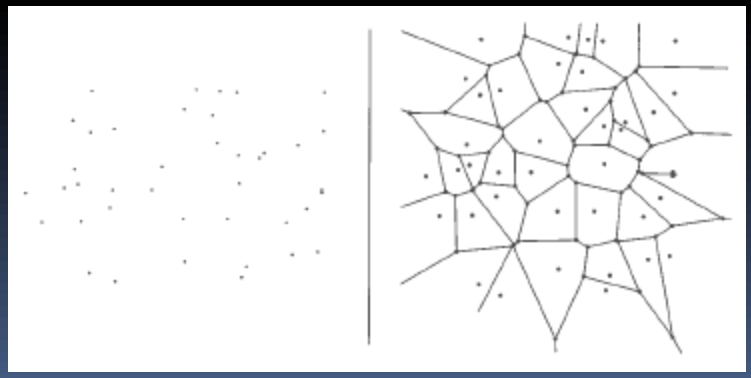


Image 7: Voronoi algorithm

Voronoi:
Decompose space into regions around each point such that all points in the region around p_i are closer to p_i than any other point in S

$O(n^{[d/2]})$



Optimal structures

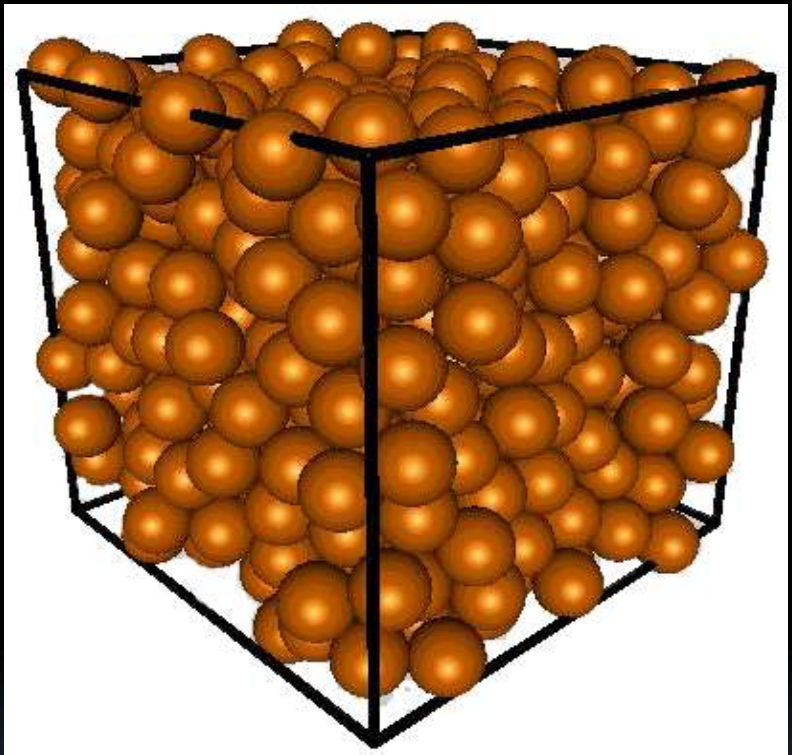


Image 8: Sphere packing

Image 9: Metal foam

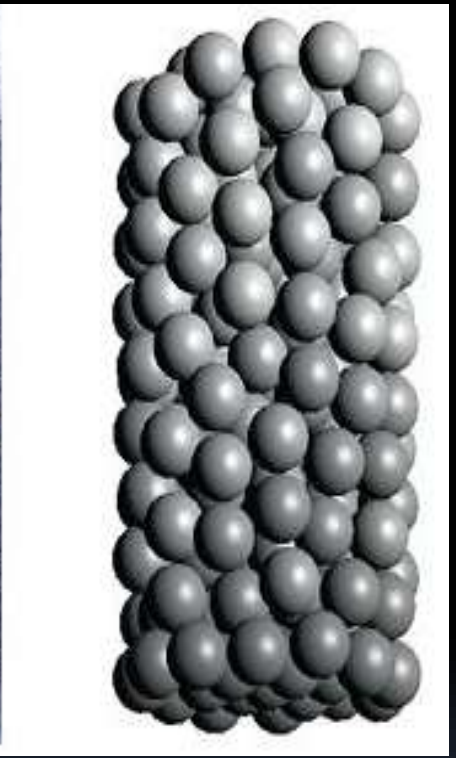
