GRAMAZIO
KOHLER
RESEARCH

dbt

ETH zürich

MAS Digital Fabrication

Implicit modeling

October 26th, 2020

ETH zürich
DARCH
Departement Architektur
Institute of Technology in Architecture
Faculty of Architecture / ETH Zurich
dbt
GRAMAZIO KOHLER RESEARCH

Week 1

Mesh Subdivision

Rule-based design

Week 2

Implicit Modeling

Distance functions

Implicit what?

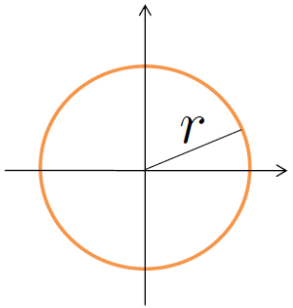
Implicit representation of geometry

Points aren't known directly, but satisfy some **relationship**

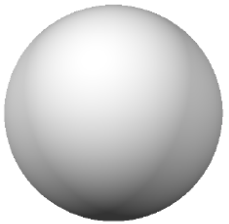
E.g., unit sphere is all points $\mathbf{p(x,y,z)}$ such that $\boldsymbol{x^2 + y^2 + z^2 = 1}$

$$f(x, y) = x^2 + y^2 - r^2$$

Frep Vs Brep

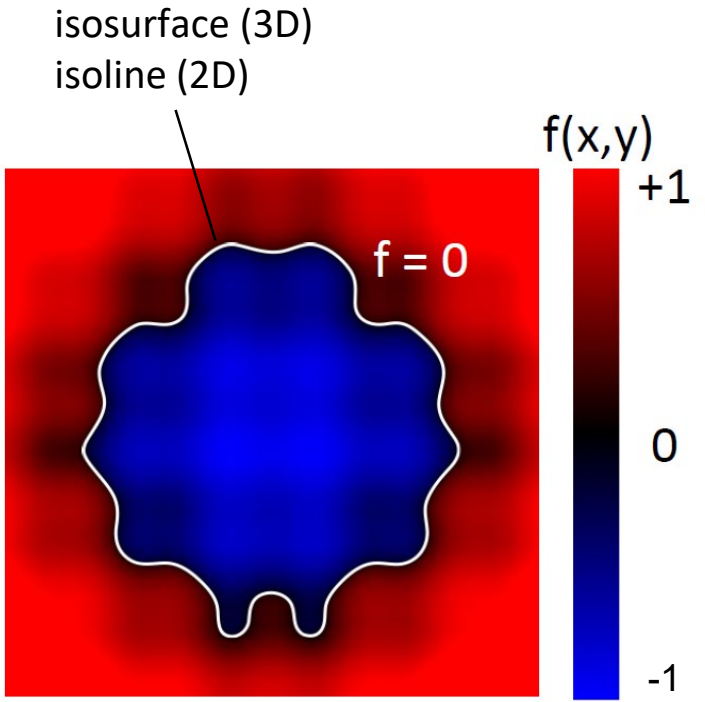


$$f(x, y, z) = x^2 + y^2 + z^2 - r^2$$



Implicit representation of geometry

More generally, **f(x,y,z) = 0 : on the surface**
f(x,y,z) < 0 : inside
f(x,y,z) > 0 : outside



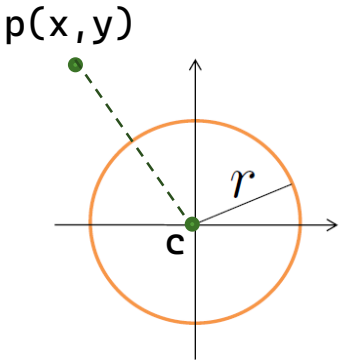
Volume representation

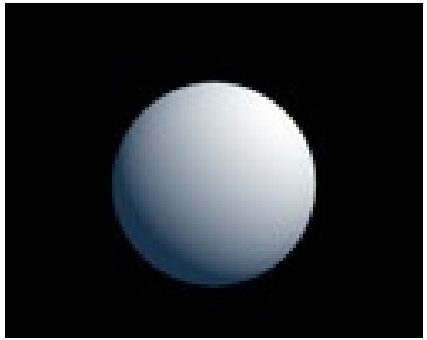
Easy inside / outside test

Unambiguous separation of inside/outside

Always ‘watertight’ shapes

Signed distance function (SDF)





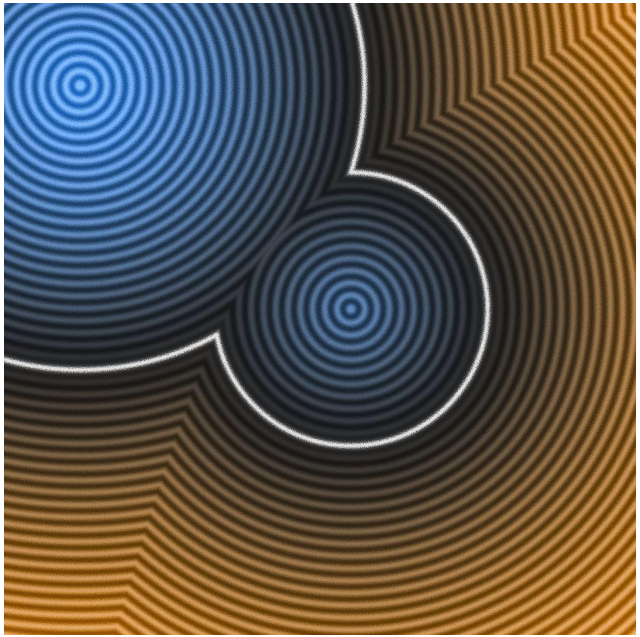
f(x,y) = dist(p(x,y), c) − r

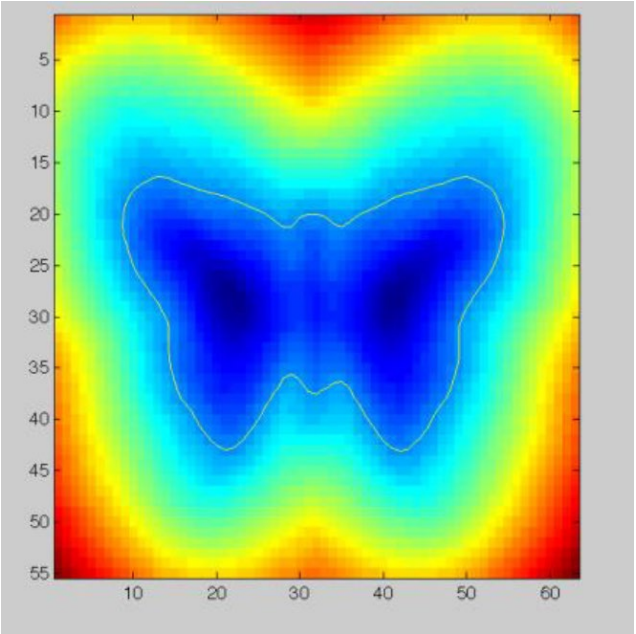
f(x,y) > 0 → outside

f(x,y) = 0 → on the surface

f(x,y) < 0 → inside

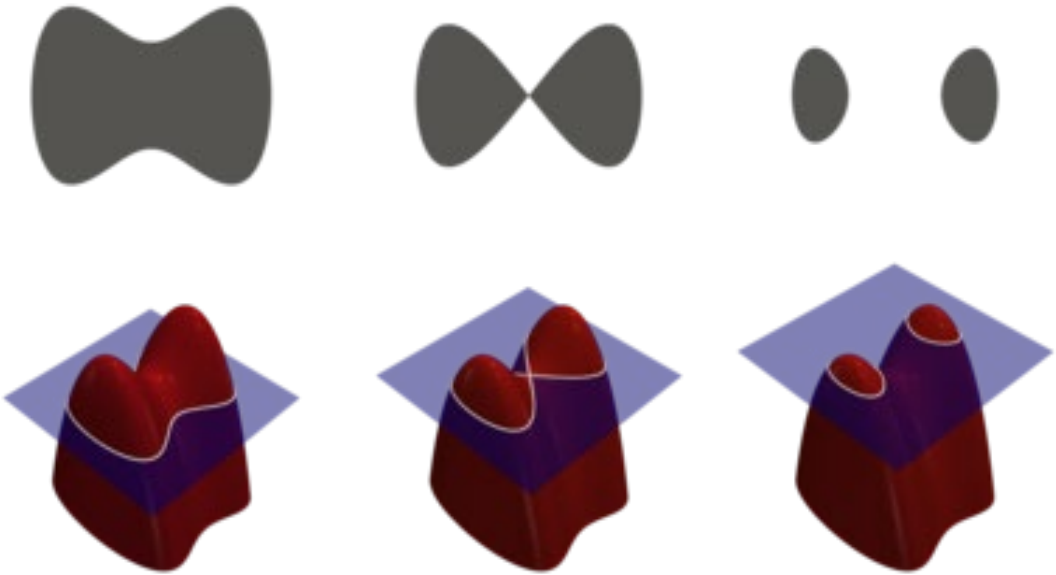
Signed distance field (SDF)



