Geometric Modeling
Exercise 1: libigl “Hello World”

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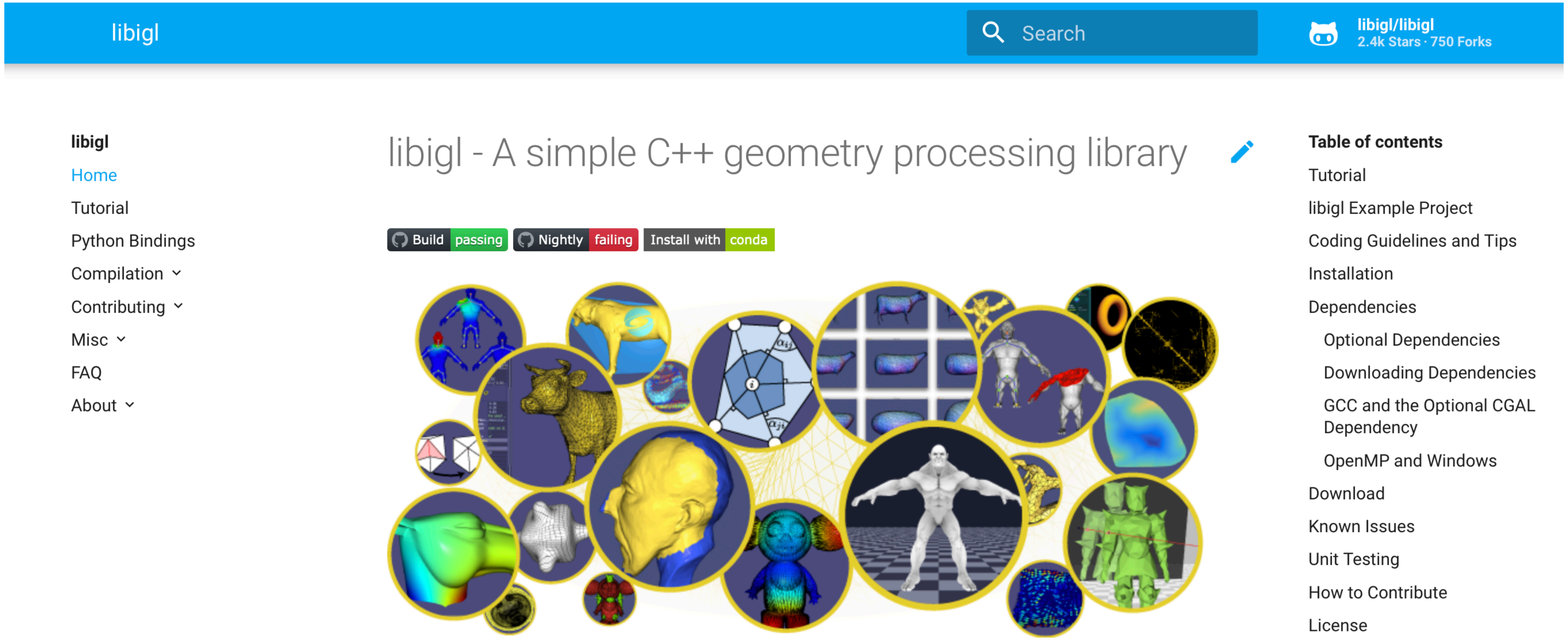
Libigl

- Experiment with the geometry processing library



libigl - A simple C++ geometry processing library

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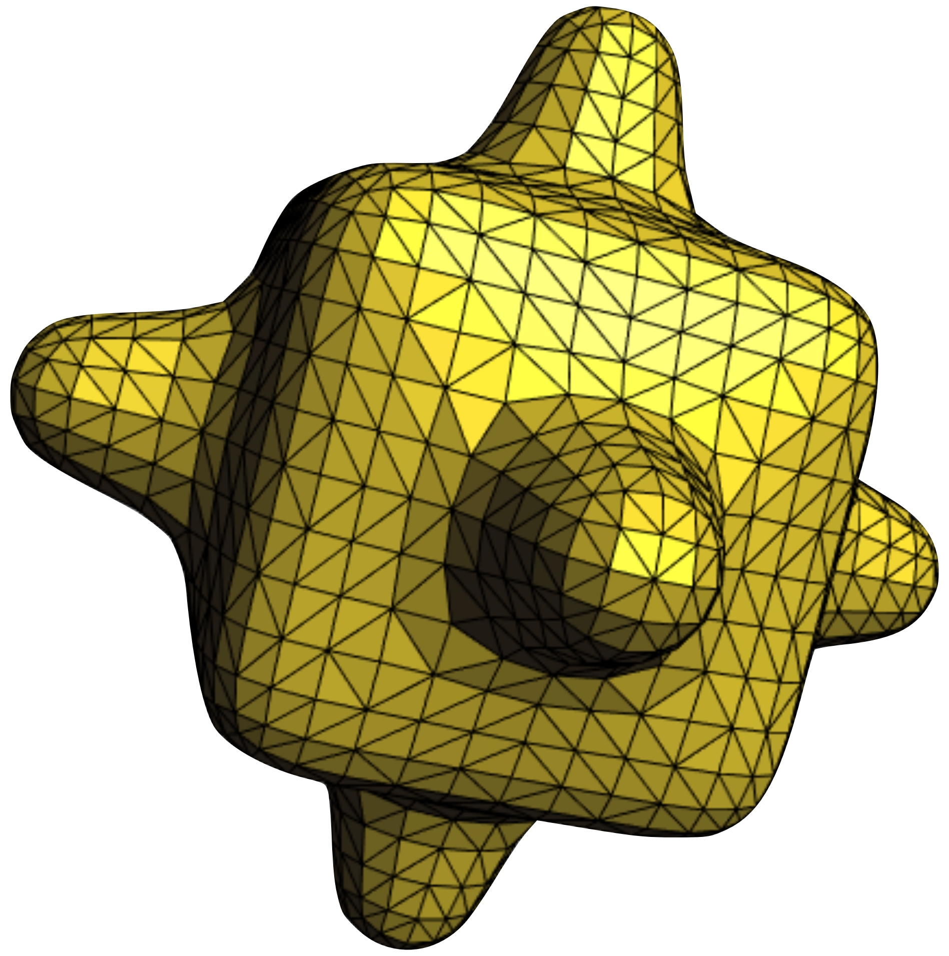
https://libigl.github.io

https://libigl.github.io/libigl-python-bindings/

Read and visualize a mesh

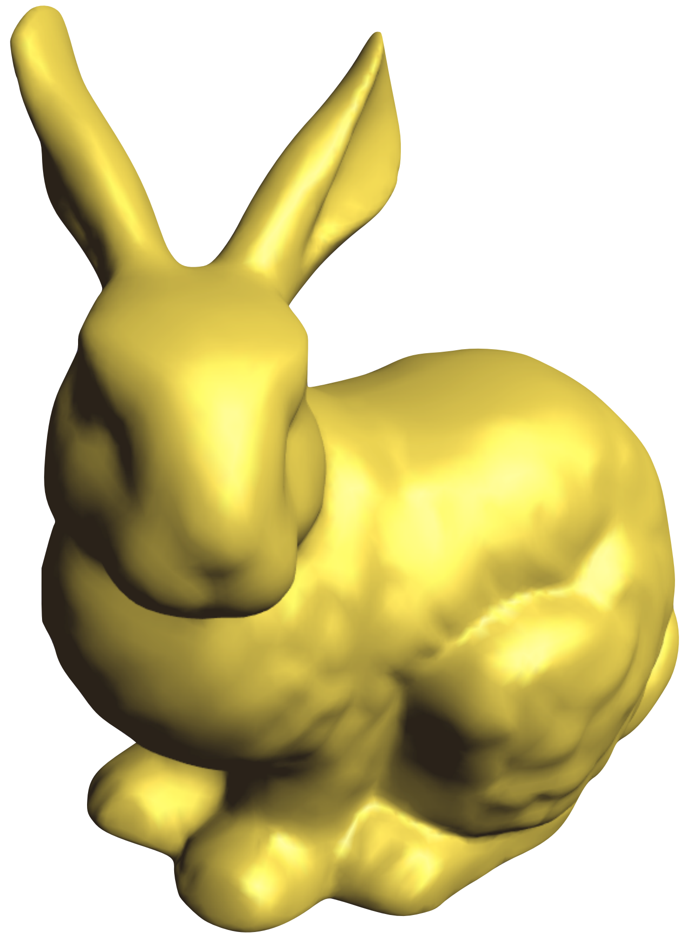
```
OFF
1250 2496 0
-2.09105 -2.09105 2.09105
-0.833333 -2.23958 2.23958
0.833333 -2.23958 2.23958
2.09105 -2.09105 2.09105
...
3 940 83 320
3 386 0 941
...
```