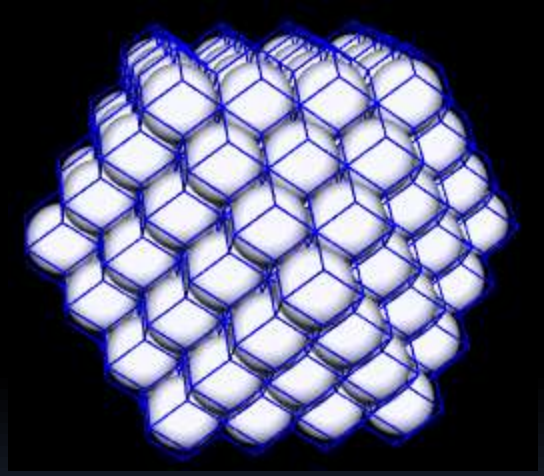


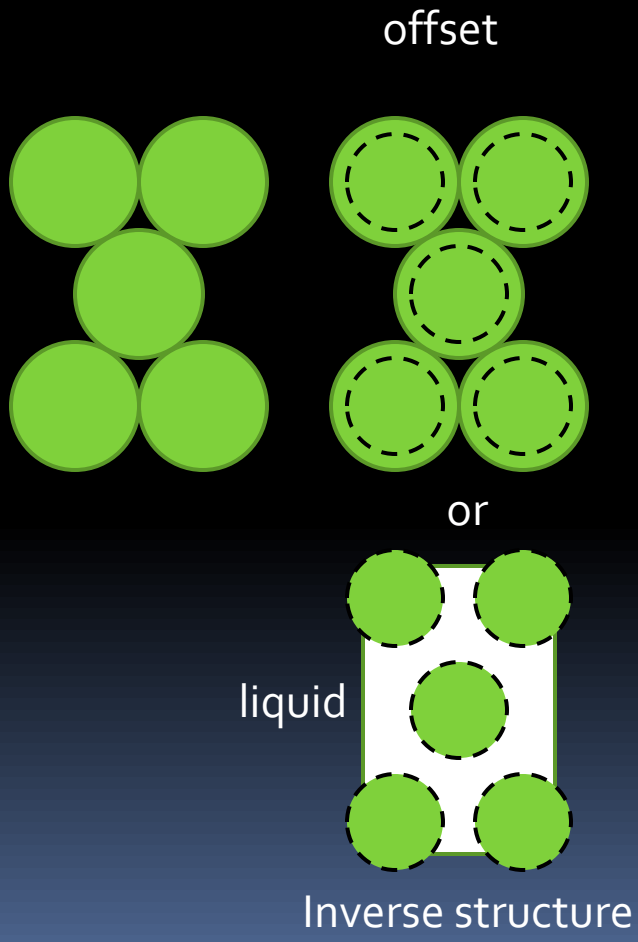
Image 10: Sphere packing

Spherepacking algorithm

Sphere packing can we used as packing a bounded domain with congruent spheres (instances). Random sphere radius is possible



Spherepacking in combination with fluids or offset we can create a polyhedral structure.



