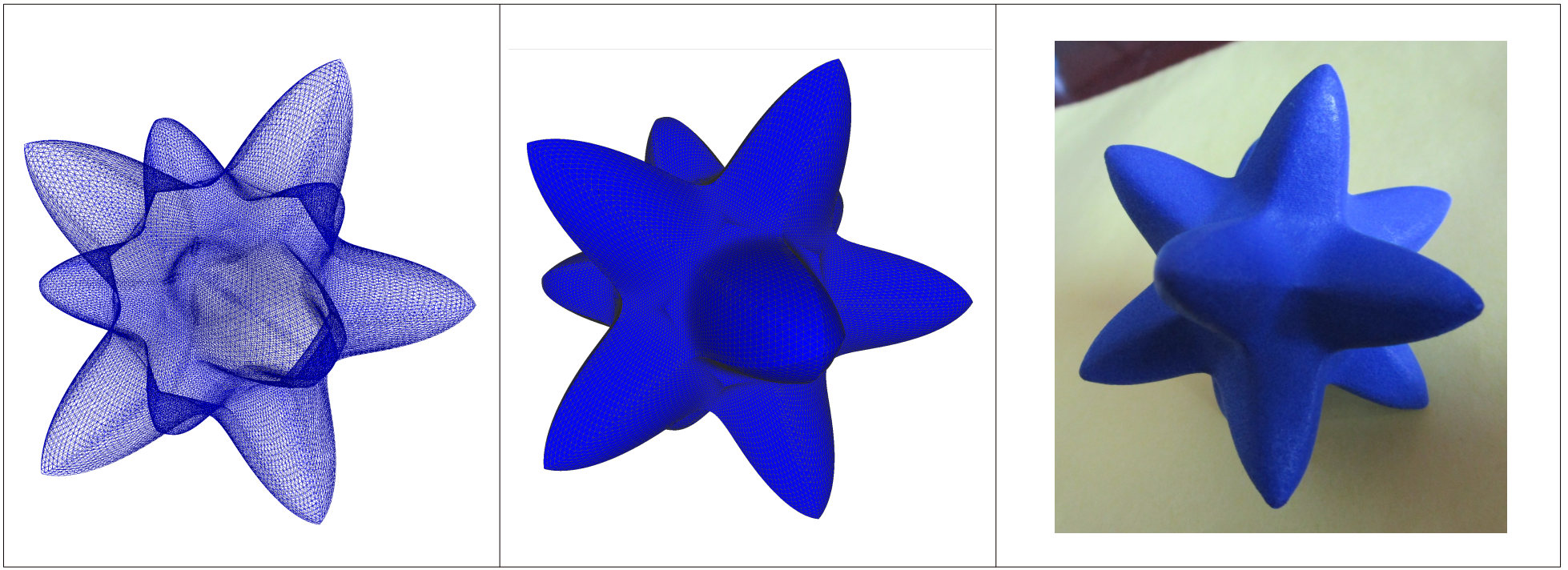
From equation to reality



MATLAB

CGAL

sculpteo

Nicolas Douillet 2017

Project context and goals

Context : Following and using my INRIA-TITANE work on the surface reconstruction benchmark.

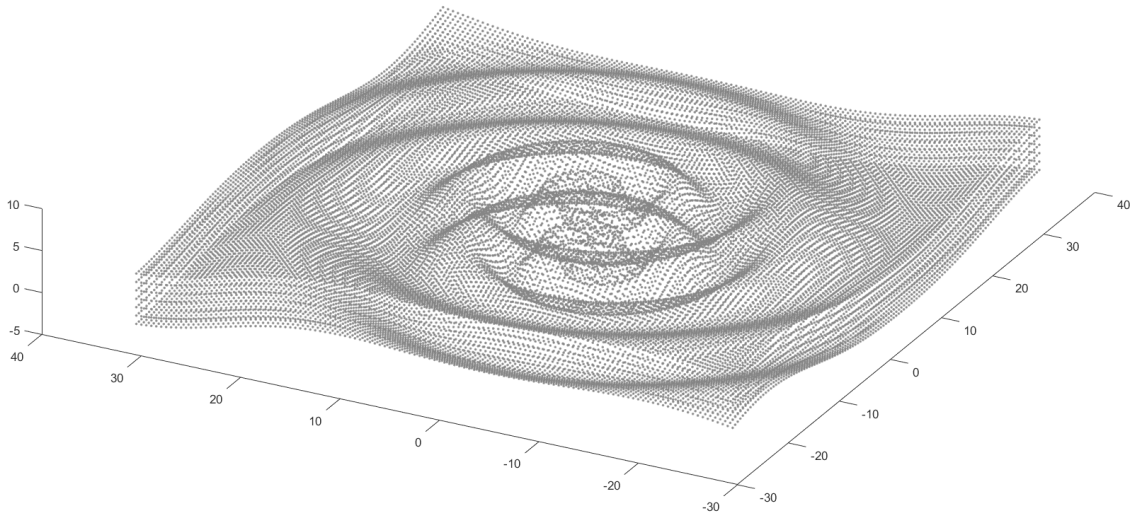
Goal #1 : Create a benchmarch of synthetic mathematical surfaces with high curvatures to study the performances and limits of CGAL meshing algorithms and 3D printing.

Goal # 2 : Go through and test whole steps of pipeline : from an idea, via successively its equation, its point set, its mesh, to its realization (3D printed object).

Outline

- (1) Step I : setting object equation and programing the point set
- (2) Step II : reconstructing / meshing the surface
- (3) Step III : printing the resulting object
- (4) : Examples and results
- (5) : Limitations and improvement paths
- (6) : Conclusion

Step I : setting object equation, Programming and sampling the point set



Sampling options :

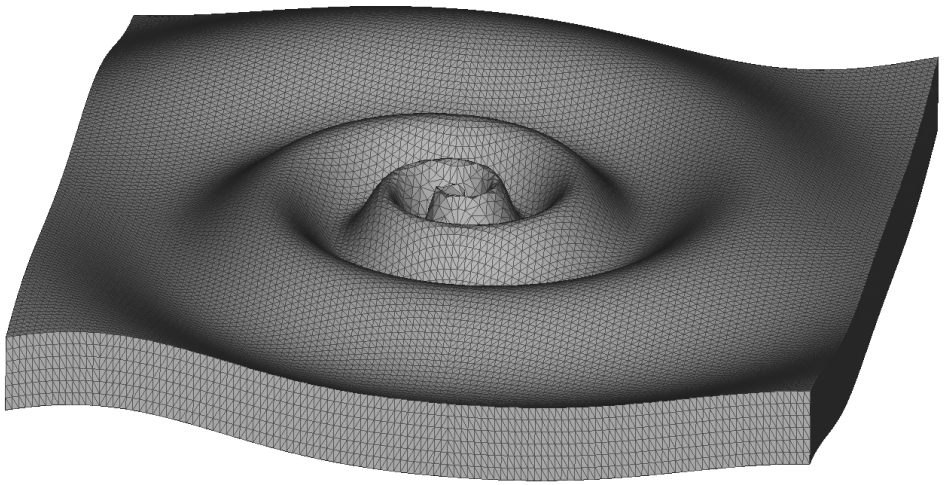
- Isotropic / anisotropic
- Steady / random