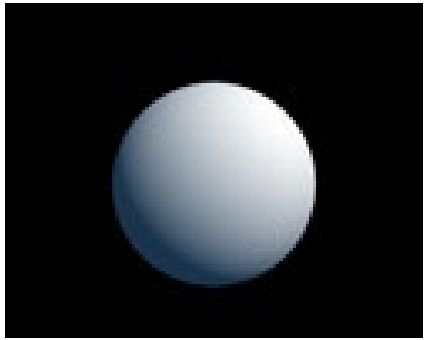


- **Offsetting** becomes very easy: to offset $f(x,y)$ just do $f(x,y) = f(x,y) + \mathbf{v}$
- **Changes in topology** do not pose any problem

Level set

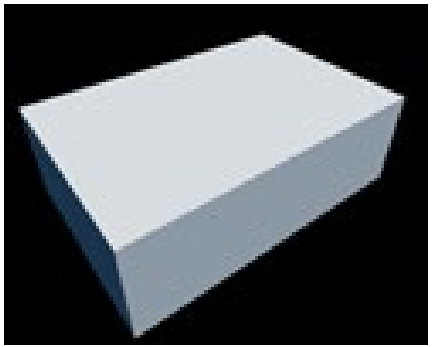


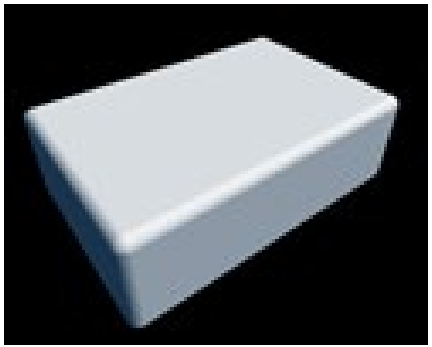
Primitives



```
dist(p(x,y,z), c) - radius = 0
```

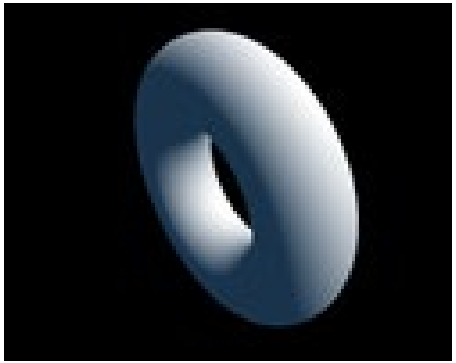
Primitives





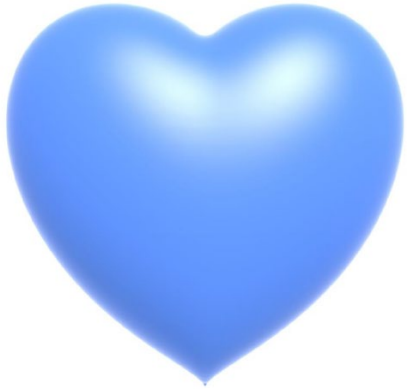
```
q = abs(p) - b
dist(max(q,0.0)) + min(max(q.x,max(q.y,q.z)),0.0) - radius = 0
```