Optimal structures

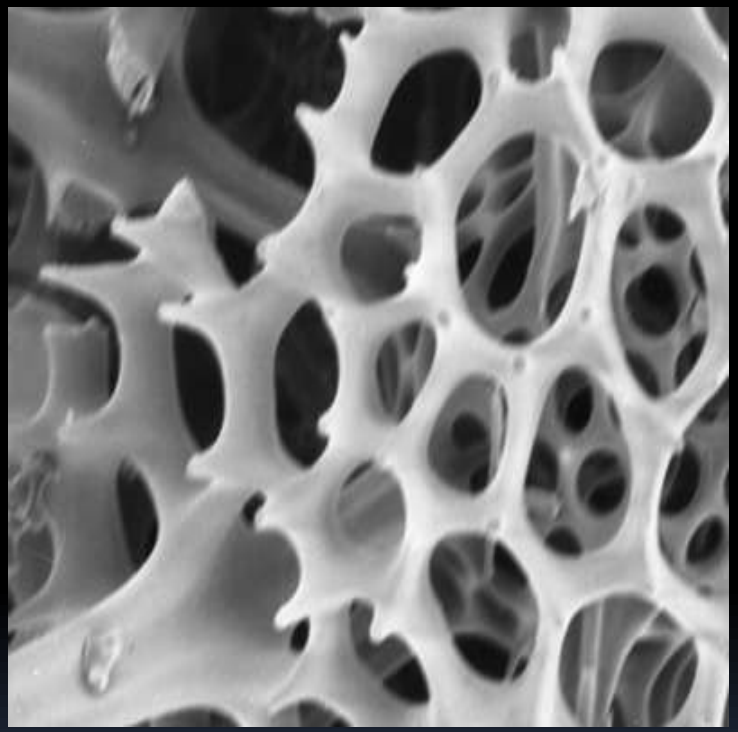


Image 11: Radiolaria, Optimal structure [micro]