Point set example : the logarithmic spiral surface

Interest : increasing curvature from the boundaries to the centre

Equation : $z(x,y)=\sin\left(\lambda \ln(r+k_1)+k_2 \arctan\left(\frac{y}{x}\right)+k_3\pi\right)$

Step II : Reconstructing the surface / meshing

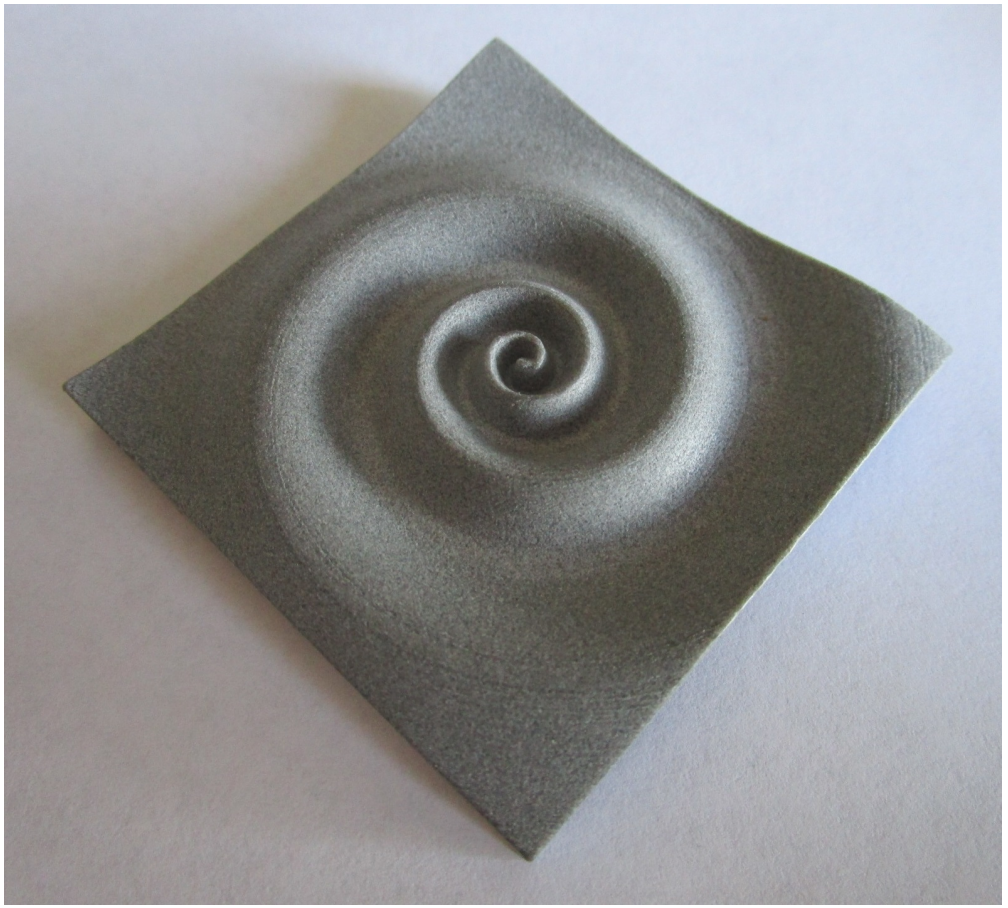


Mesh : CGAL advancing front

Properties :

- Vertices XYZ coordinates + facet indices (.xyz or .ply)
- 2D-manifold closed surface
- Watertight
- Facet normals oriented

Step III : printing the resulting object



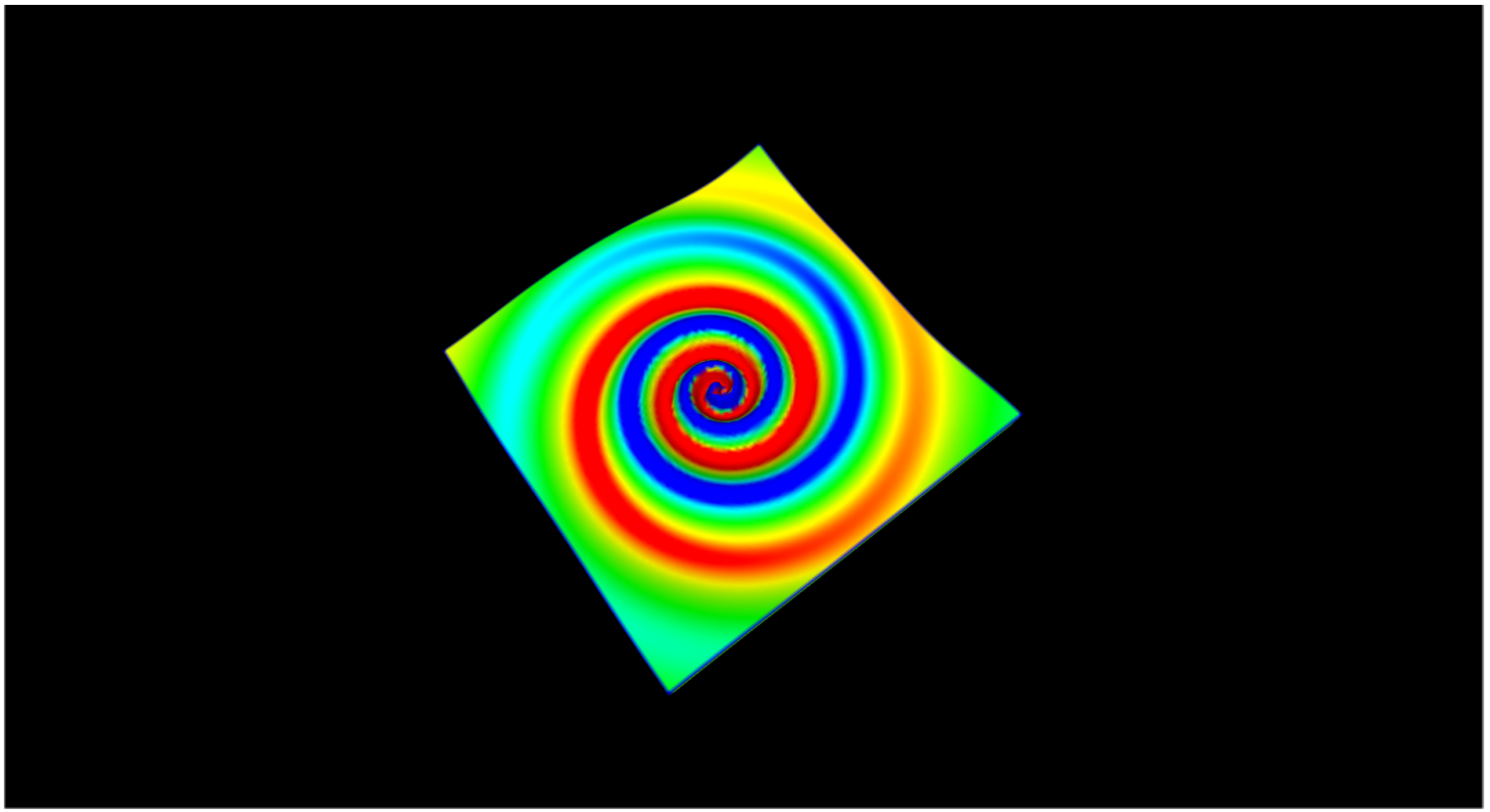
Printed object (Sculpteo)