Primitives



```
q = vec2(length(p.xz)-t.x,p.y)
      length(q)-t.y = 0
```

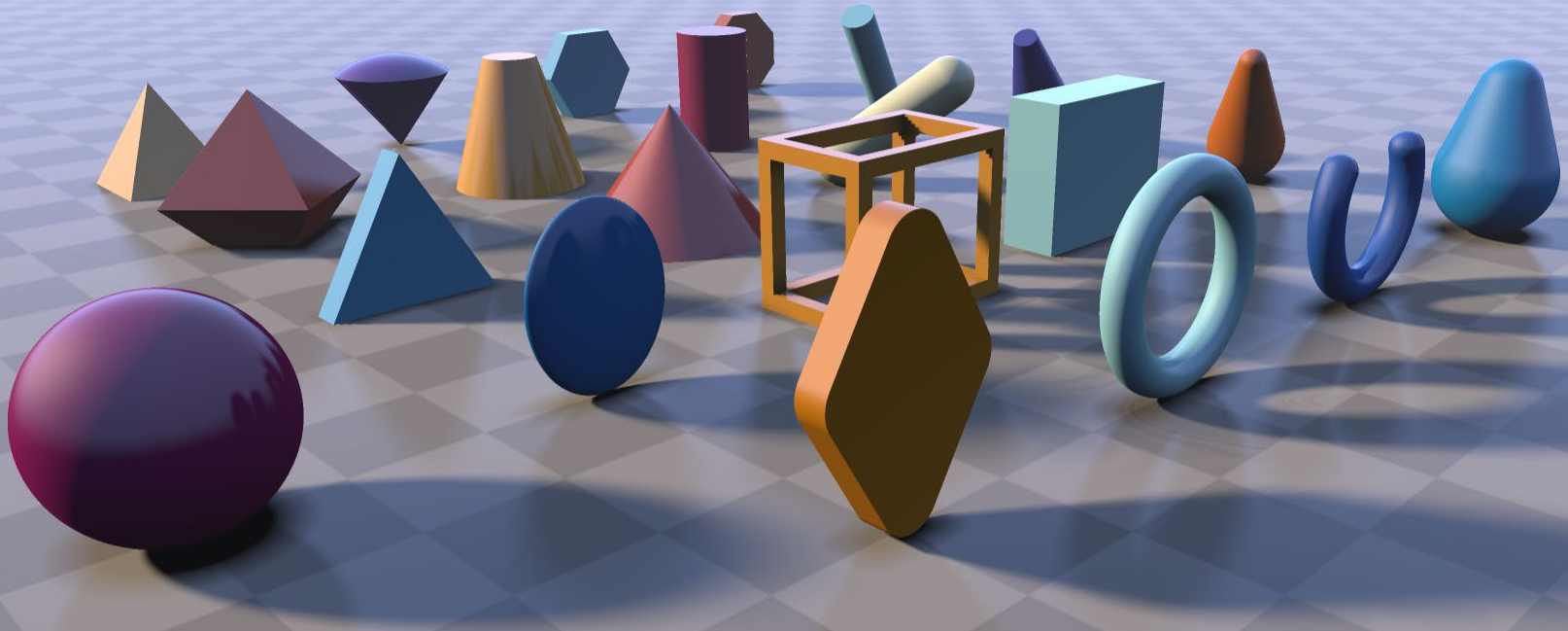
Primitives



$$(x^2 + \frac{9y^2}{4} + z^2 - 1)^3 = x^2 z^3 + \frac{9y^2 z^3}{80}$$

Making a heart with mathematics: https://www.youtube.com/watch?v=aNR4n0i2ZlM

Primitives



Inigo Quilez, www.iquilezles.org/www/articles/distfunctions/distfunctions.htm

Boolean combinations

union

$f(x) = \mathbf{min}(\text{sphere}(x),\text{box}(x))$

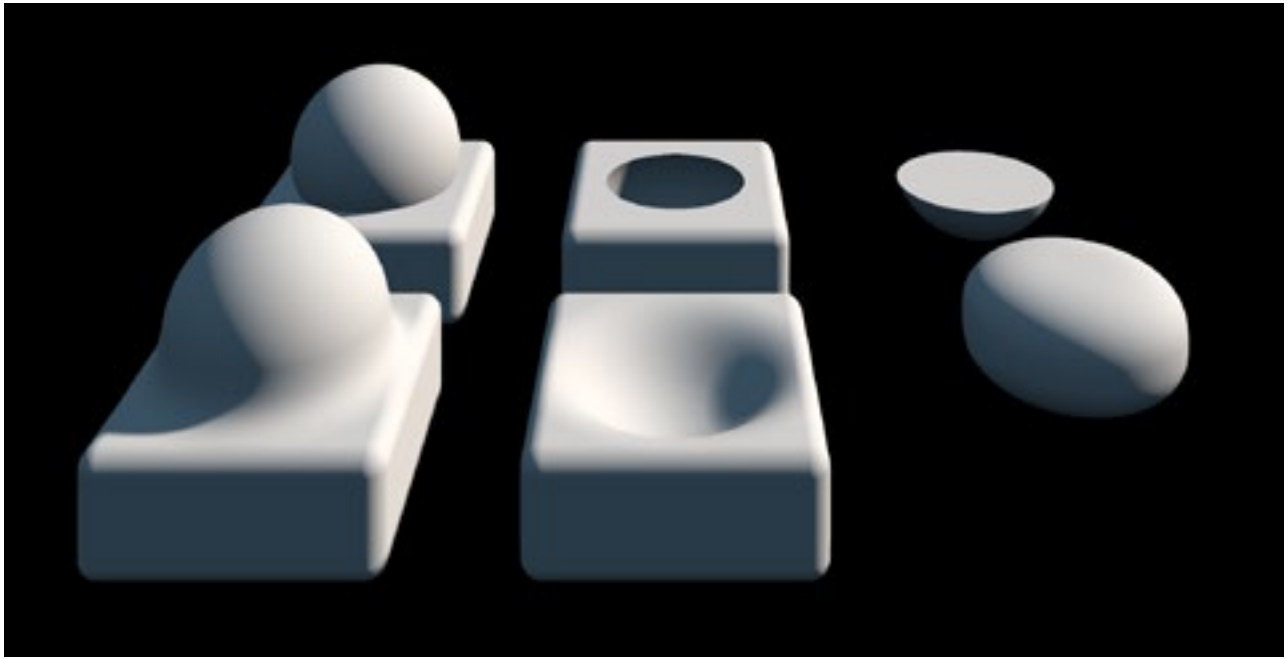
subtraction

$f(x) = \mathbf{max}(\mathbf{-}\text{sphere}(x),\text{box}(x))$

intersection

$f(x) = \mathbf{max}(\text{sphere}(x), \text{box}(x))$

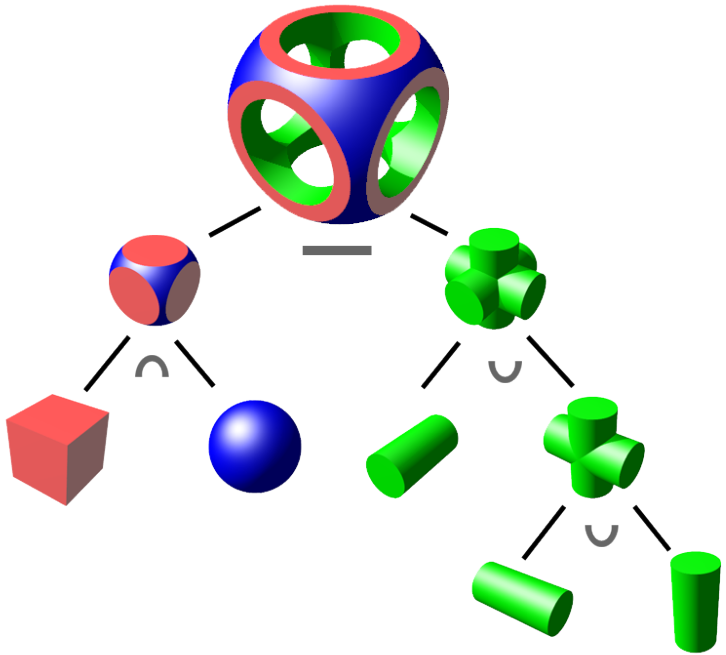
Boolean combinations



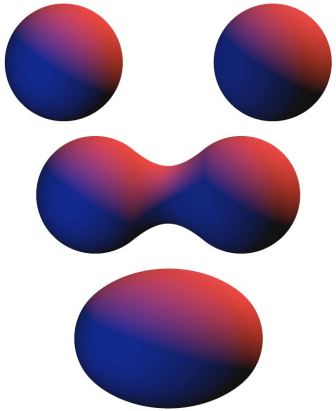
smooth union smooth subtraction smooth intersection