Optimal structures

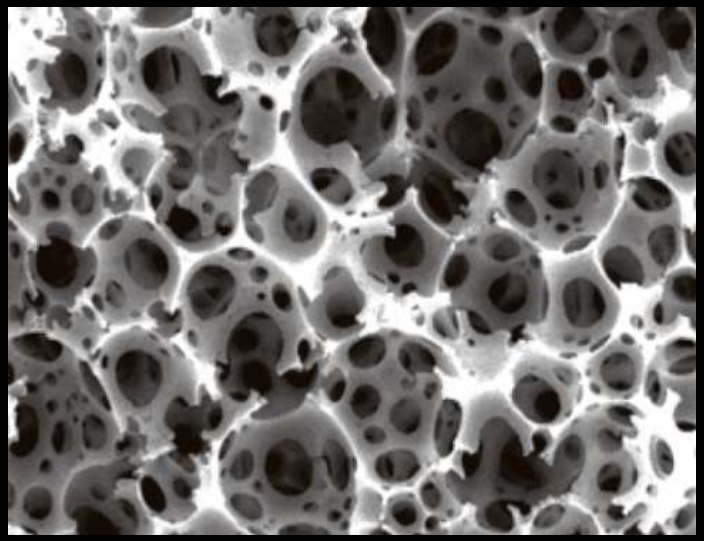


Image 12: Polymer foam

Image 12: Plateau border and Polymer foam

Optimal structures

Space filling algorithm

Shortest path algorithm

Circle packing algorithm

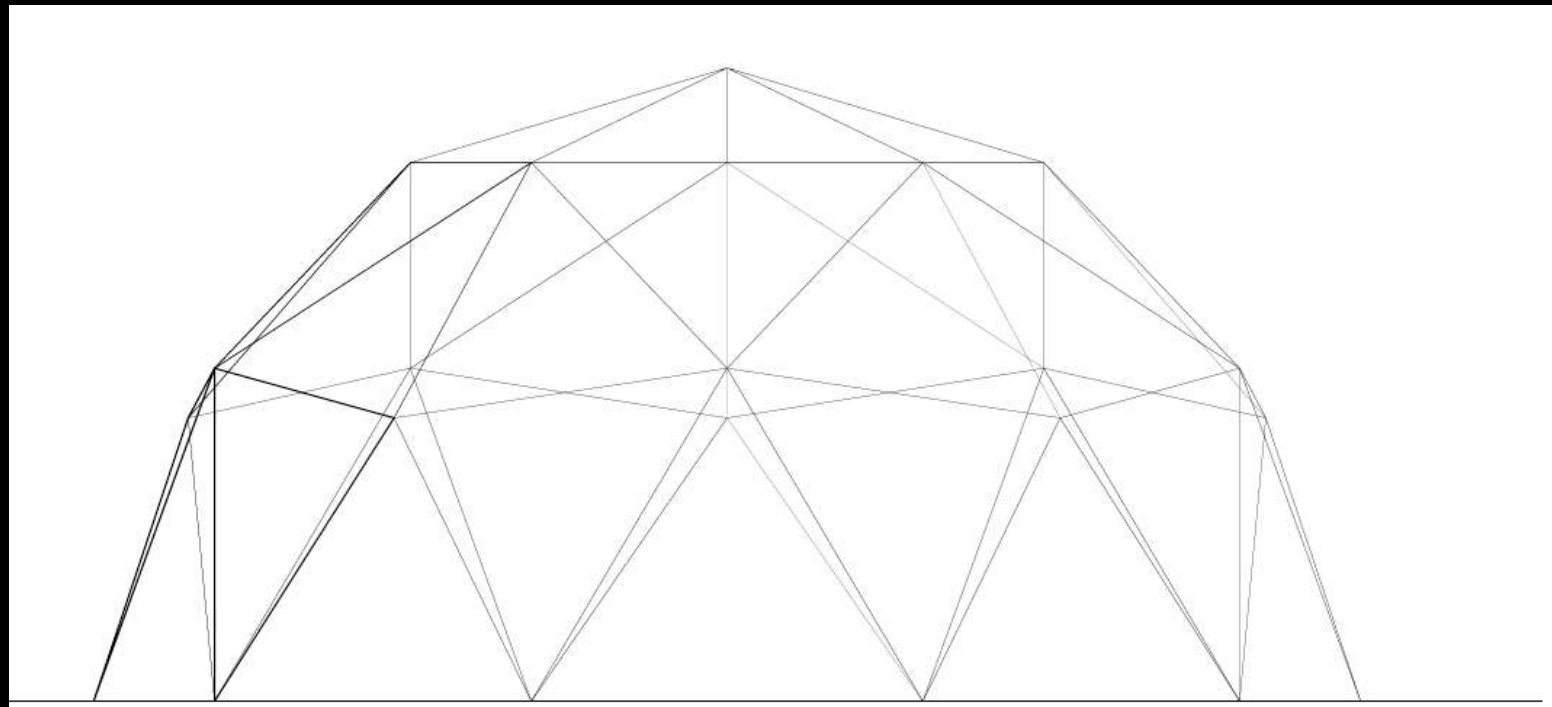
Voronoi algorithm
Delaunay algorithm

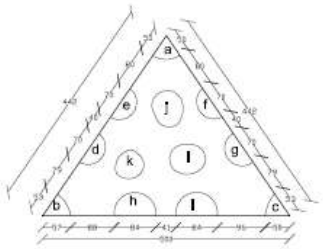
Production process [membrane moulding + concrete]

Tool, producing optimal structures [analysis] + synchronizati on mould

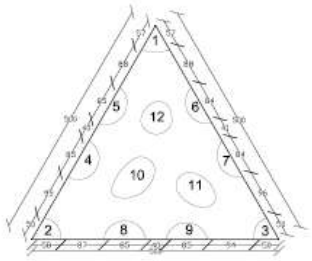
Optimal structure

- Based on algorithms, we will create a tool to generate a `tool' which can generate optimal structures, based on open cell structures. In this tool there will be a connection with production process [membranes/mould + concrete]
- Analysis spacefilling and shortest path algorithms.