bumpy_cube.off

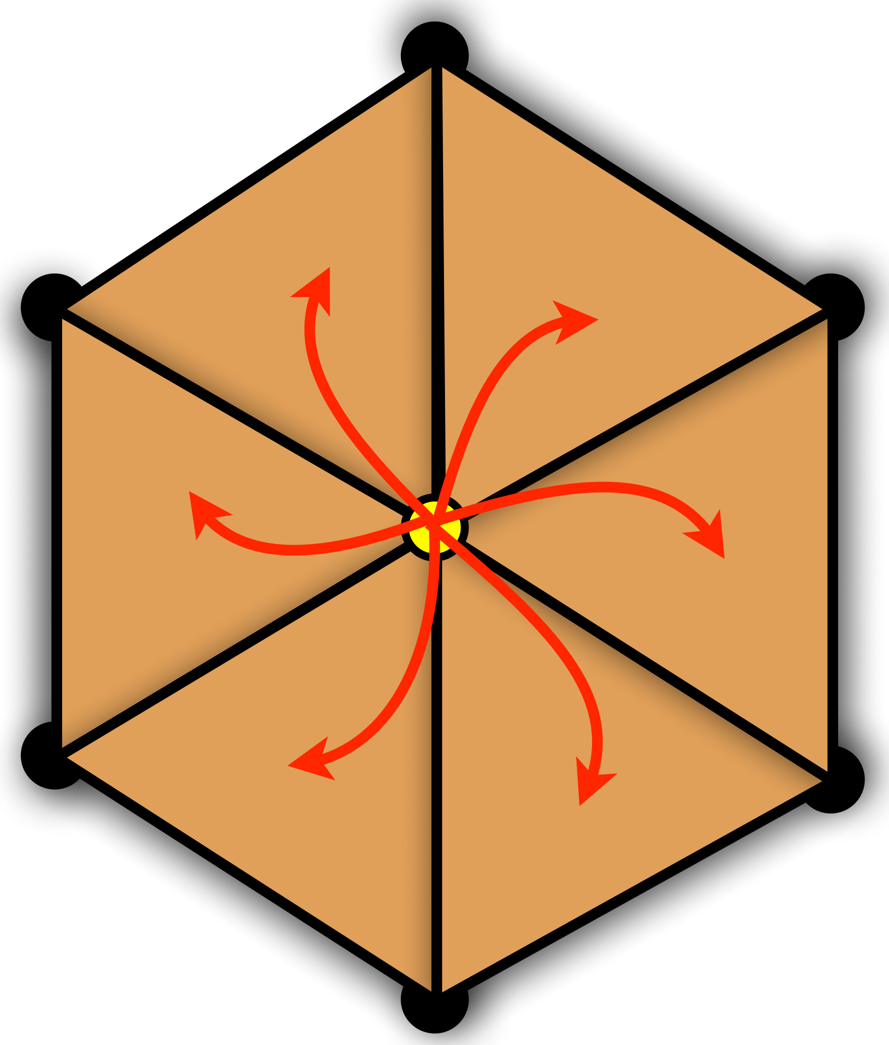


```
# Wavefront OBJ file
v 30.50959969 12.17459898 -15.84426970
v 30.49857998 11.87718728 -15.40759913
v 30.53679943 12.68500615 -14.82485356
v 30.67168999 11.71161003 -15.78844530
...
f  633/16706 11590/29979 4339/16704
f  11590/3161 633/16716 19901/16699
...
```