Inigo Quilez, www.iquilezles.org/www/articles/distfunctions/distfunctions.htm

Constructive solid geometry tree



Metaballs, blobs

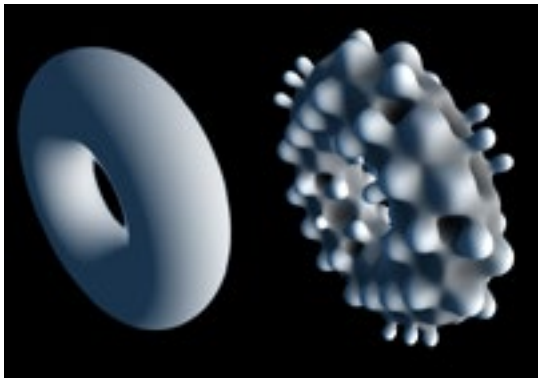


$$\sum_{i=0}^{m} metaball_i(x, y, z) \leq threshold$$

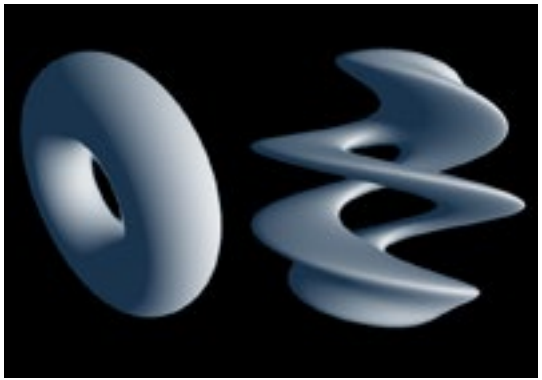
Metaballs, Jim Blinn, 1980s

Blob wall, Greg Lynn, Venice Biennale 2008

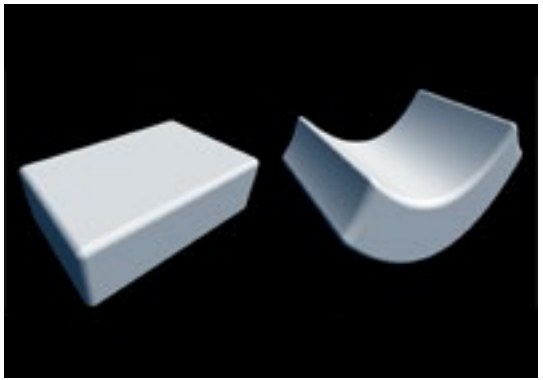
Deformations, distortions



displacement



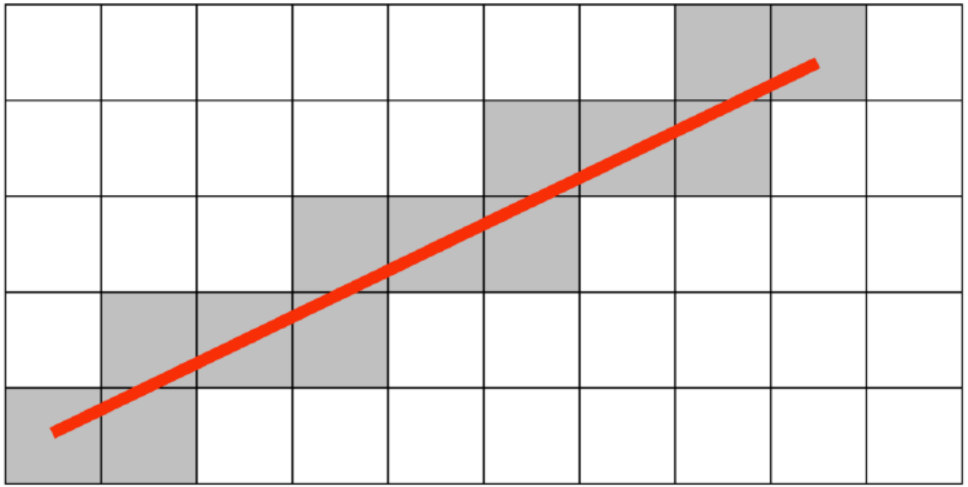
twist



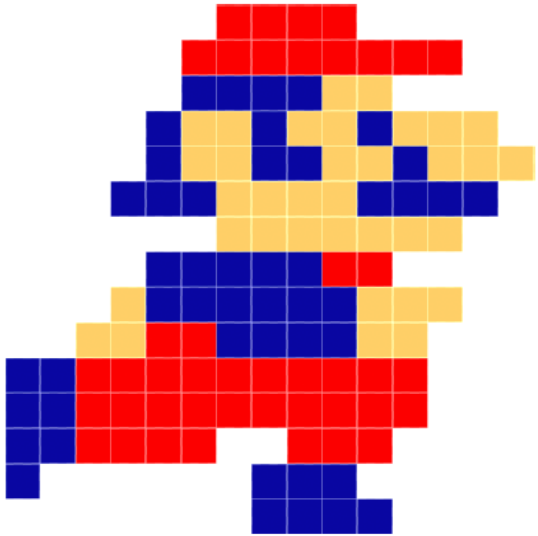
bending

From the continuous to the discrete world

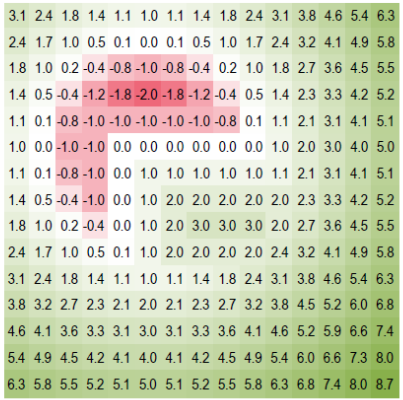
Discretization

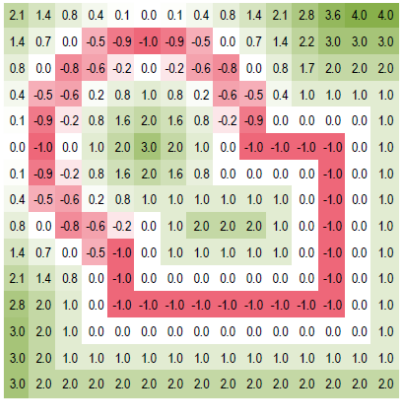


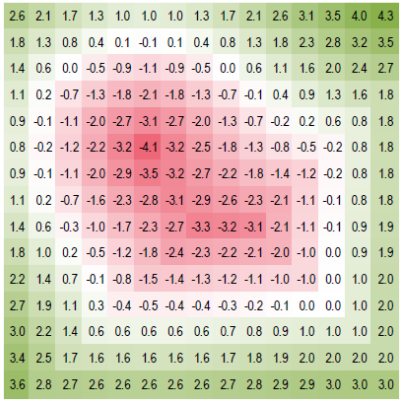
Discretization



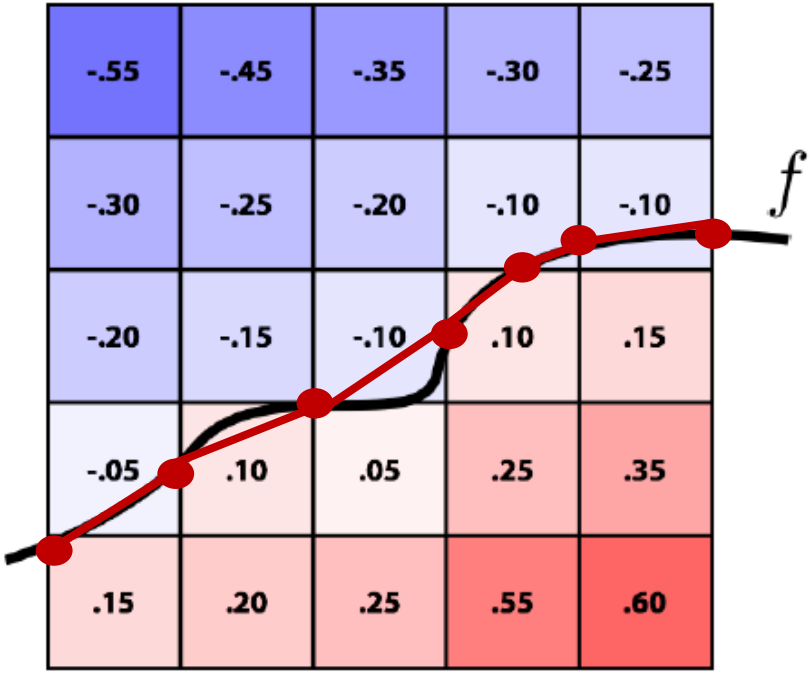
Regular grid, 2D