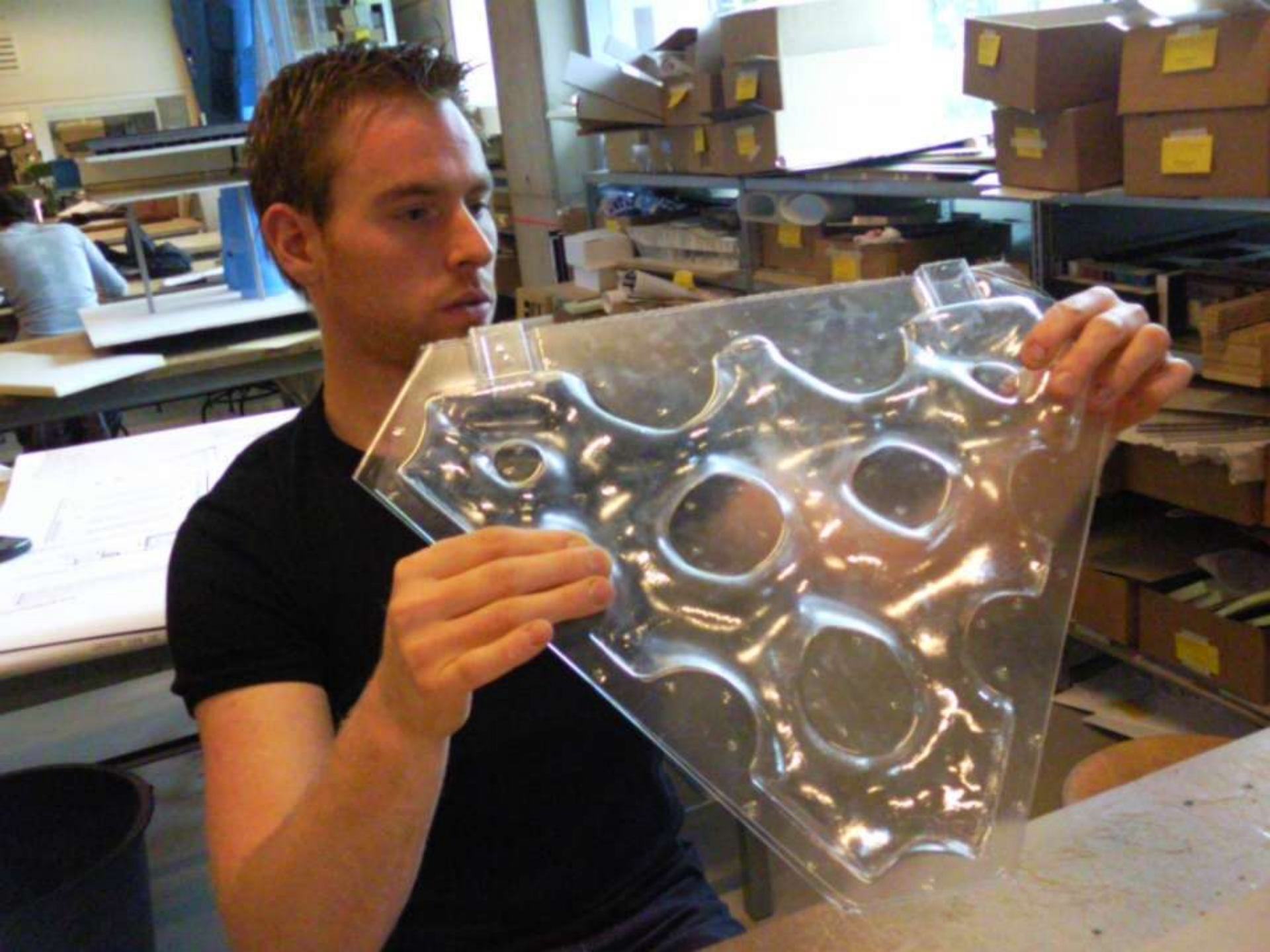
Driehoek A x40

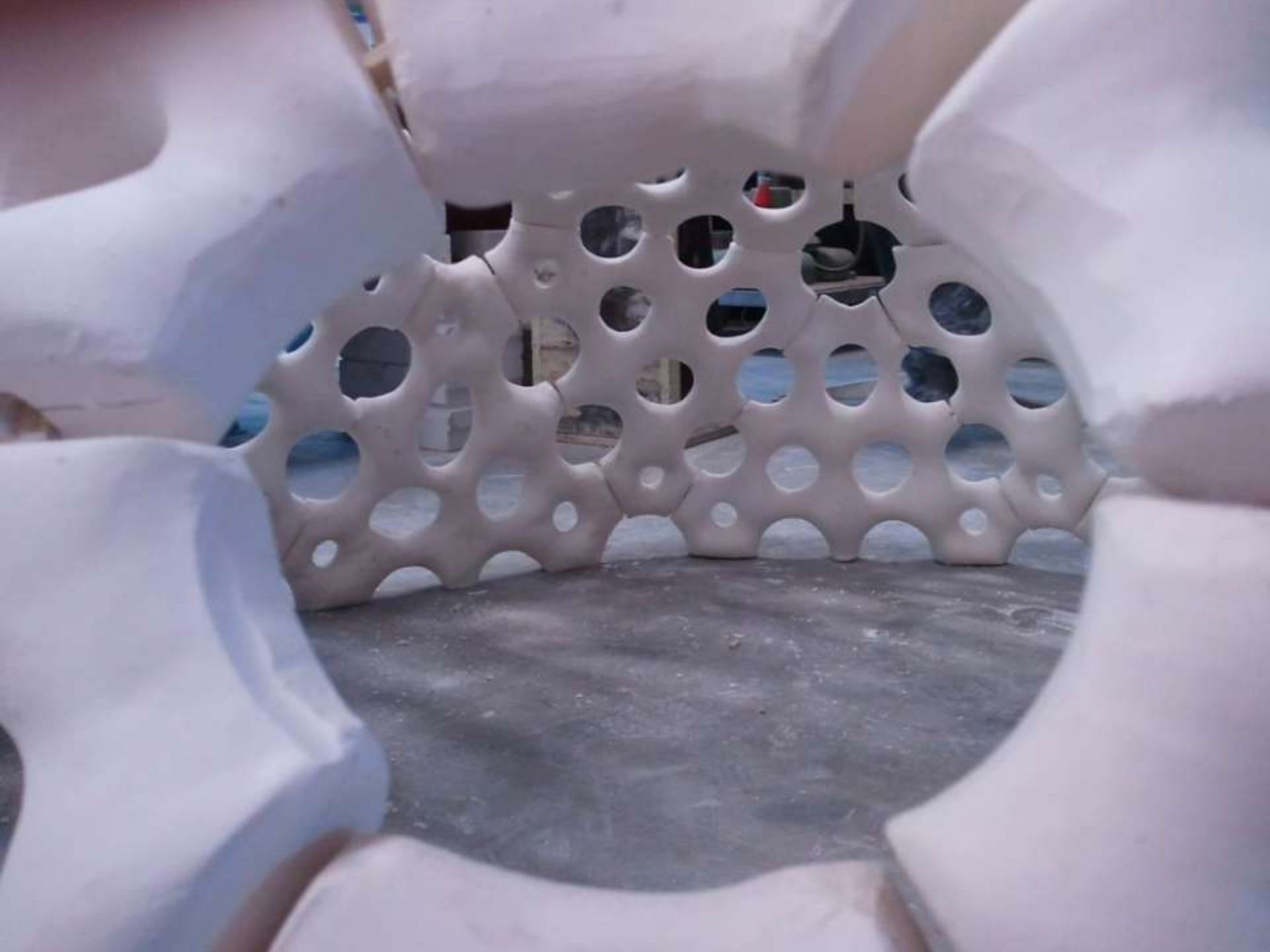