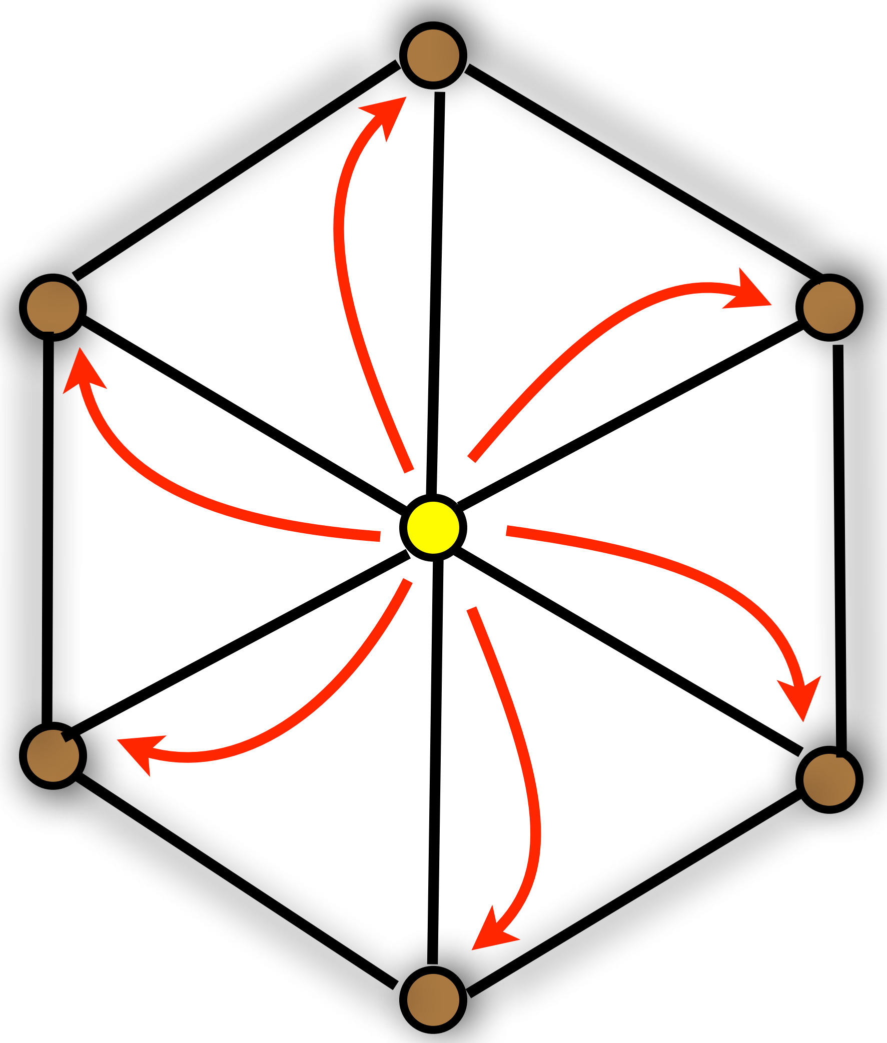
bunny.obj



Perform simple neighborhood calculations



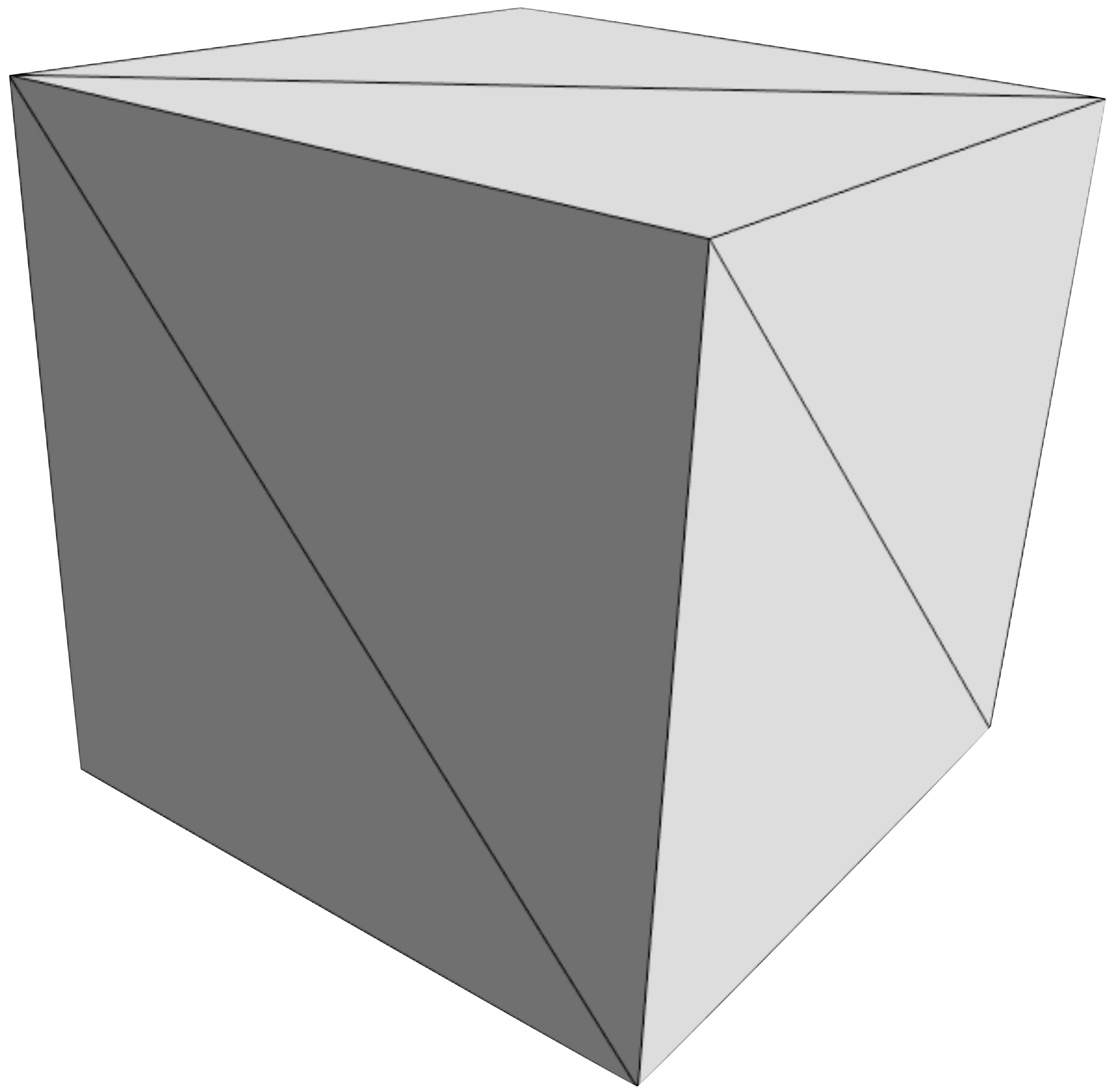
vertex-to-face



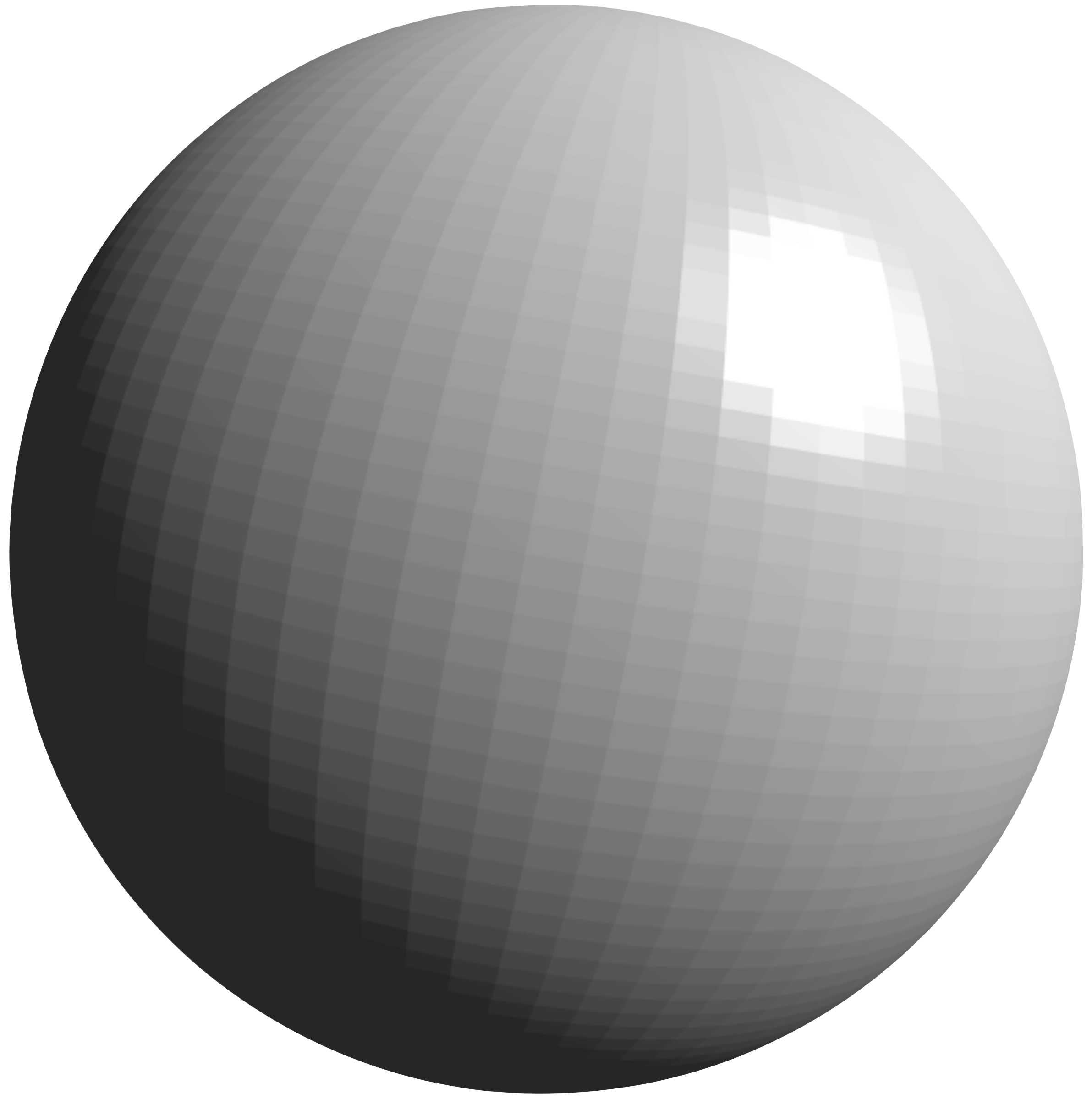
vertex-to-vertex

Flat shading

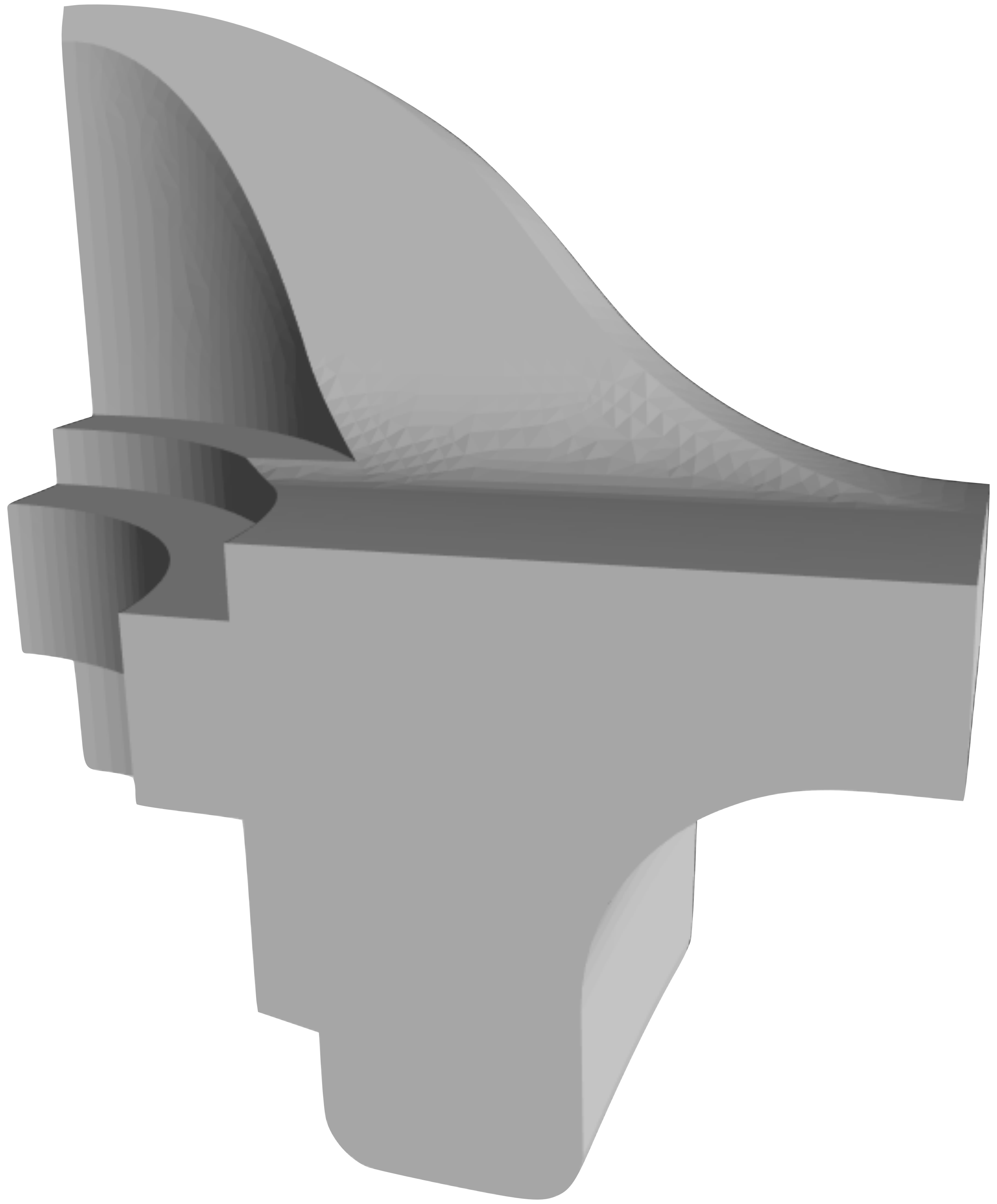
- Compute one normal per polygon



Creased surfaces render well.