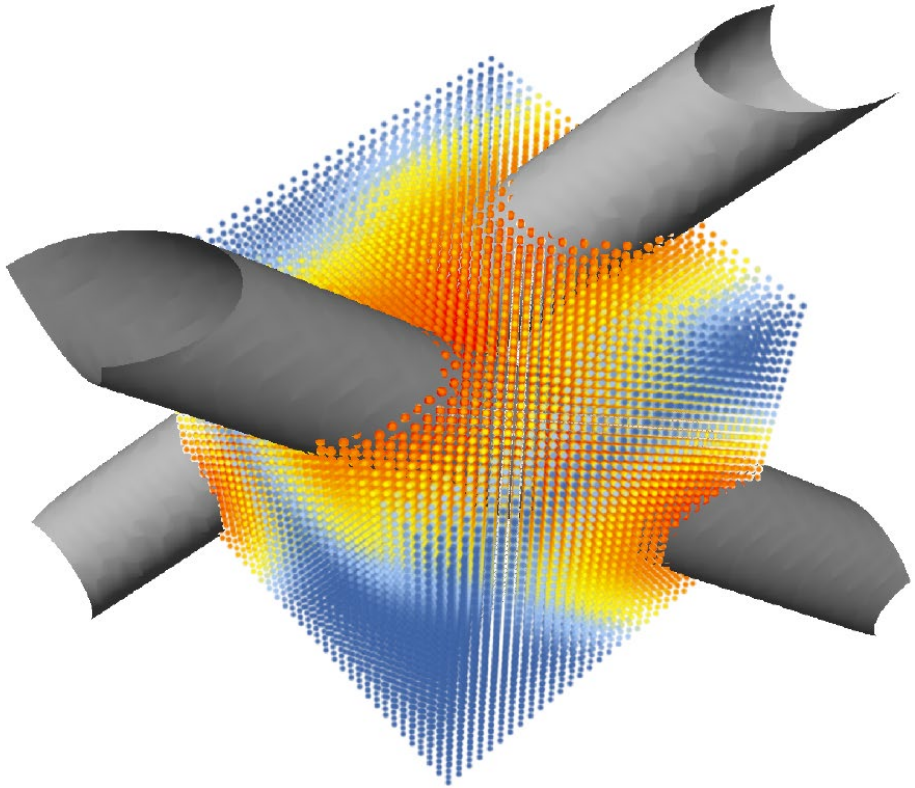


Regular grid, 2D



$$f(\mathbf{x}) = 0$$

Regular grid, 3D

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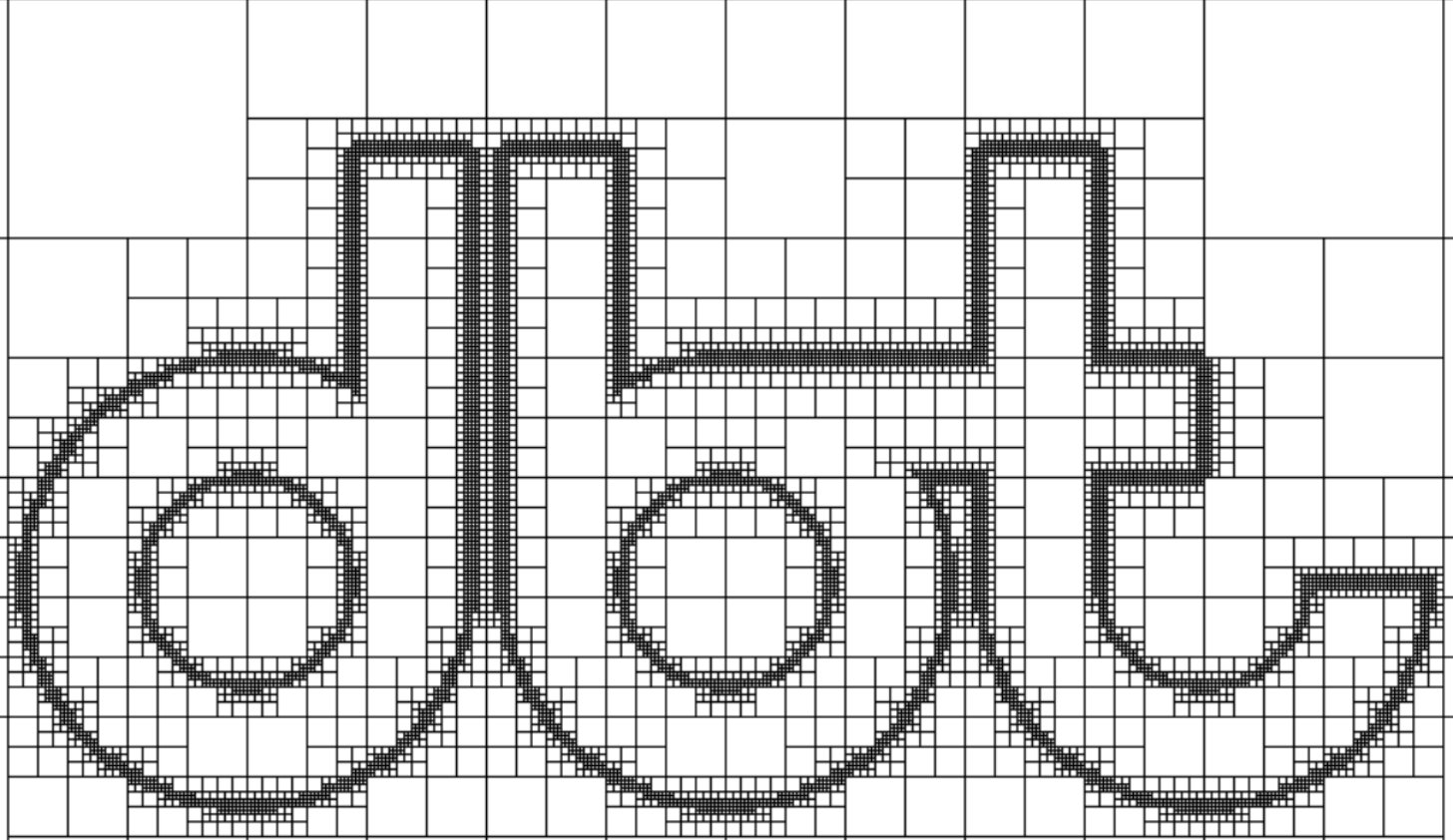
Octree



Applications

Jipa, A., Bernhard, M., Ruffray, N., Wangler, T., Flatt, R., & Dillenburger, B. (2017). *skelETHon Formwork*. In SIGraDi 2017, XXI Congreso de la Sociedad Ibero-americana de Gráfica Digital. Concepción, Chile.

Jipa, A., Bernhard, M., Ruffray, N., Wangler, T., Flatt, R., & Dillenburger, B. (2017). *skelETHon Formwork 3D Printed Plastic Formwork for Load-Bearing Concrete Structures*. In Blucher Design Proceedings (pp. 345–352). São Paulo

Jipa, A., Bernhard, M., & Dillenburger, B. (2017). *Submillimeter Formwork*. 2017 TxA Emerging Design + Technology. Austin, Texas, USA.