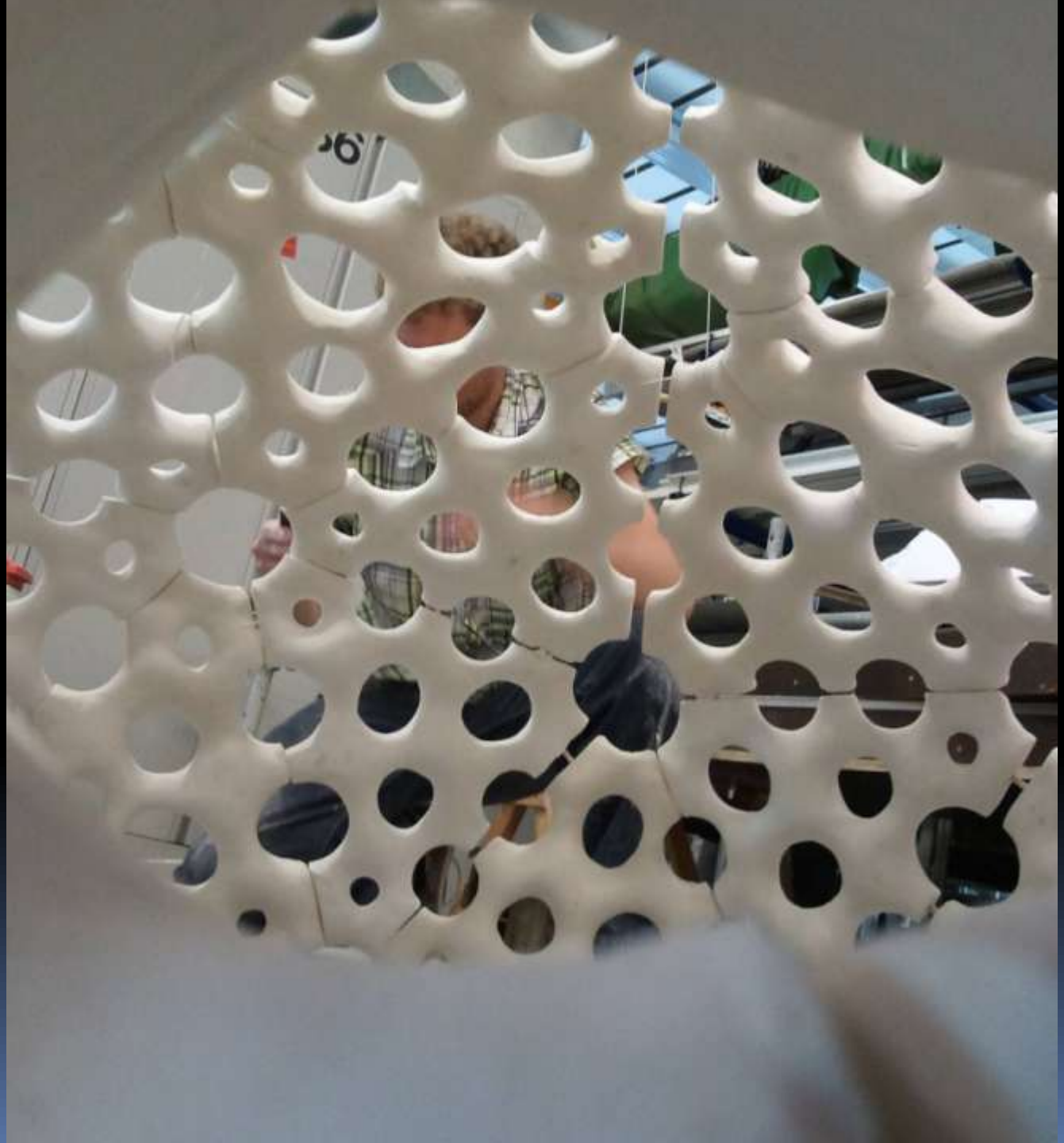
Driehoek B x10

Students project 2010, Dome with triangular `bone-elements’







Questions?