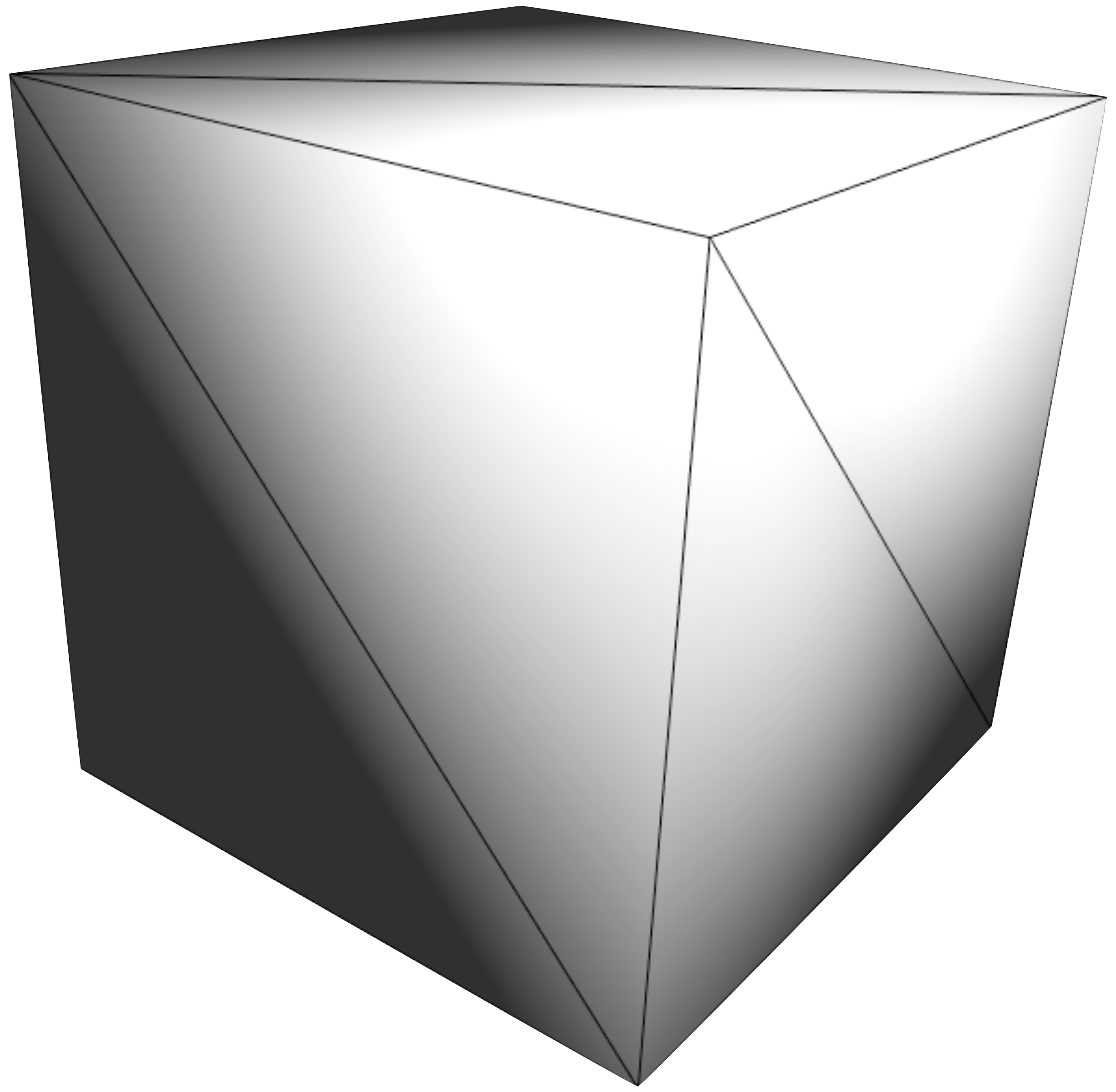


But discontinuous normals lead to poor results for smooth surfaces.



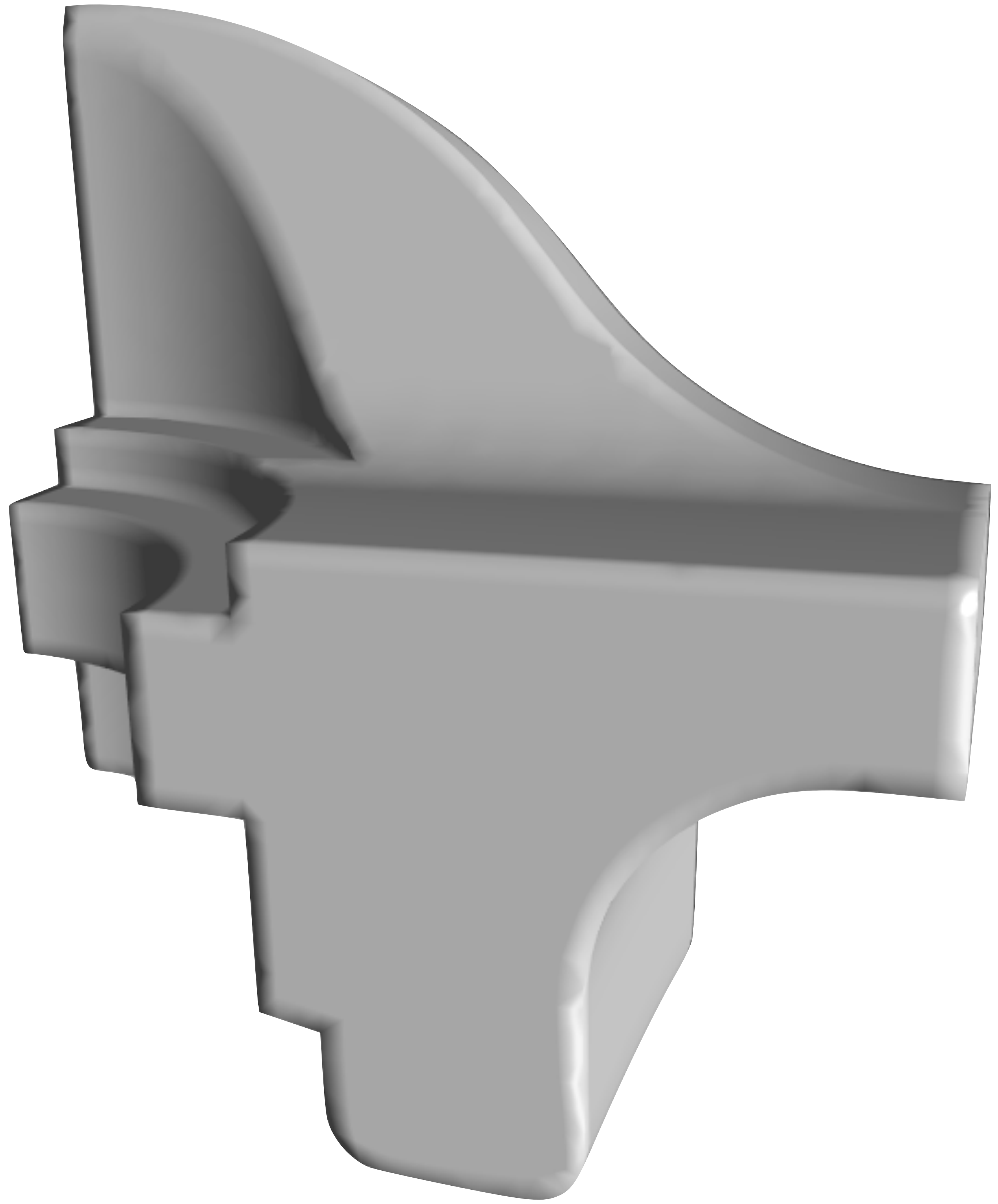
Smooth (Gouraud) Shading

- One normal per vertex (average incident tri's normals)



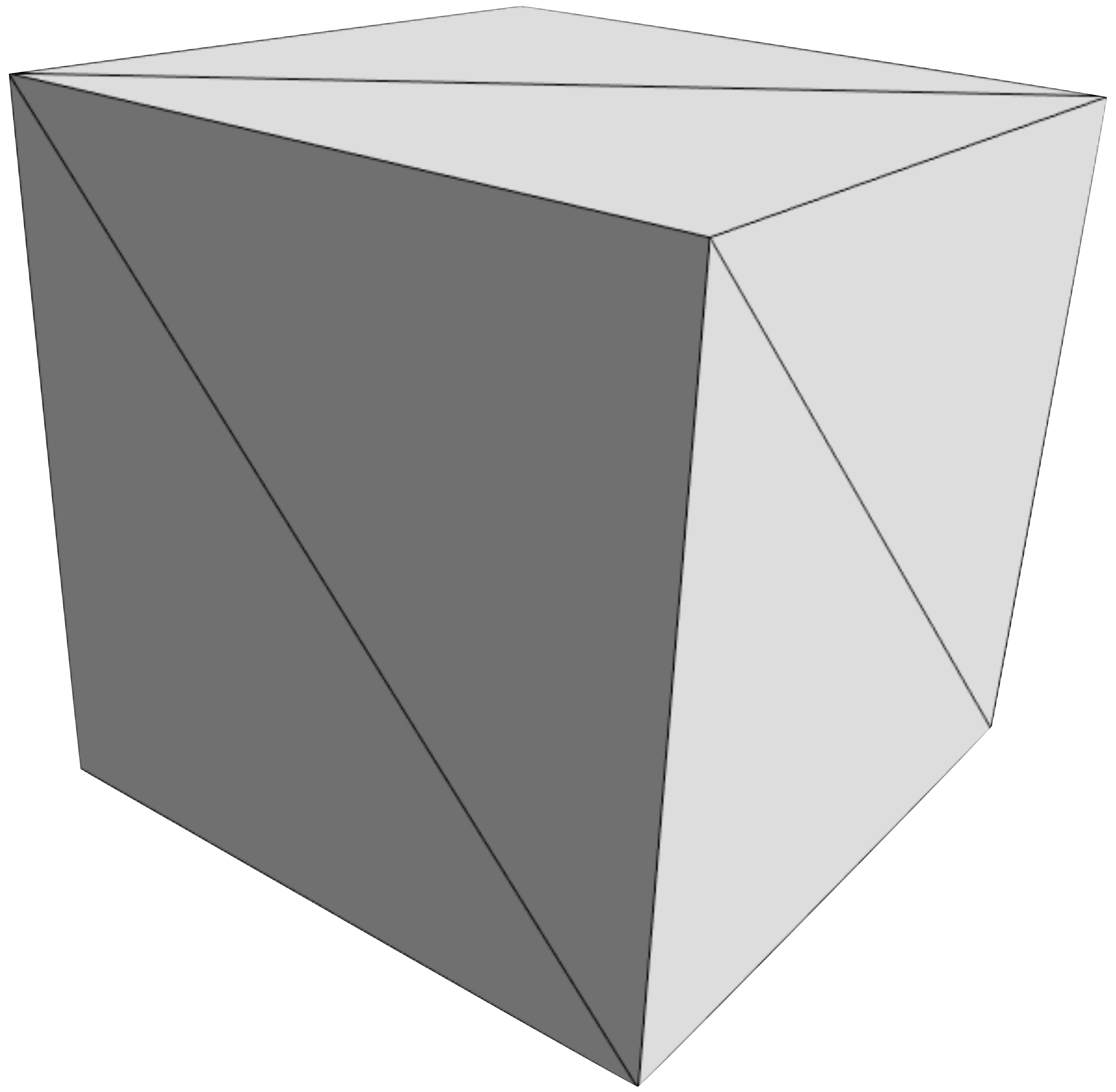
Creased surfaces look strange and burry.