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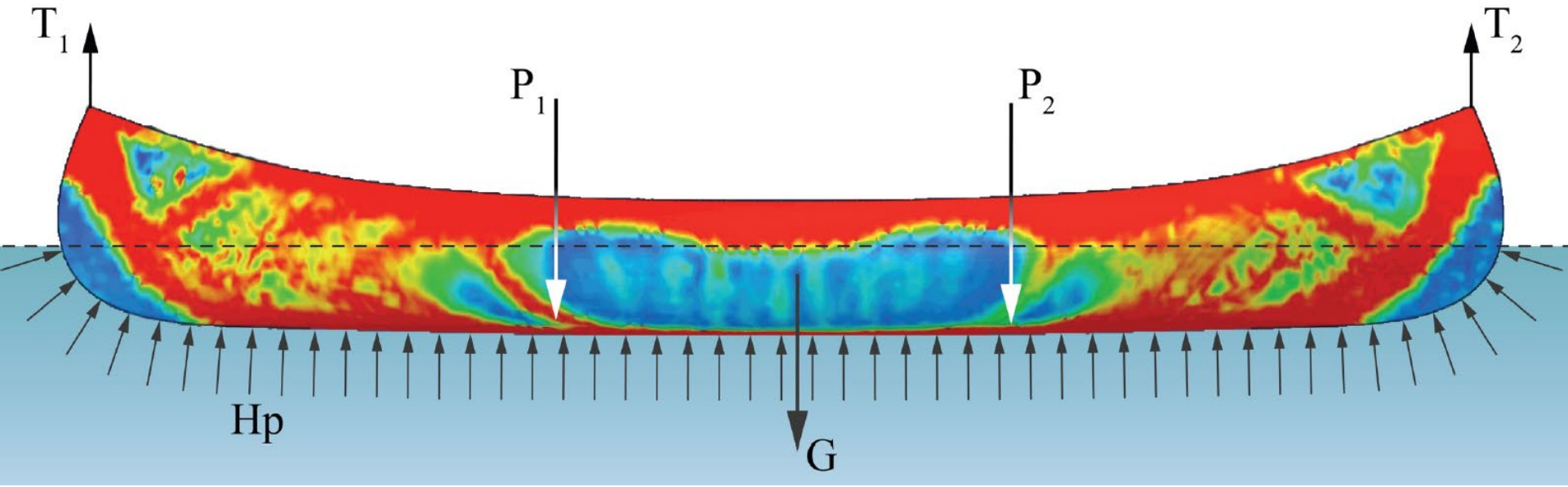
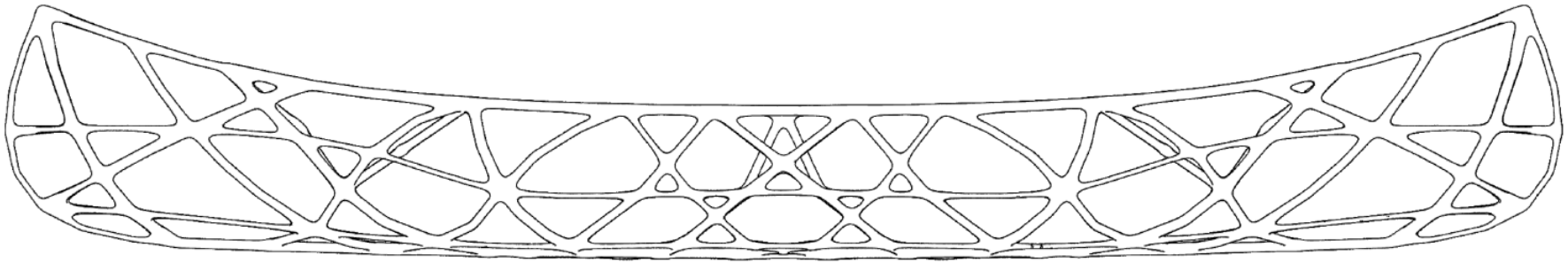
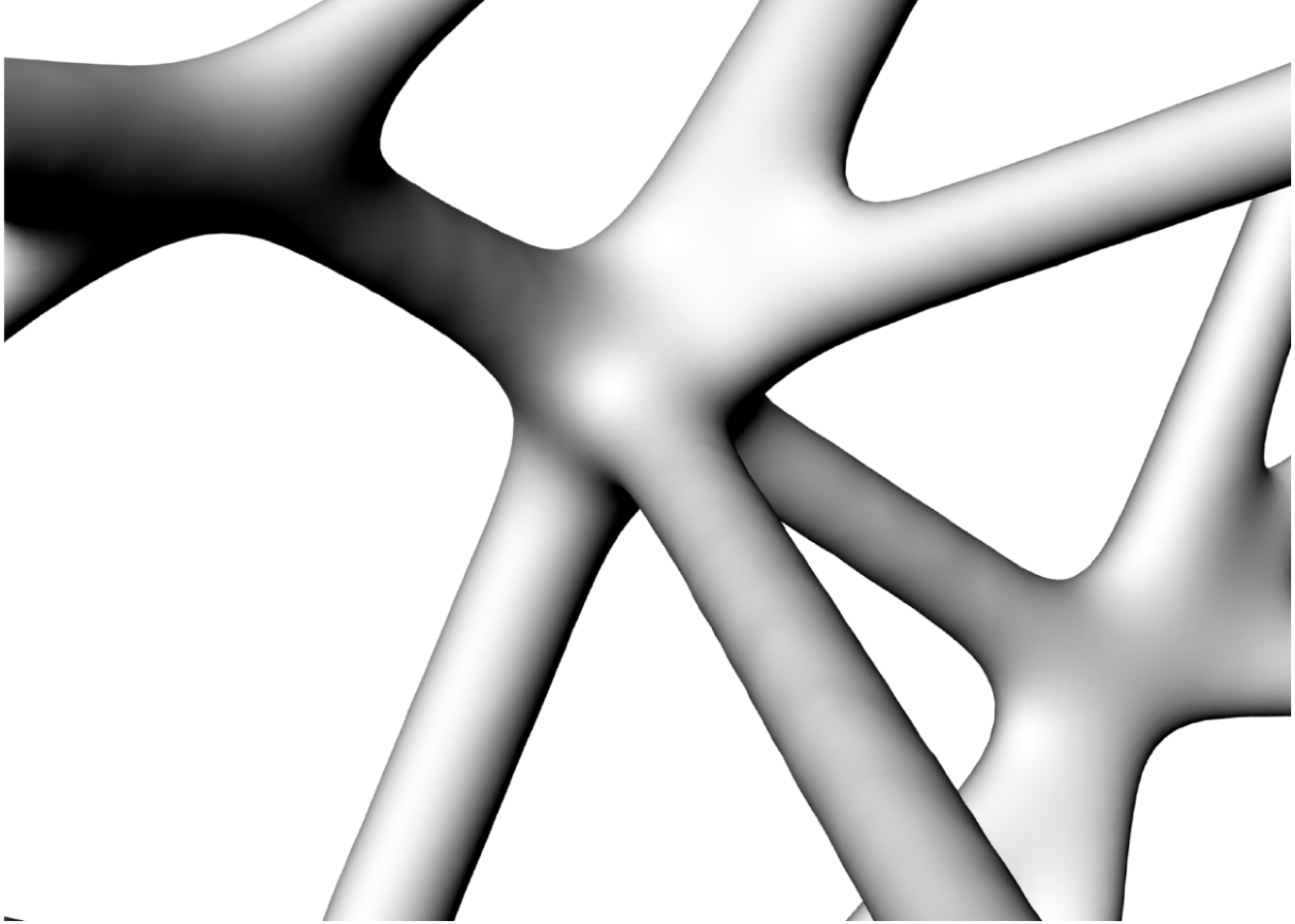
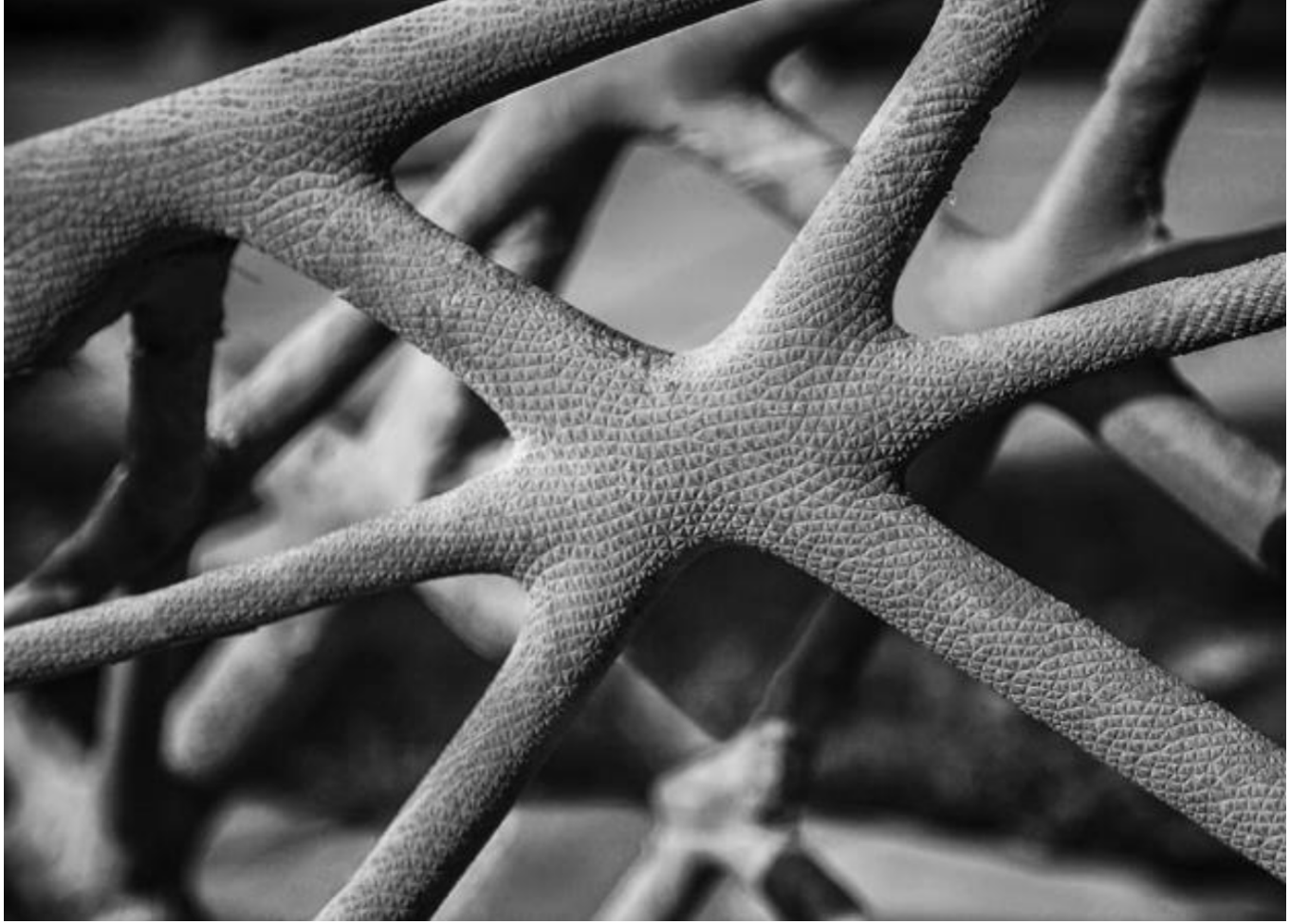
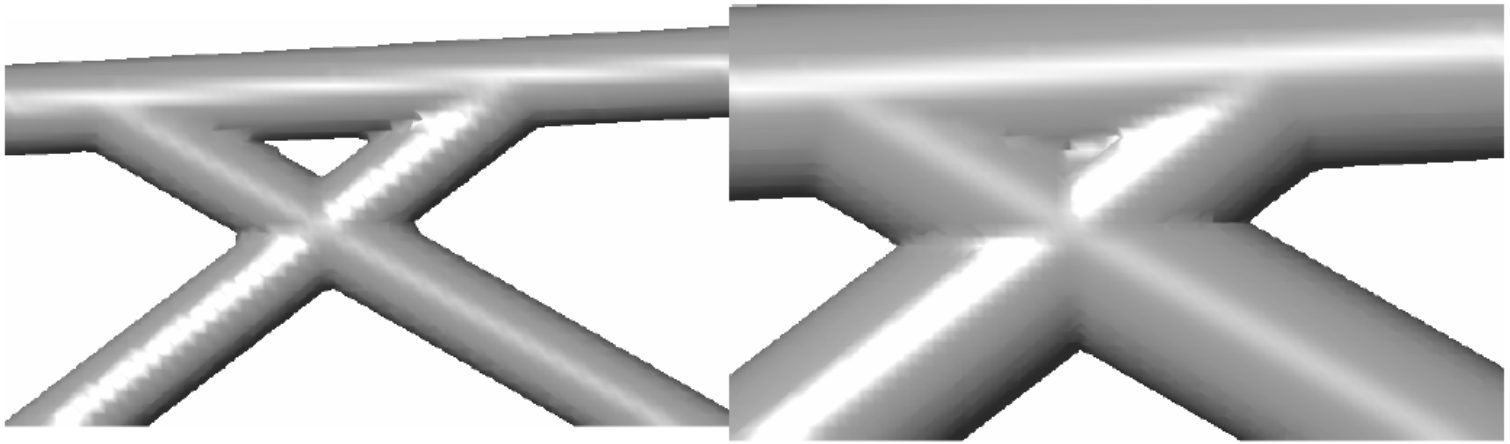