- .stl file for 3D printing via Sculpteo

- SLS plastic technology

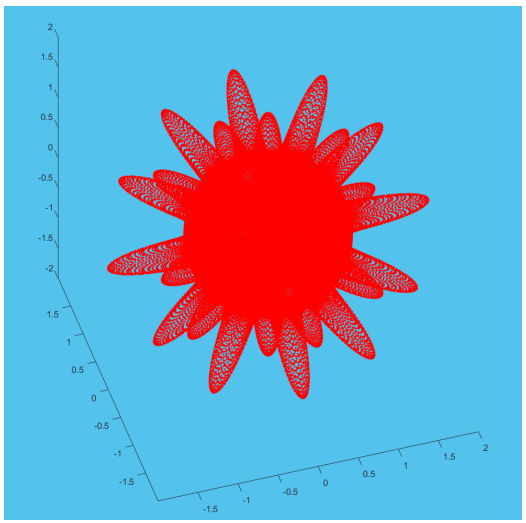
- ~ submillimetric size details (centre) for a 60mm x 60mm square base

Logarithmic spiral surface mean curvature

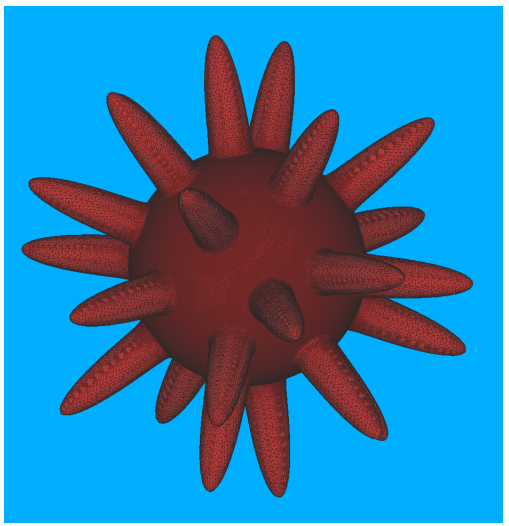


Face symetric, as expected, + edges curvature

Example #1 : sea mine



Point set

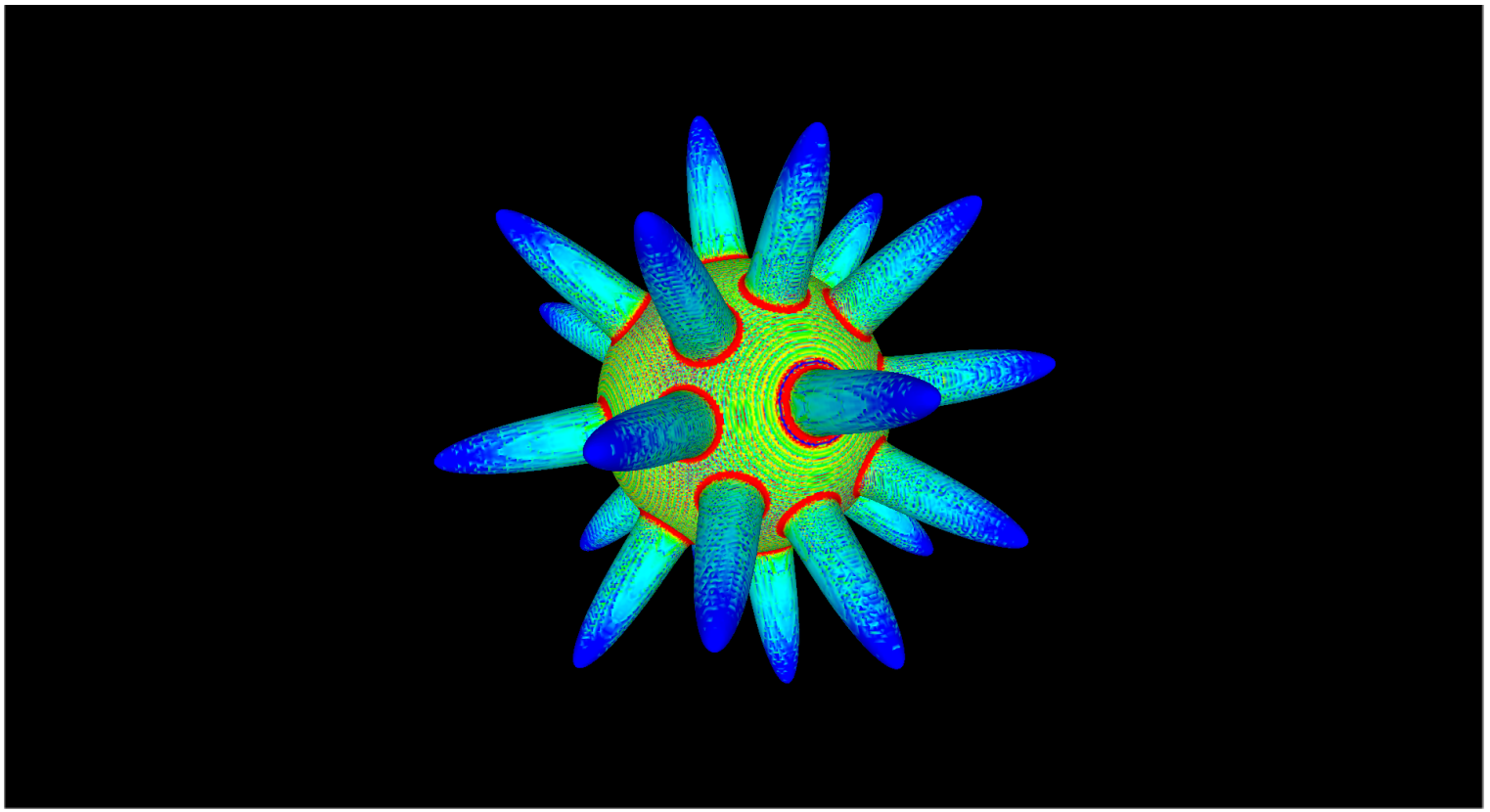


Mesh (Poisson)

Printed object (Sculpteo)

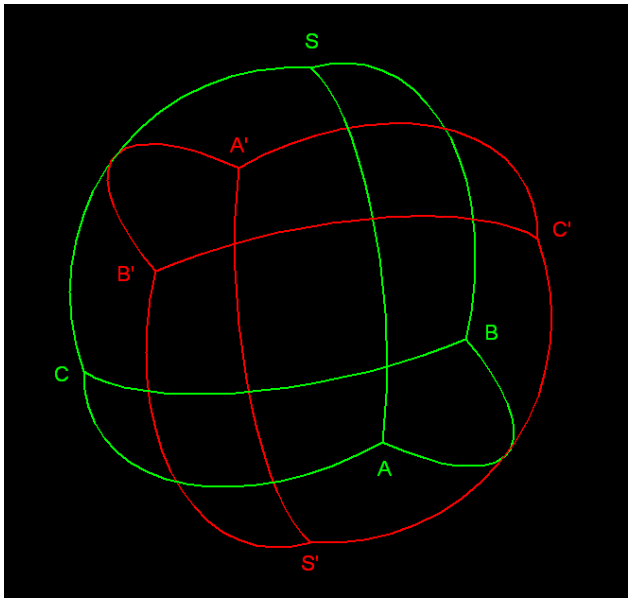
Interest : high curvature areas at the top and bottom of sinusoïdal peaks.

