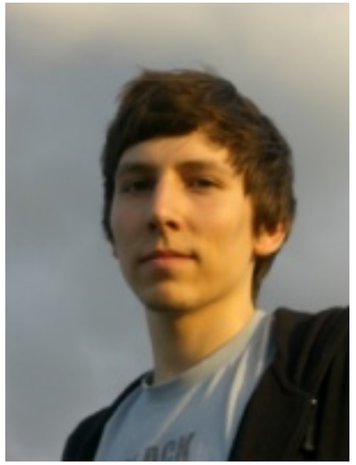
Geometric Computing with Python

Sebastian Koch, **Teseo** Schneider, Francis Williams,
Chencheng Li, **Daniele** Panozzo

https://geometryprocessing.github.io/geometric-computing-python/

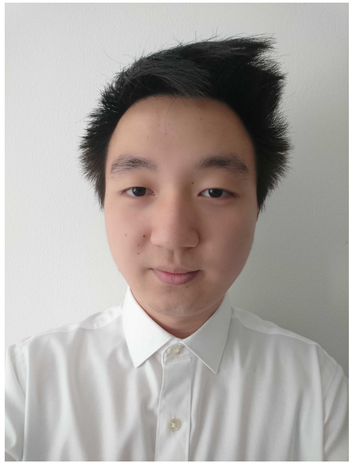
Who are we?



Sebastian Koch

Teseo Schneider

Francis Williams



ChenCheng Li

Daniele Panozzo

Course Goals

- Learn how to design, program, and analyze algorithms for **geometric computing**
- Hands-on experience with shape modeling and geometry processing algorithms
- Learn how to batch process large collections of geometric data and integrate it in deep learning pipelines

Geometric Computing

Geometric Computing

Discrete Differential Geometry

- Surface and volumes representation
- Differential properties and operators

Geometric Computing

Discrete Differential Geometry

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- Differential properties and operators

Numerical Method for PDEs

- Focus on real-time approximations
- Irregular domains

Geometric Computing

Discrete Differential Geometry

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- Differential properties and operators

High Performance Computing

- Vectorized computation
- Multi-core and distributed computation
- GPU accelerators

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Geometric Computing

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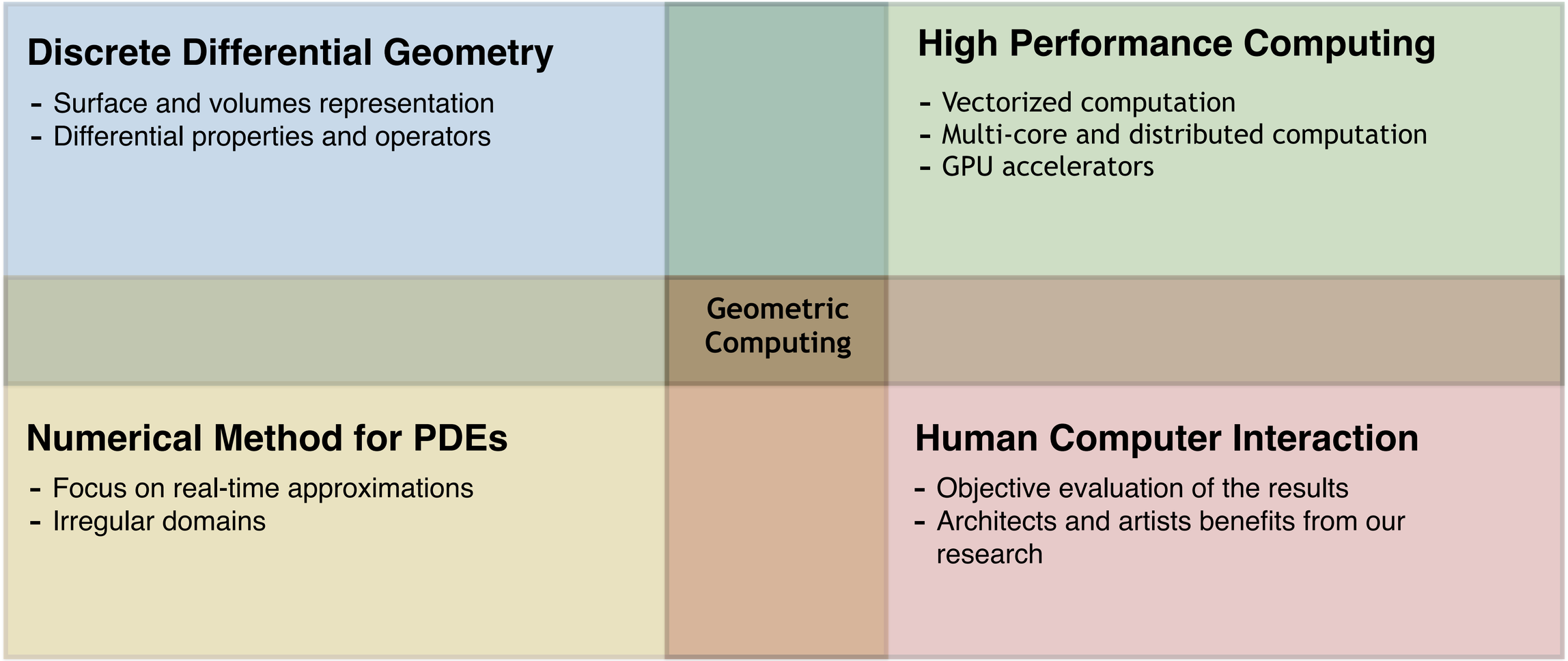
- Irregular domains