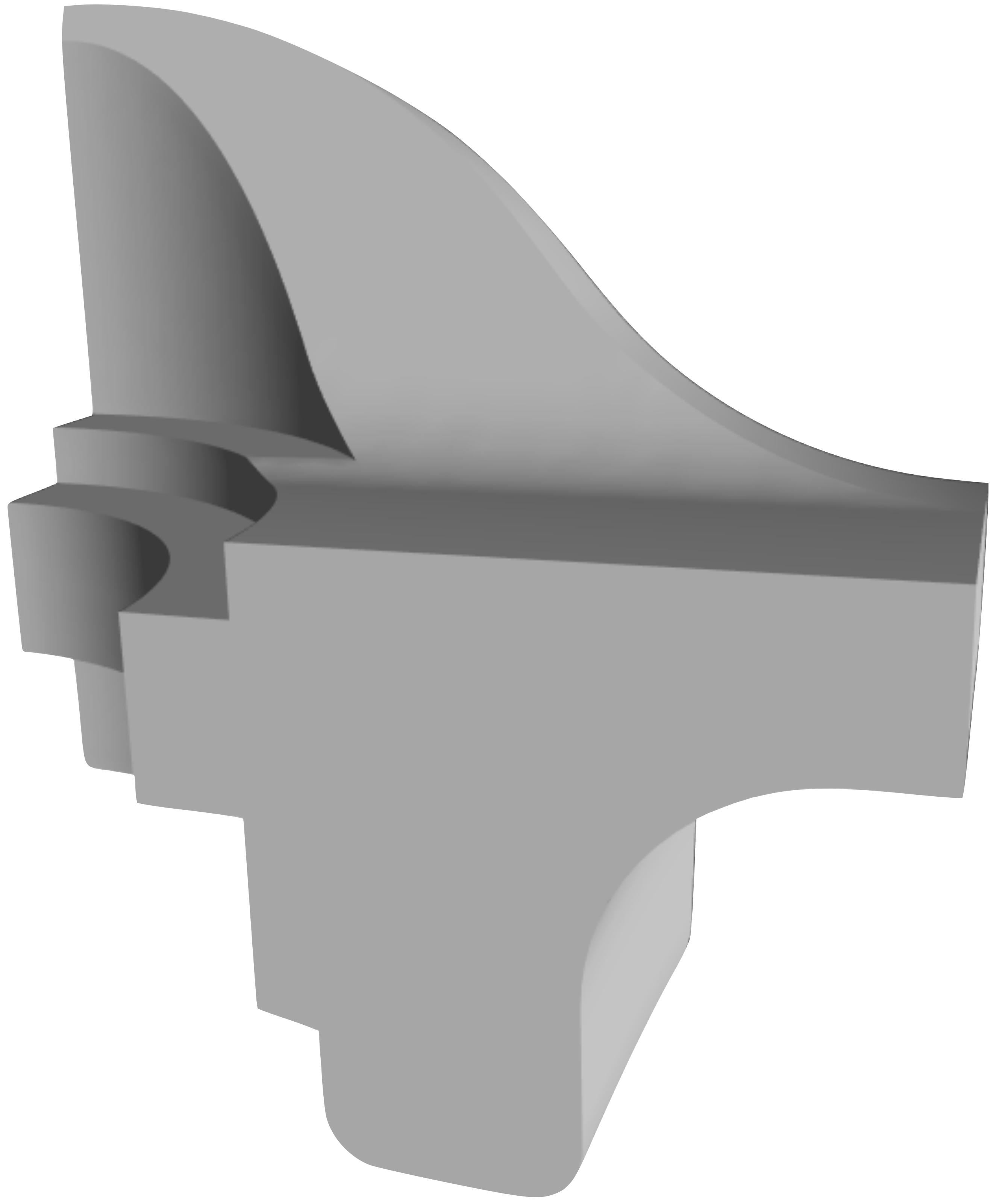
Smooth surfaces look nice.



Per-corner Shading: find a nice balance

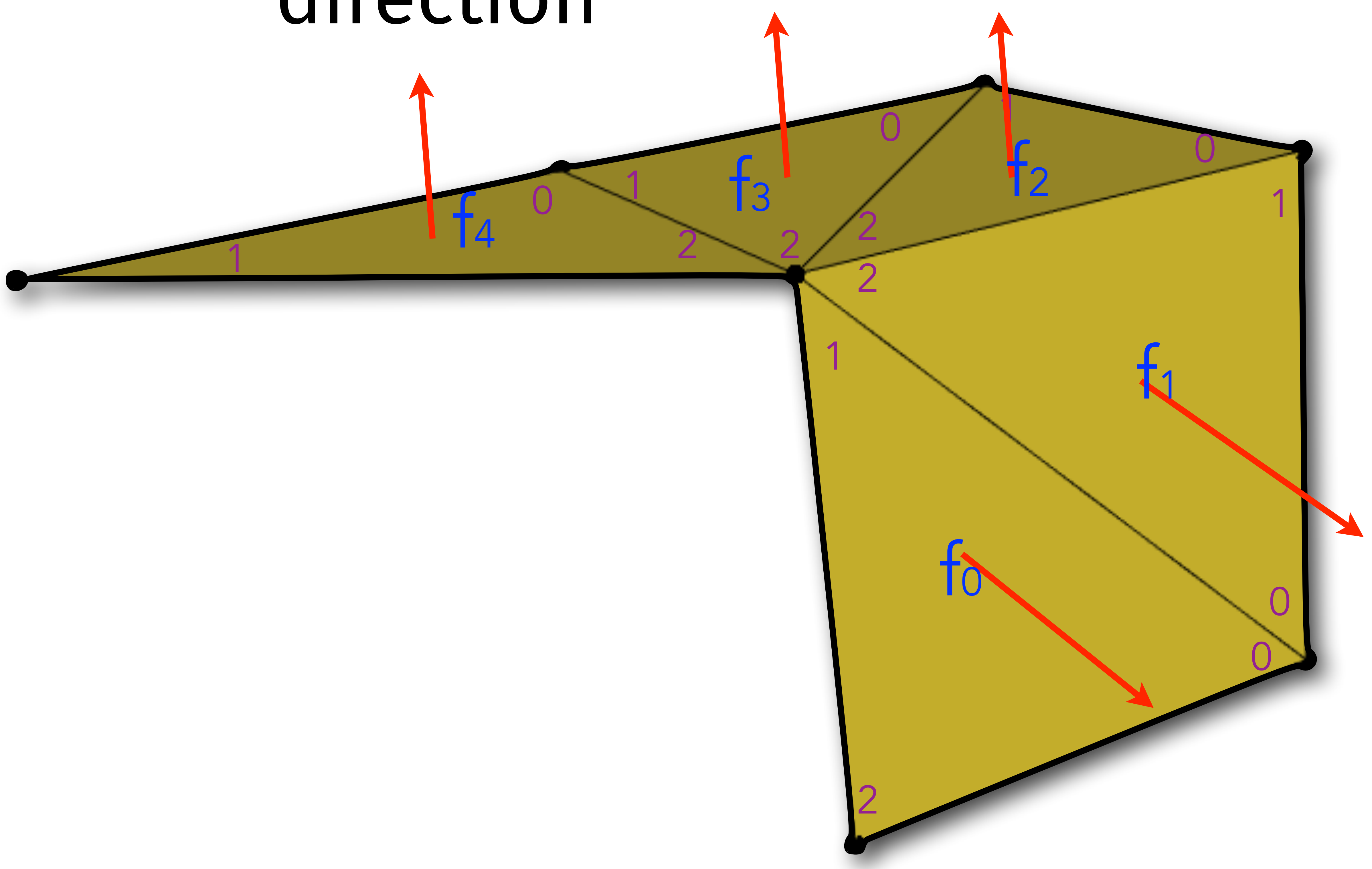
- Compute 3 separate normals for each tri (one per corner)
- Average normals with “smoothly incident neighbors,” but preserve discontinuities across sharp edges.





Corner normals

- For each corner, average adjacent face normals if they're close enough in direction



corner_normals(f4*3+2) =
corner_normals(f3*3+2) =
corner_normals(f2*3+2) =
average(face_normals(f2), face_normals(f3), face_normals(f4))