Sea mine mean curvature

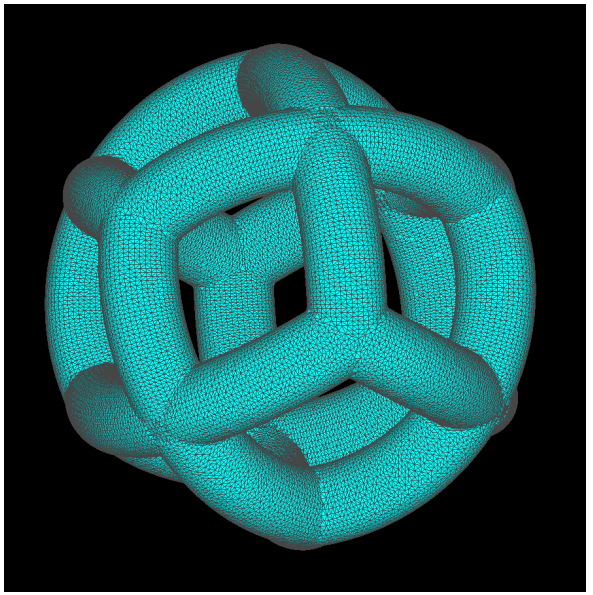


Top and bottom peaks curvature only
(construction pattern « hysteresis »)

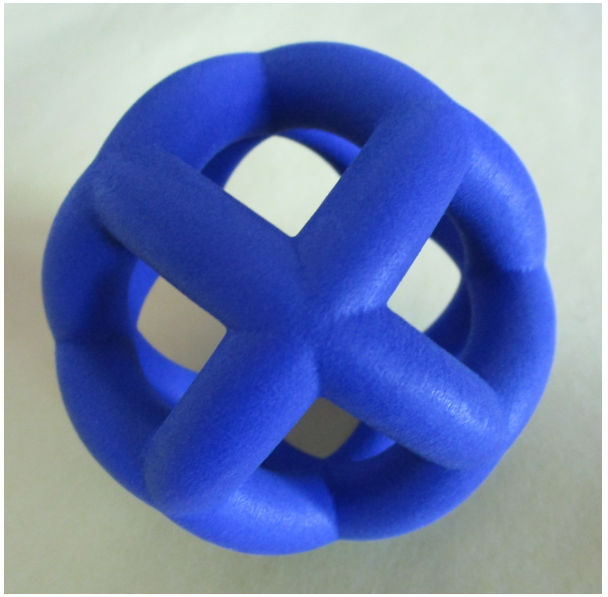
Example #2 : spherical tetrahedron



Skeleton



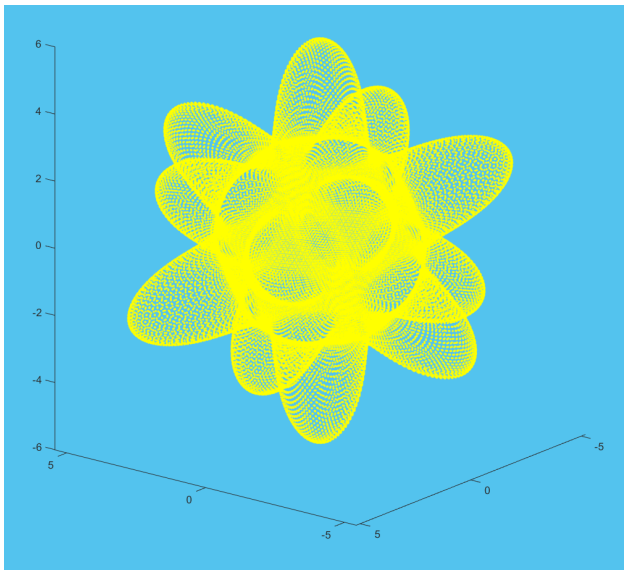
Point set and mesh



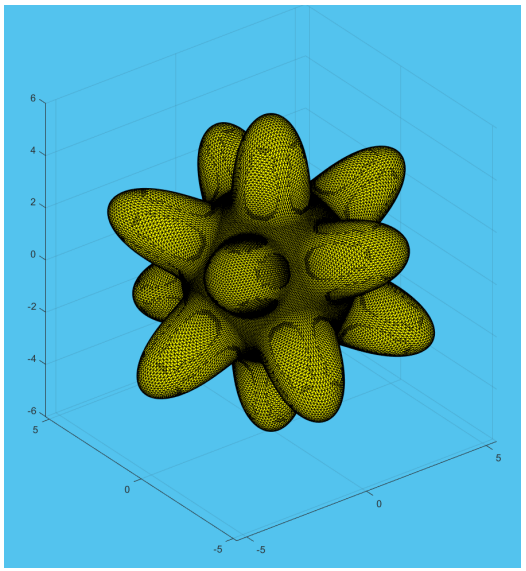
Printed object (Sculpteo)

Interests : Point set synthesis from / around its skeleton. Segmented mesh.

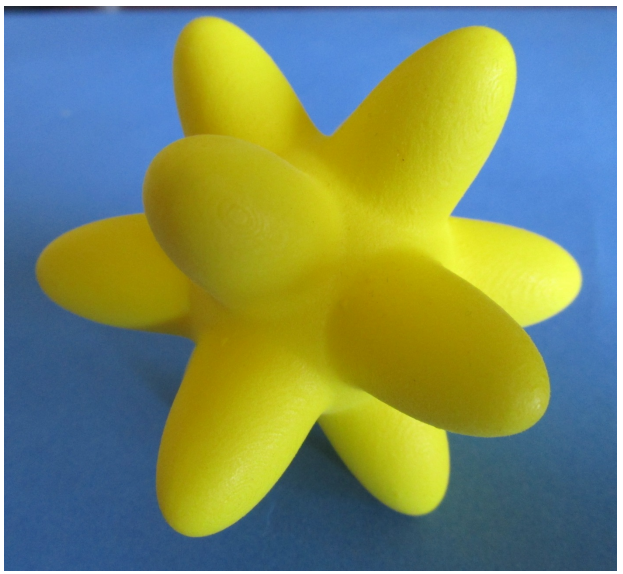
Example #3 : sinusoïdal icosahedron



Point set

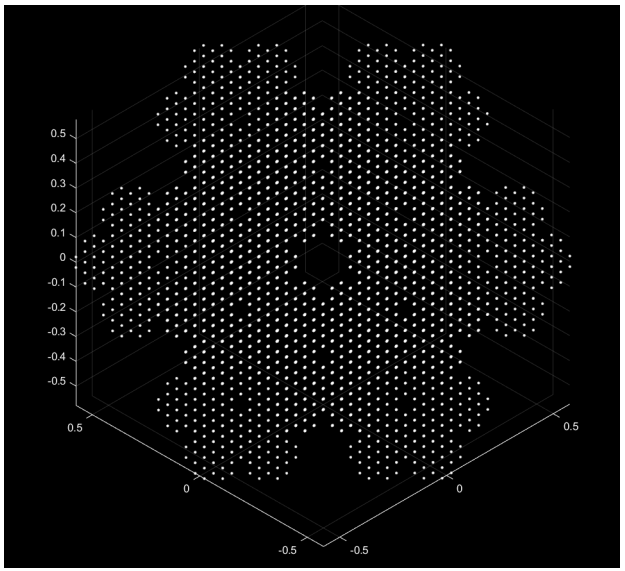


Mesh
(CGAL scale space meshing)