Human Computer Interaction

- Objective evaluation of the results
- Architects and artists benefits from our research

Geometric Computing



Geometric Computing

Big Data

Discrete Differential Geometry

- Surface and volumes representation
- Differential properties and operators

High Performance Computing

- Vectorized computation
- Multi-core and distributed computation
- GPU accelerators

Geometric Computing

Numerical Method for PDEs

- Focus on real-time approximations
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Human Computer Interaction

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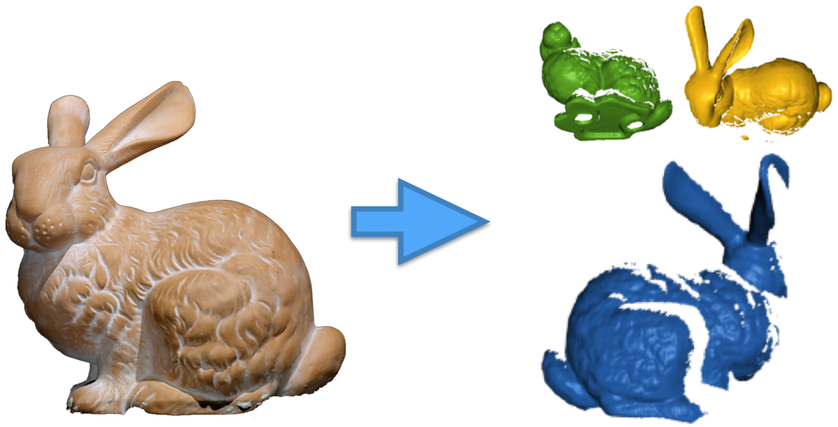
Geometric Computing