T1
P1
P2
T2
Hp
G



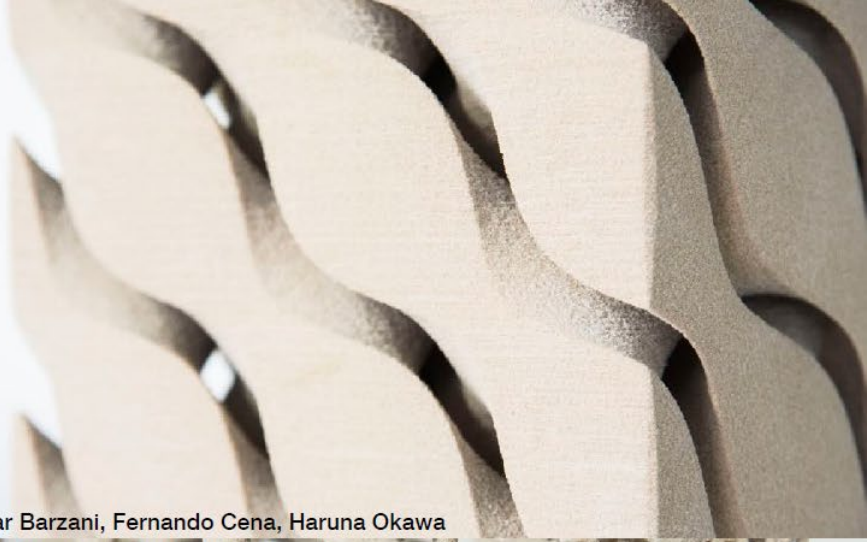






MAS 17/18

Angela Yoo, Jetana Ruangjun
Frank Lin, Jun Su



Sahar Barzani, Fernando Cena, Haruna Okawa
Rafael Pastrana, Francisco Regalado

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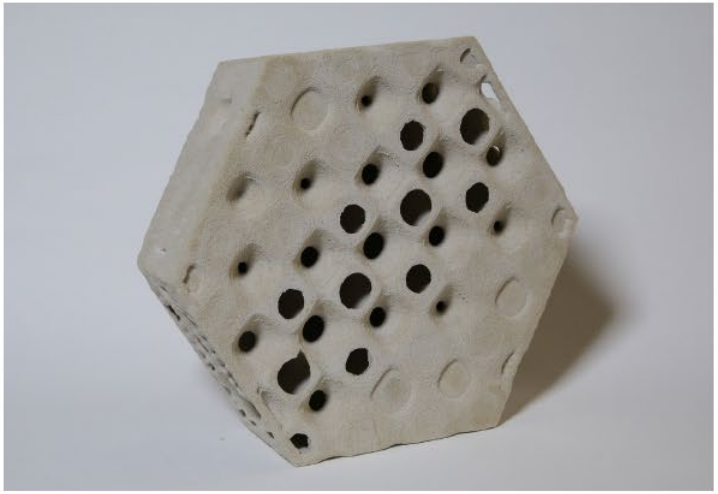
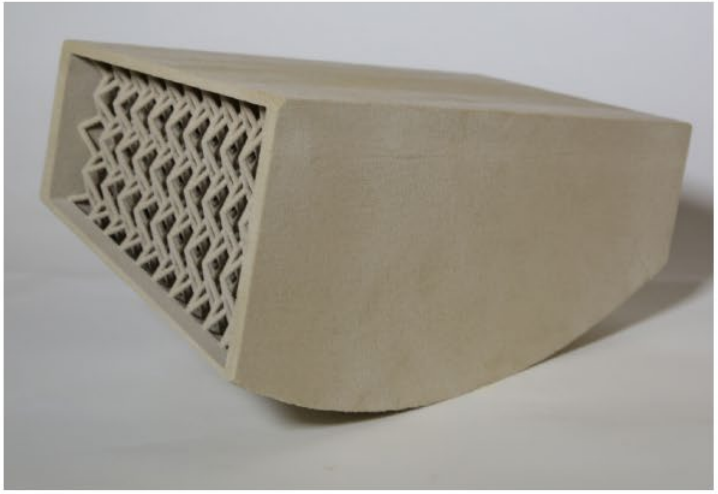




top left: Noor Khader and Yoana Taseva

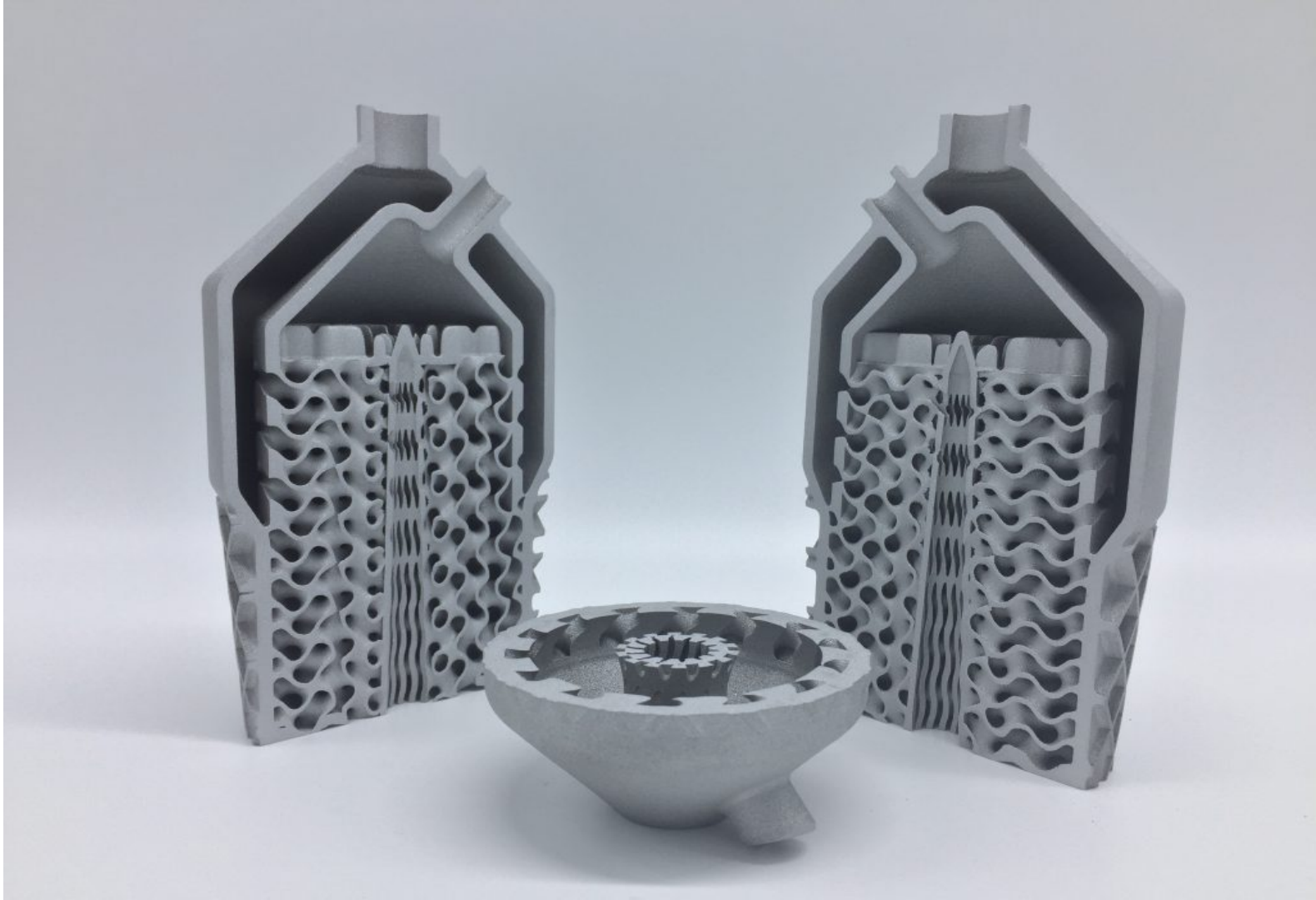
top right: Nik Eftekhar Olivo and Wenqian Yang