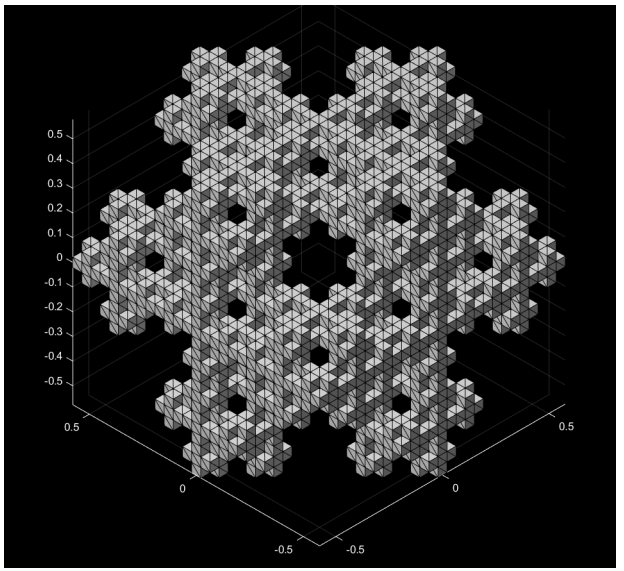


Printed object (Sculpteo)

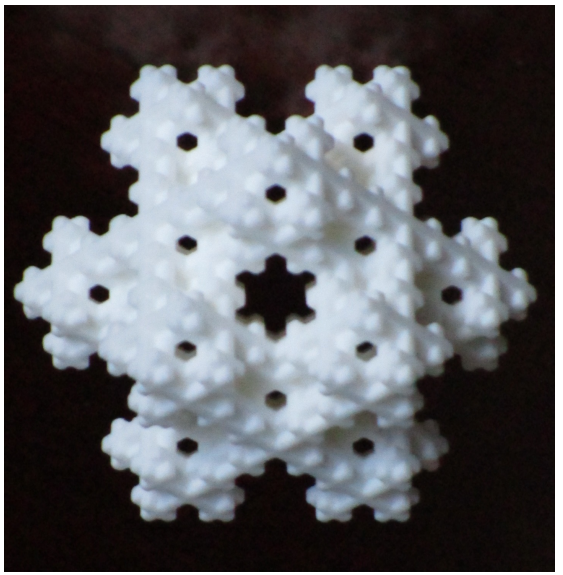
Example #4 : cube base 3D Koch snowflake