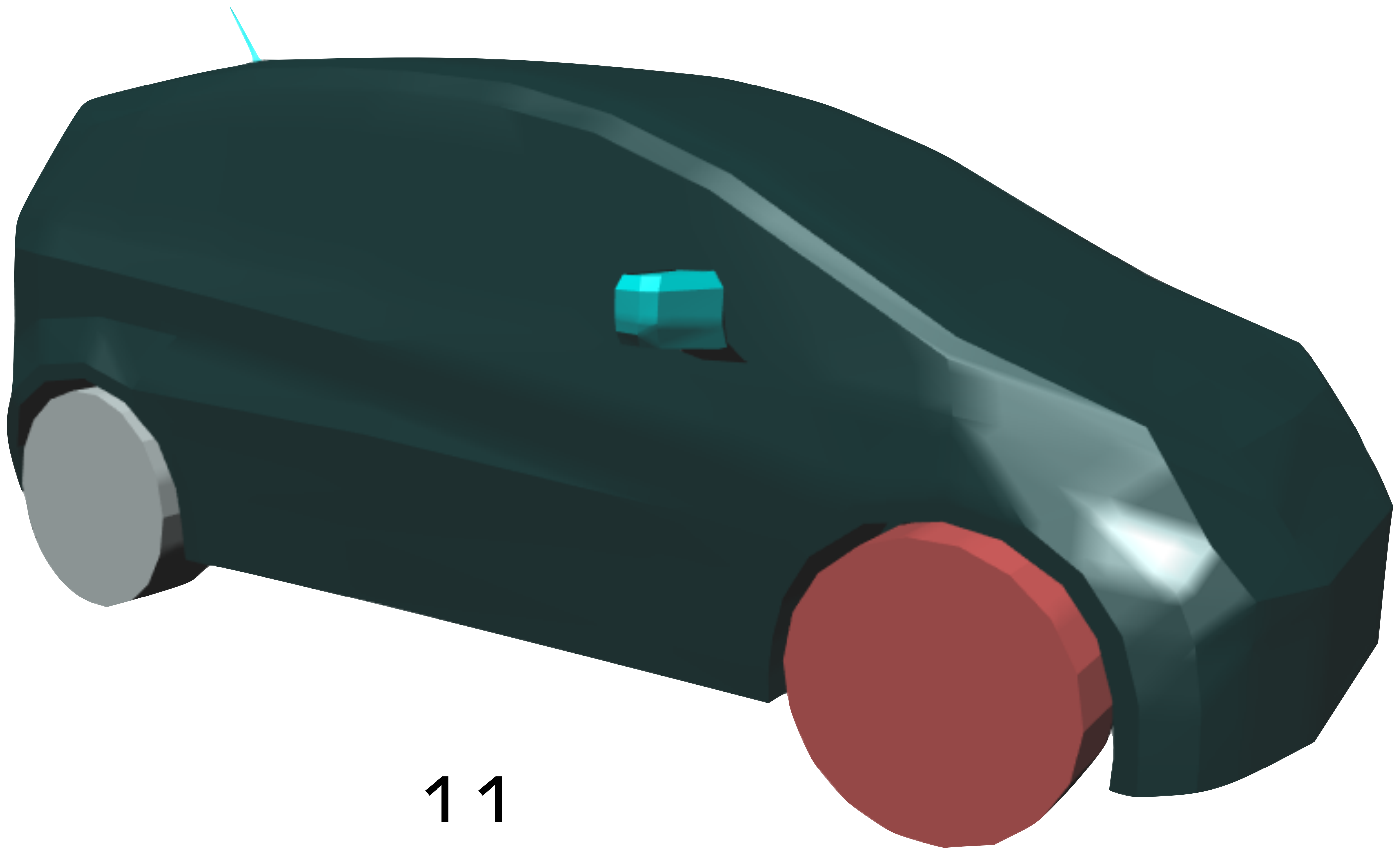
corner_normals(f0*3+1) =
corner_normals(f1*3+2) =
average(face_normals(f0), face_normals(f1))

```
corner_normal(f0*3+0)
corner_normal(f0*3+1)
corner_normal(f0*3+2)
corner_normal(f1*3+0)
corner_normal(f1*3+1)
corner_normal(f1*3+2)
…
corner_normal(f4*3+0)
corner_normal(f4*3+1)
corner_normal(f4*3+2)
```

stack all corner normals for a face sequentially for all faces

corner_normals(i*3+j) =
corner normal at corner j of face i (for triangle faces)

Connected Components



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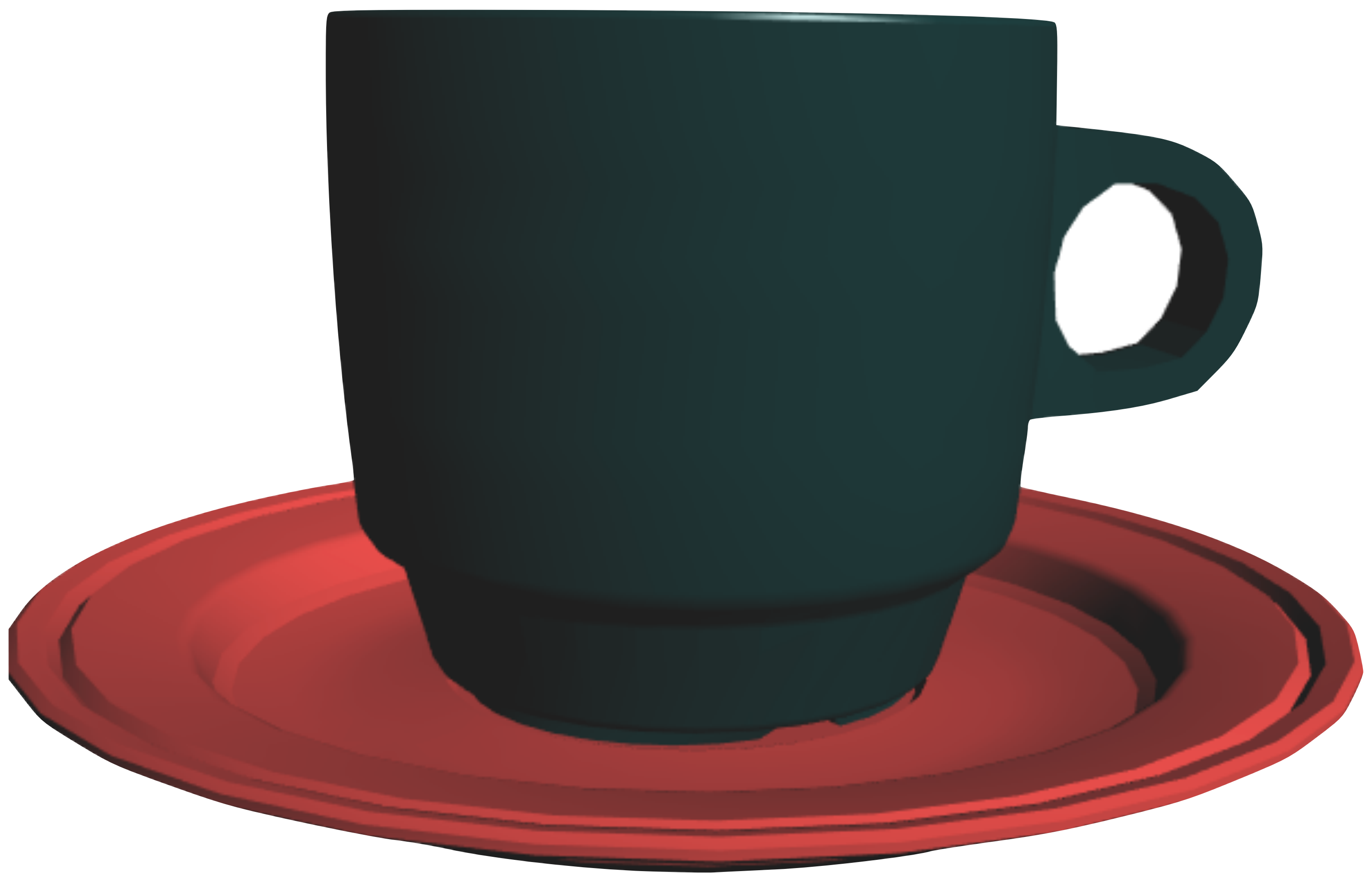
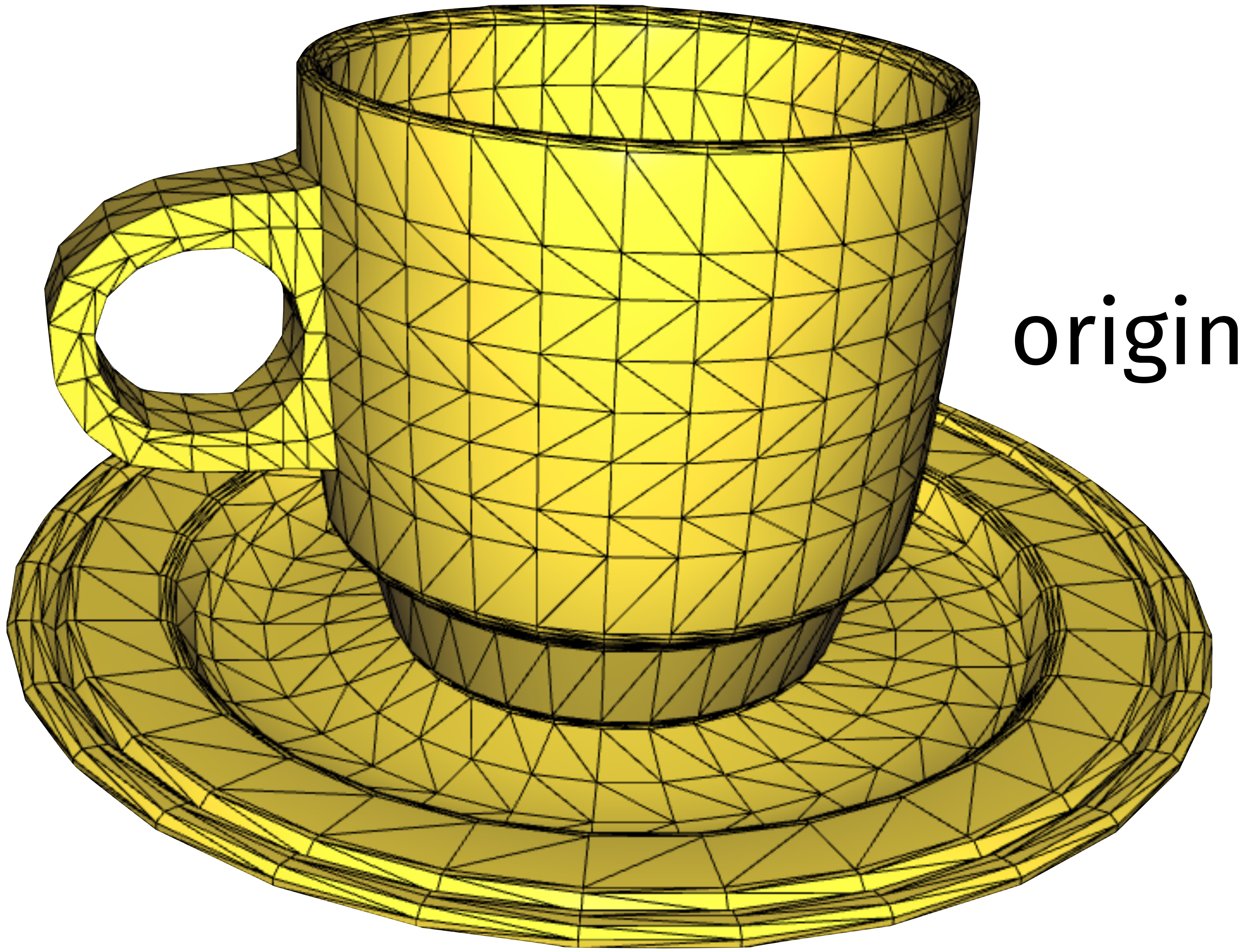
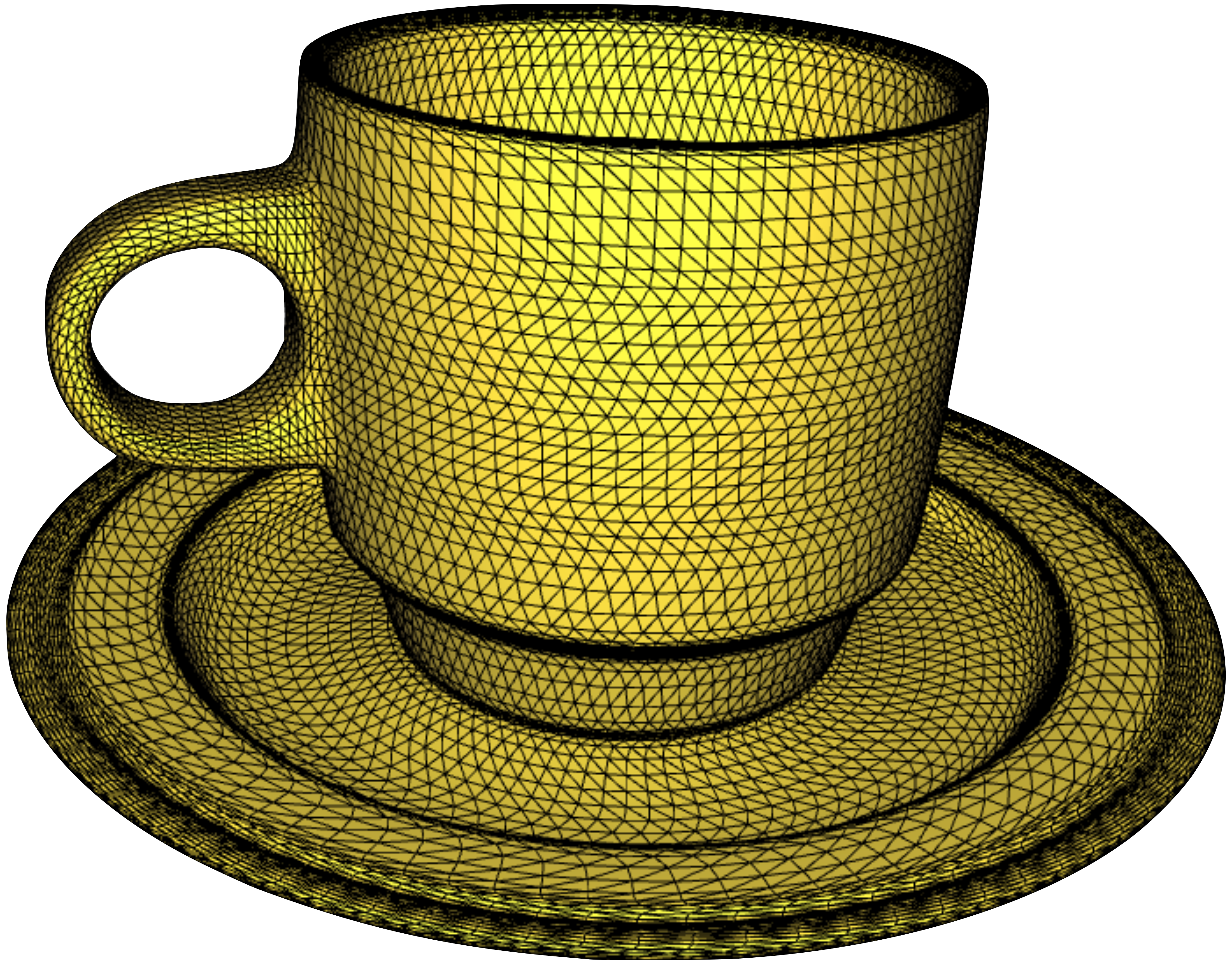