bottom left: Antonio Barney and Nicolas Feihl

bottom right: Keerthana Udaykumar and Eleni Skevaki

photos: Tom Mundy

NTopology



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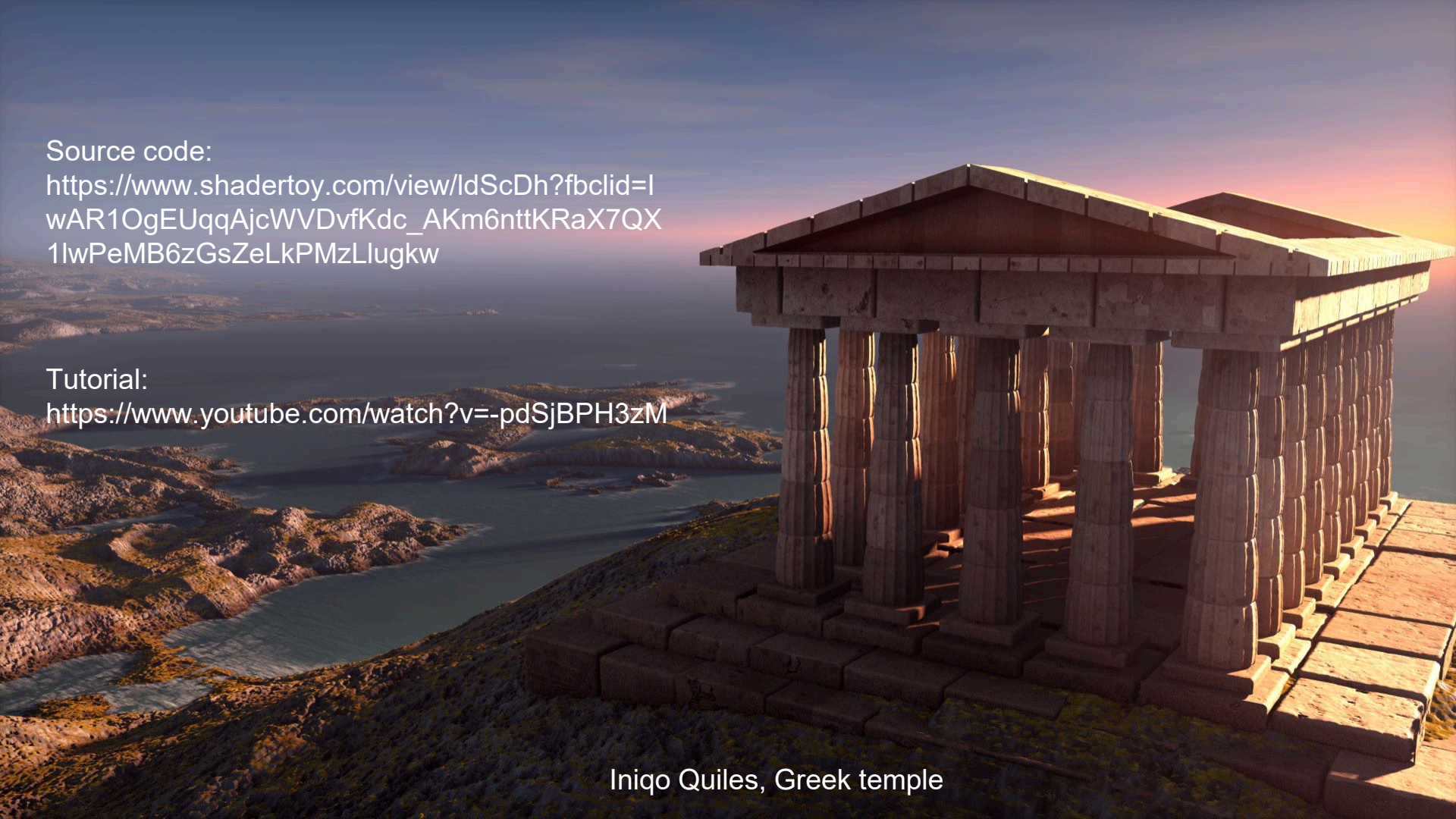
Fermi Paradox by Mercury, Demoscene 2016


Source code:
https://www.shadertoy.com/view/ldScDh?fbclid=IwAR1OgEUqqAjcWVDvfKdc_AKm6nttKRaX7QX1IwPeMB6zGsZeLkPMzLlugkw
Tutorial:
https://www.youtube.com/watch?v=-pdSjBPH3zM
Iniqo Quiles, Greek temple

Summary

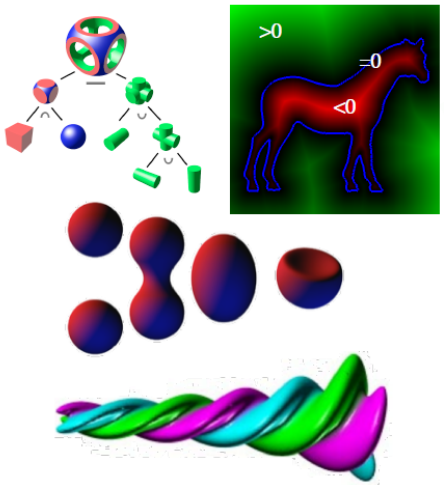
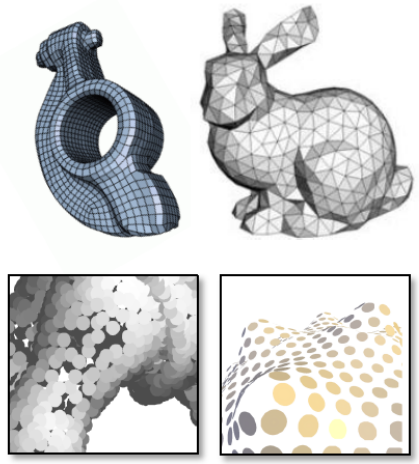
Implicit	Discrete/Sampled
 • Metaballs/blobs • Distance fields	 • Meshes • Point set surfaces

Illustration from igl lab, ETH

Comparison of geometry representation methods

Very compact and lightweight description

implicit

discrete / sampled

Comparison of geometry representation methods

Easy to find points that lie exactly on the surface

implicit

Very compact and lightweight description

discrete / sampled

Comparison of geometry representation methods

Easy to determine if a point is inside
or outside of the surface

implicit	**discrete / sampled**
Very compact and lightweight description	Easy to find points that lie exactly on the surface

Comparison of geometry representation methods

Easy to handle changes in topology

implicit

Very compact and lightweight description

Easy to determine if a point is inside or outside of the surface

discrete / sampled

Easy to find points that lie exactly on the surface

Comparison of geometry representation methods

Intuitive for modeling a complex shape

implicit

Very compact and lightweight description

Easy to determine if a point is inside or outside of the surface

Easy to handle changes in topology

discrete / sampled

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Comparison of geometry representation methods

Is the most standard and widespread
geometry representation

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Easy to determine if a point is inside
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discrete / sampled

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Comparison of geometry representation methods

Easy to create a watertight surface
without holes or degenerate parts

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Volume representation,
has information on the entire space

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Comparison of geometry representation methods

Surface / boundary representation

implicit

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Surface / boundary representation

Thank you