Point set



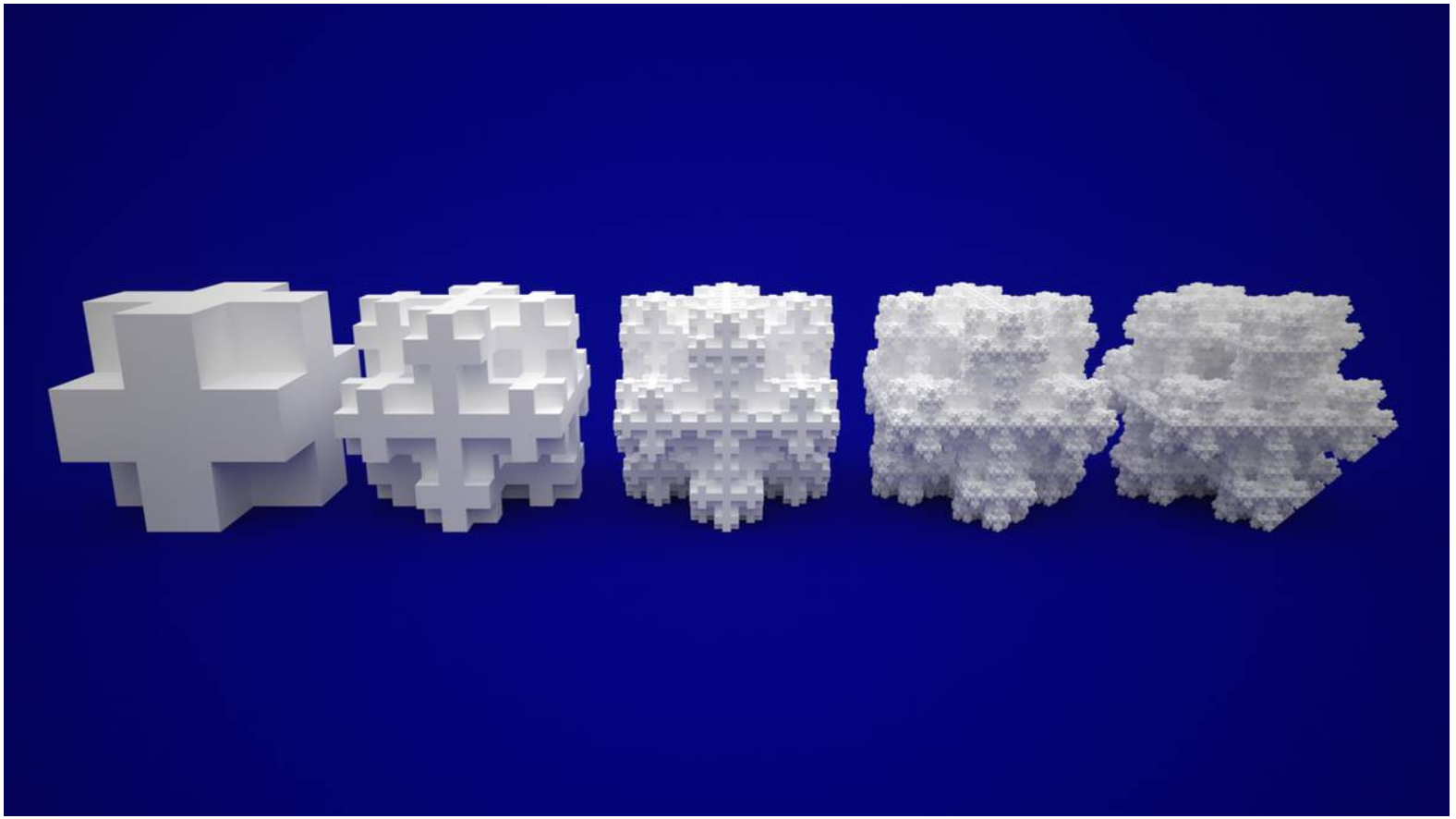
Mesh



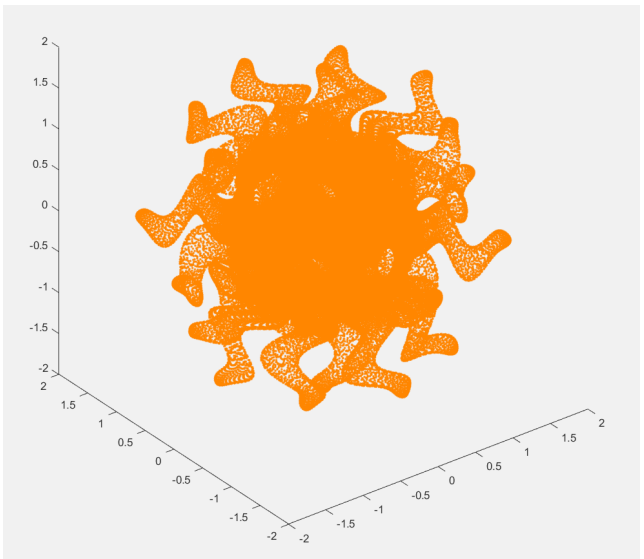
Printed object (Sculpteo)

Interest : fractal sponge shape, multiscale details

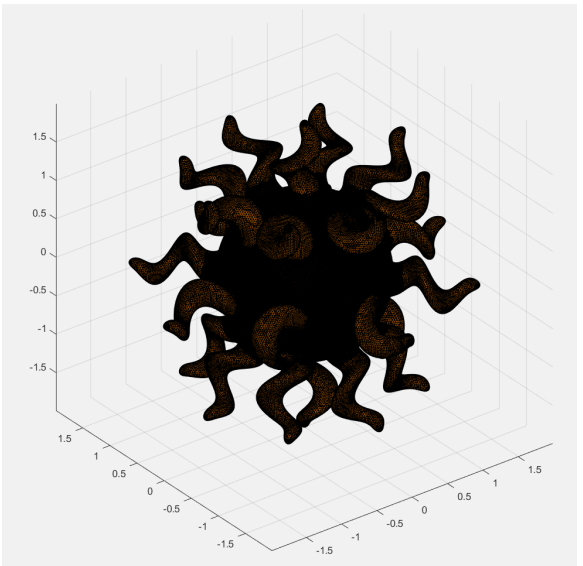
Cube base 3D Kock snowflake : algorithm steps



Example #5 : « octopus » surface



Point set

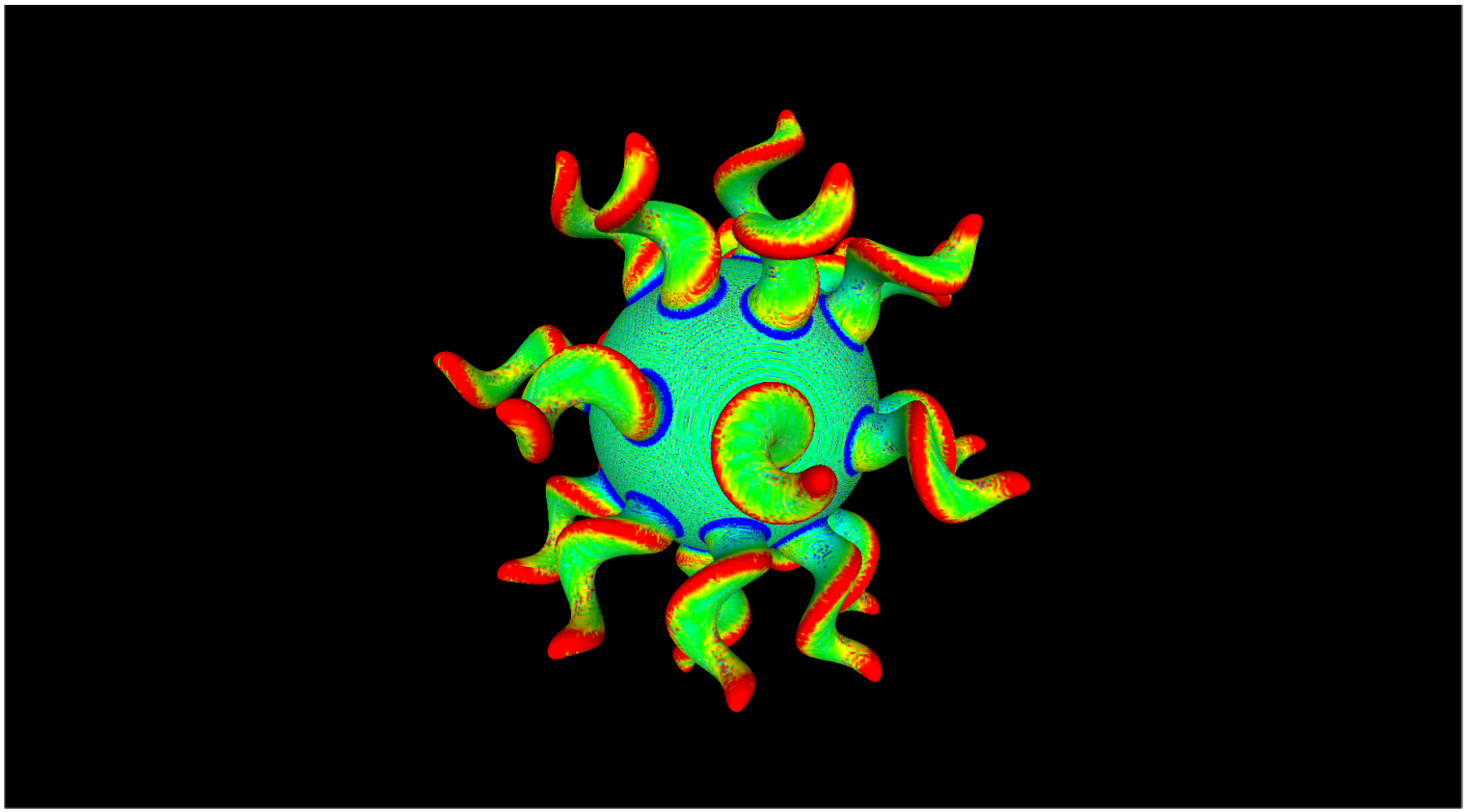


Mesh

Printed object (Sculpteo)

Interest : extreme peaks curvature (obtained with the convolution between a sinusoïd and half of a cardioïd).