2

Sqrt(3) Subdivision



original



after 2 subd. steps

Sqrt(3) Subdivision

original

add vertices at

connect new

move old vertices

flip original

NumPy and SciPy

- NumPy is the fundamental package for scientific computing with Python. It supports matrices, vectors
  - https://numpy.org

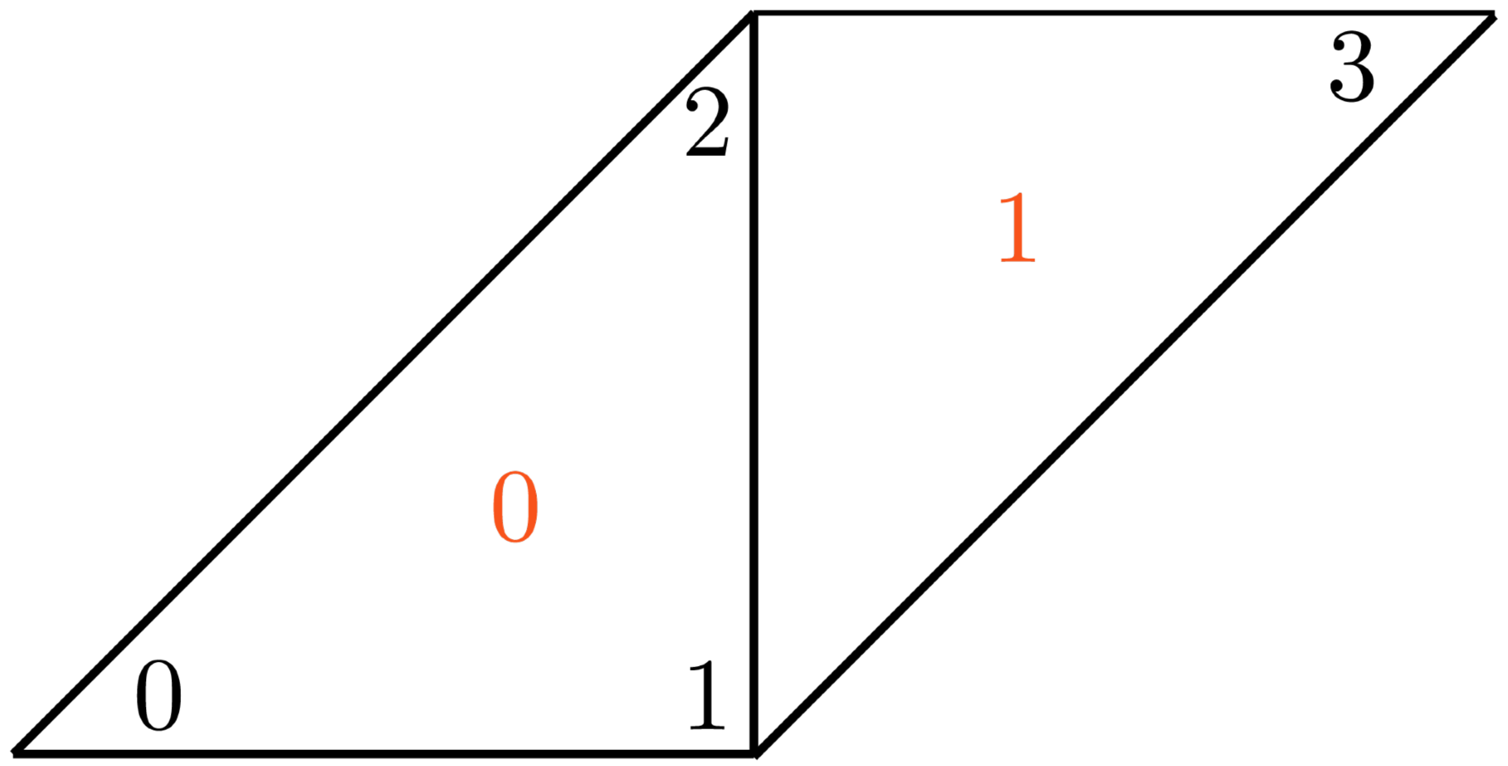
- SciPy is a Python ecosystem of software for mathematics, science, and engineering. In particular it contains numerical solvers, and sparse matrices.
  - https://www.scipy.org

Mesh Representation with NumPy

An numpy matrix

```
numpy.array([...], dtype=...)
```

$$V = \begin{pmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 1 & 1 \\ 2 & 1 & 0 \end{pmatrix} \qquad F = \begin{pmatrix} 0 & 1 & 2 \\ 1 & 3 & 2 \end{pmatrix}$$



- Everything you need to display the mesh

```
V = numpy.array([...], dtype=numpy.double)
F = numpy.array([...], dtype=numpy.int32)
```

Initialization and Element Access

Initialization

```
m1 = numpy.zeros((rows, cols))                  #numpy.double numpy matrix
v1 = numpy.zeros(rows)                          #numpy.double numpy vector
v2 = numpy.array([x, y, z, w])                  #initialize with default values
m2 = numpy.zeros((rows, cols), dtype=numpy.int64) #numpy.int64 numpy matrix
m3 = numpy.eye(size)                            #generate an identity matrix
```

Element Access

```
matrix[i,j]
vector[i]
```

NumPy Quickstart

- Most element-wise and matrix operations supported
  - element-wise addition, subtraction, multiplication
  - multiplication by scalar
  - matrix-matrix multiplication
  - transposition, adjoint
  - norm, normalization
  - dot product
  - cross product (3d vectors only)
  - sub-matrix manipulation
  - trigonometric functions
  - ….