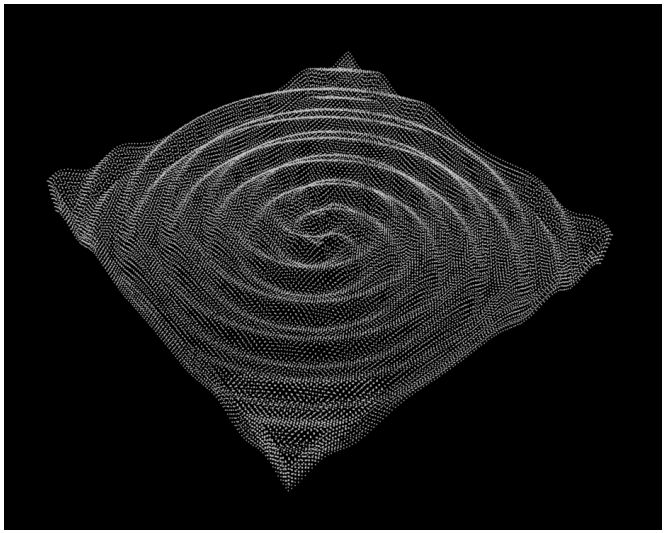
« Octopus » surface mean curvature



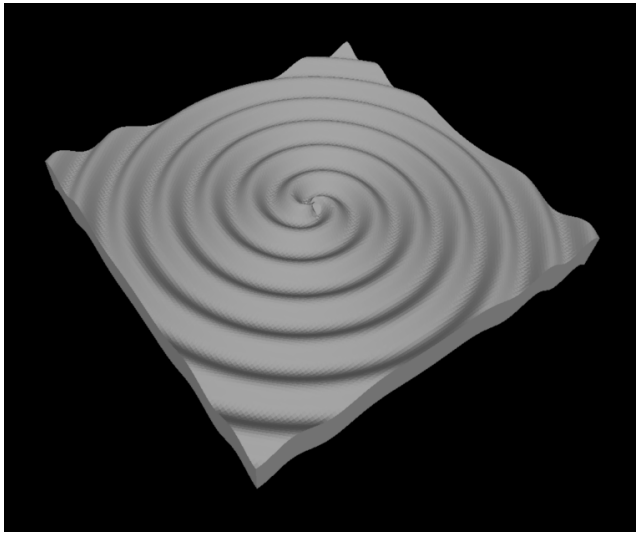
Top and bottom and edges peaks curvature only

Exemple #6 : Archimede spiral surface

Equation $z(x,y)=\sin\left(r+k_1\arctan\left(\frac{y}{x}\right)+k_2\pi\right)$



Point set

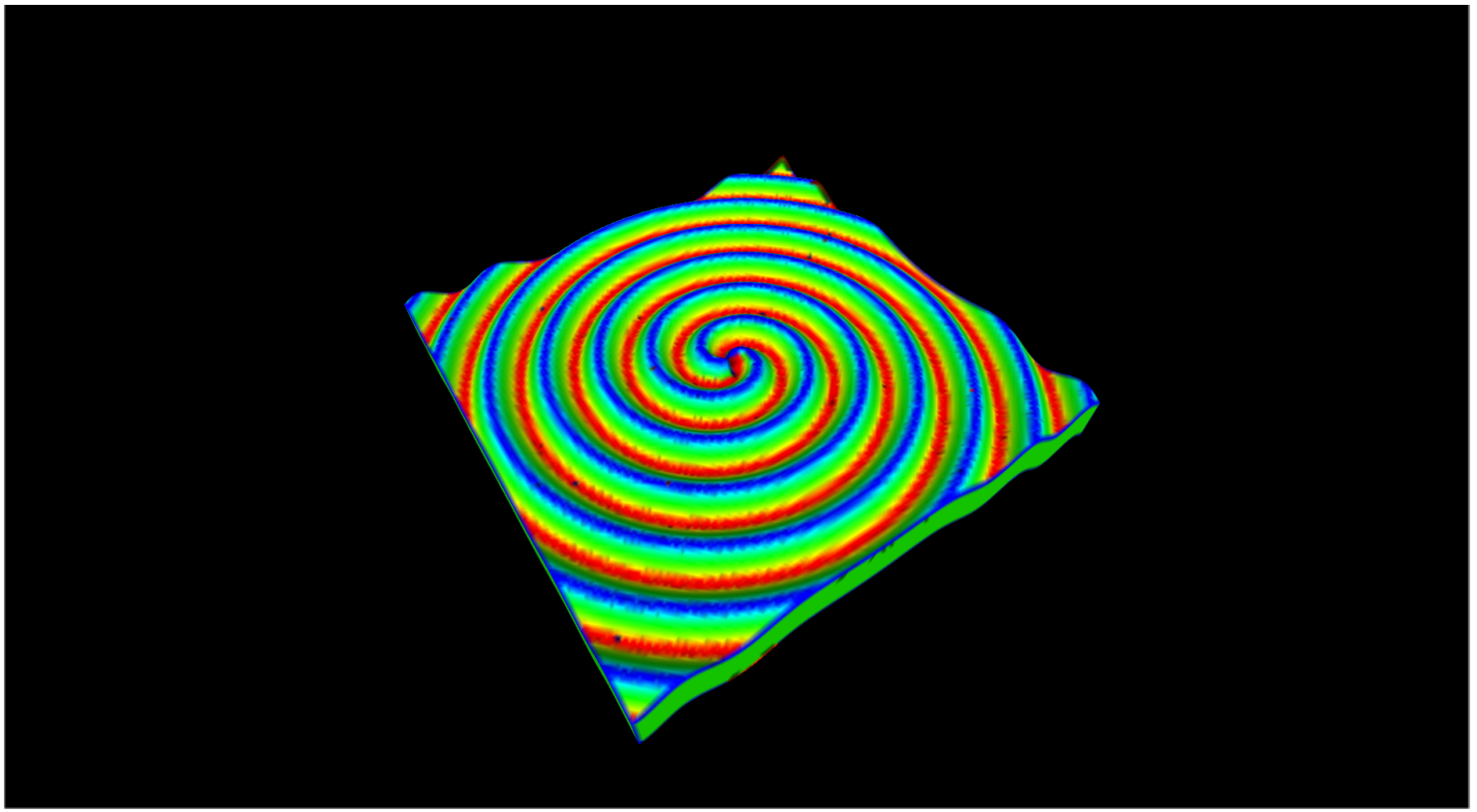


Mesh

Printed object (Sculpteo)

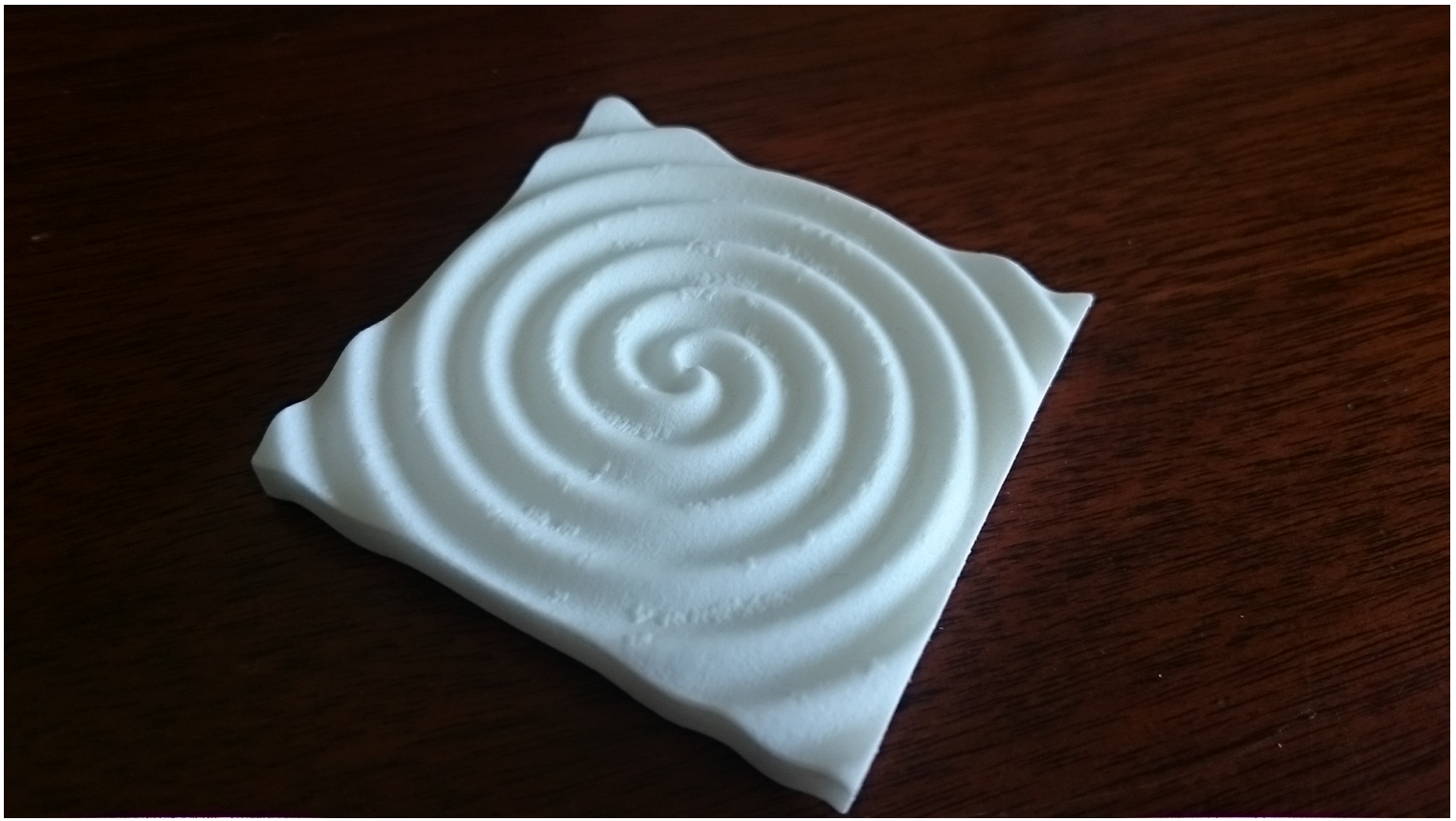
Interest : constant high curvature

Archimede spiral surface mean curvature

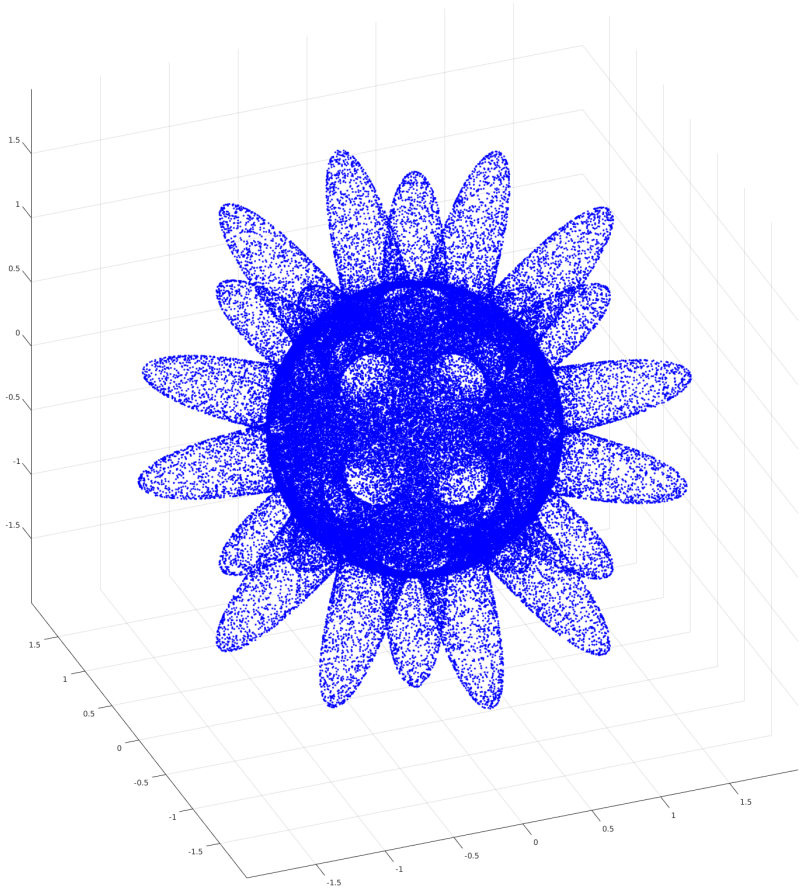


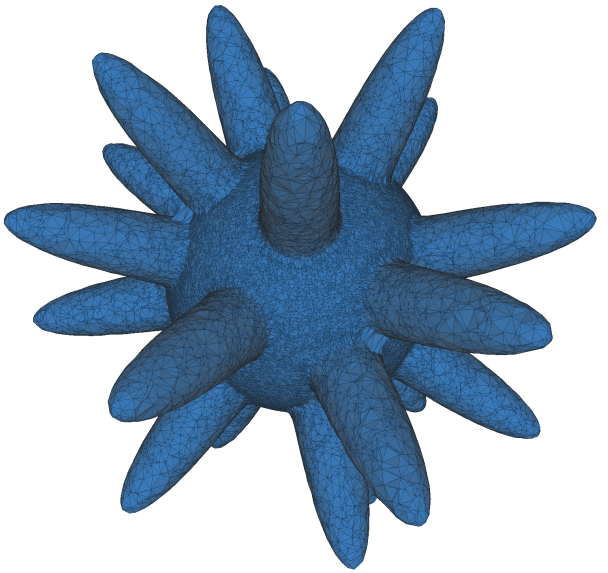
Face symetric, as expected, + edges curvature. Some small artefacts due to CGAL mesh imperfections

Limitations : failed print example due to imperfect mesh



Random isotropic sampled point sets and meshes





Steady isotropic sampling not always the best choice depending on the object shape.

→ High curvature area need highier point density than the rest.

Conclusion

Goal #1 : (mesh generation & processing benchmark) → reached ✓

Goal #2 : Idea → equation → point set → mesh → 3D object : done ✓
+ tested 3D printing resolution limits

Extra : sampling technique for synthetic surfaces has influence on the mesh and then on the 3D printed resulting object.

→ Now developping my own mesh generation processing libraries
(multiresolution mesh from convex hull divide and conquer algorithm)

Triangle base 3D Kock snowflake algorithm steps