See https://numpy.org/doc/stable/user/quickstart.html

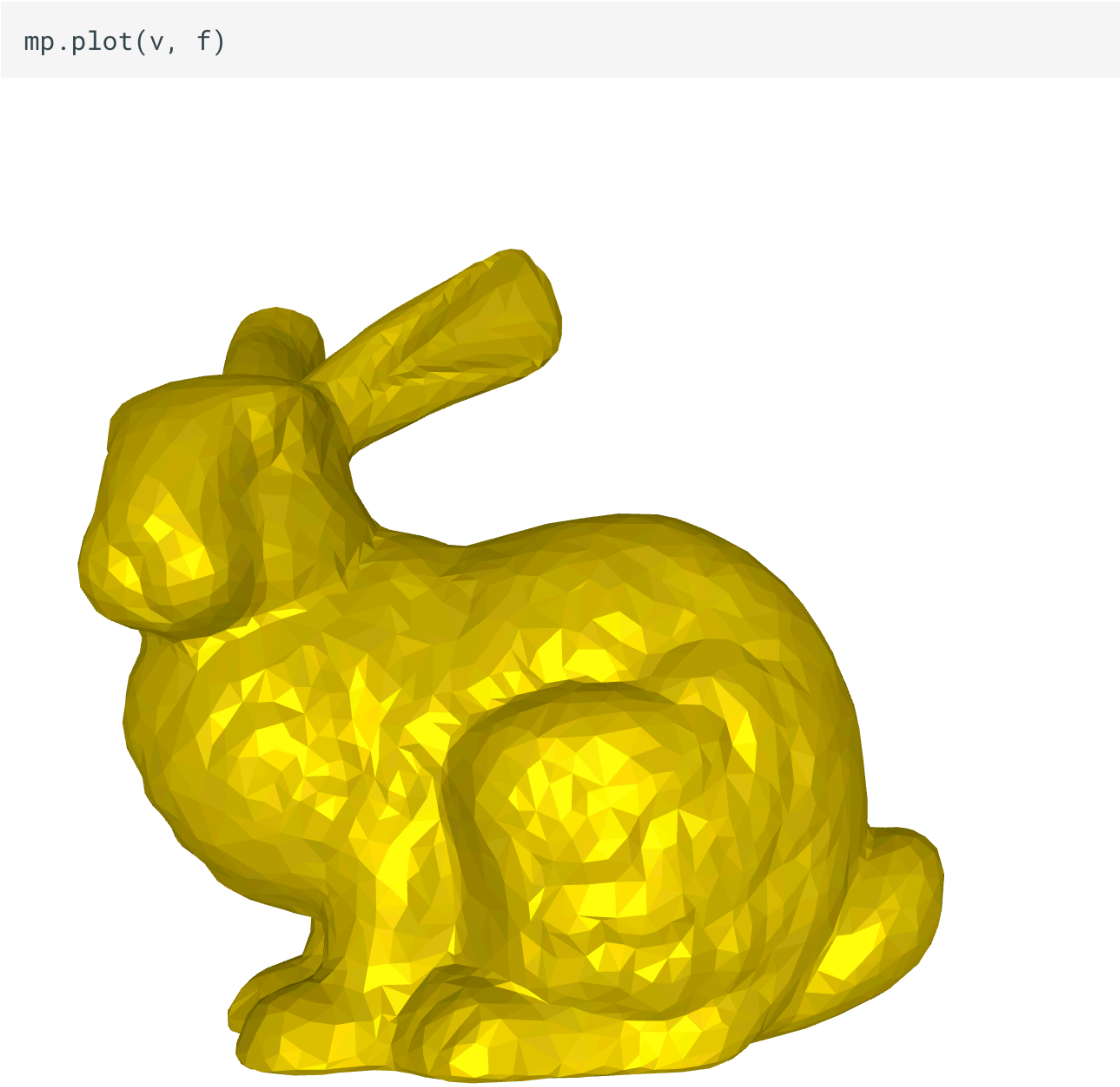
Python Libigl

- https://github.com/libigl/libigl.git
- https://libigl.github.io/libigl-python-bindings/
- Open source C++/Python library for geometry processing
    - No complex data types, only numpy

```
V, F = igl.read_triangle_mesh(“../shared/cube.off”)
```

The meshplot Viewer

- Very basic UI options
    - Rotate (left click and drag)
      Translate (right click and drag)
      Zoom (scroll)
    - Texture/normals
    - Some material/color options
- Integrated in Jupyter
- https://skoch9.github.io/meshplot/

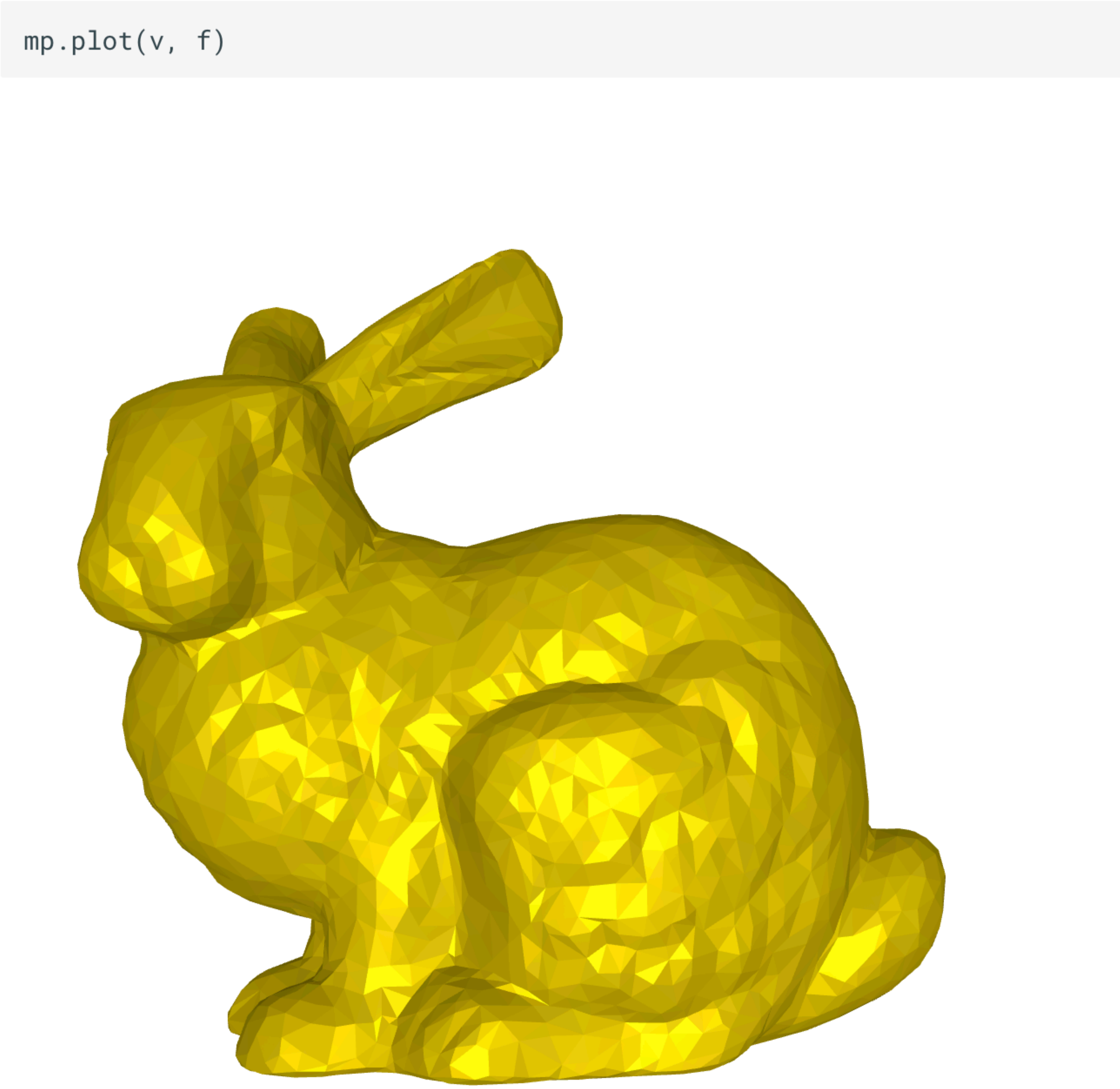


```
mp.plot(v, f)
```

“Hello Viewer”

```
import igl
import meshplot

V, F = igl.read_triangle_mesh("bunny.off")
meshplot.plot(V, F)
  shading={"wireframe": True})
```



```
mp.plot(v, f)
```

Python Setup for Assignment 1

- Anaconda is a package manager used in particular for Python

- For the course you will need some libraries

- Anaconda (or Miniconda) can be installed form https://docs.conda.io/en/latest/miniconda.html

- We suggest to install them trough conda

Conda Setup

- In a terminal (or conda terminal) type

```
conda create -n gp
conda activate gp

conda config --add channels conda-forge

conda install numpy
conda install scipy
conda install igl
conda install meshplot
conda install notebook
```

Creates a new virtual environment called gp

Activates the environment, all changes will affect only the gp environment

Add a new channel, all libraries are on conda-forge

Installs the necessary packages