Geometric Computing

Physical Object

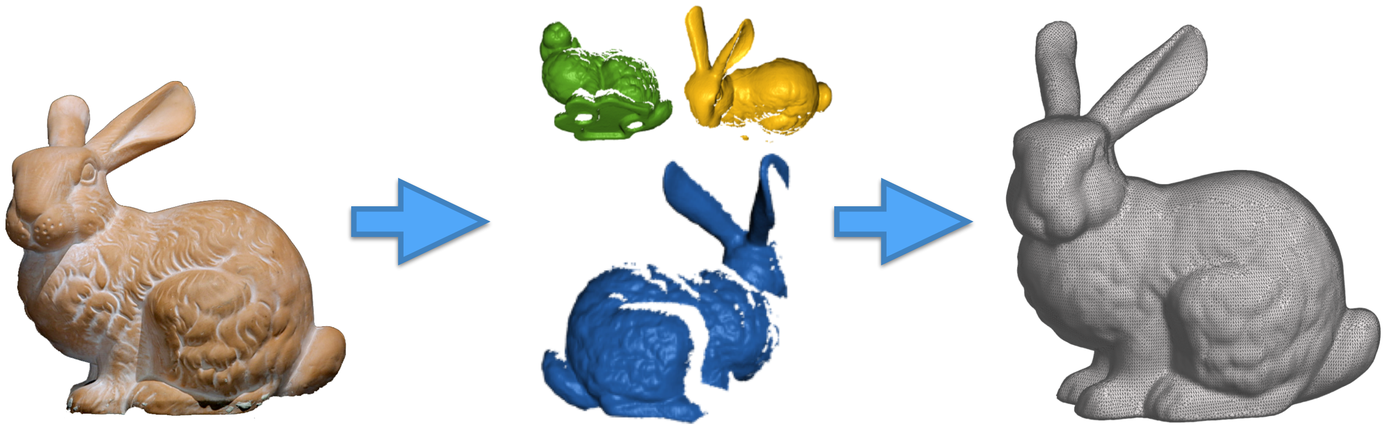
Geometric Computing



Physical Object

Range Images

Geometric Computing

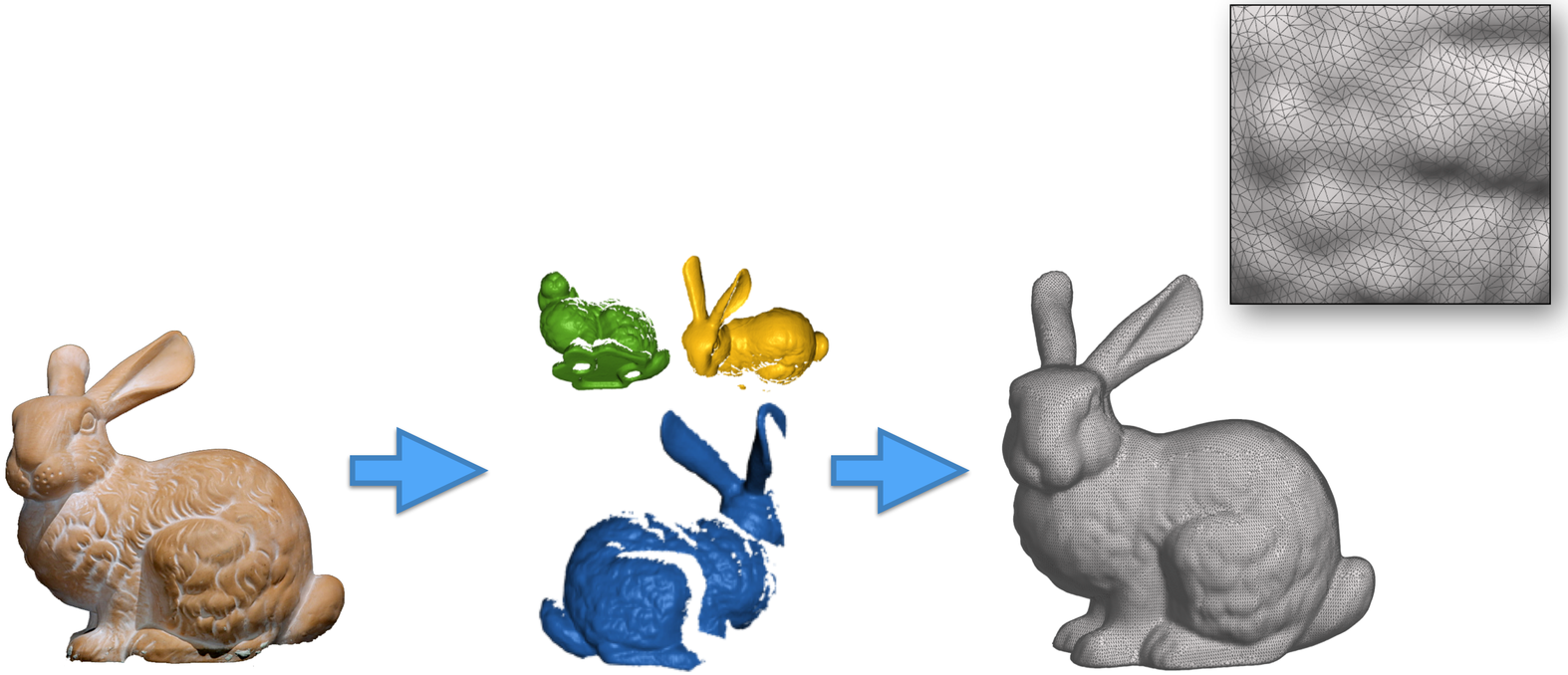


Physical Object

Range Images

Unstructured Model

Geometric Computing



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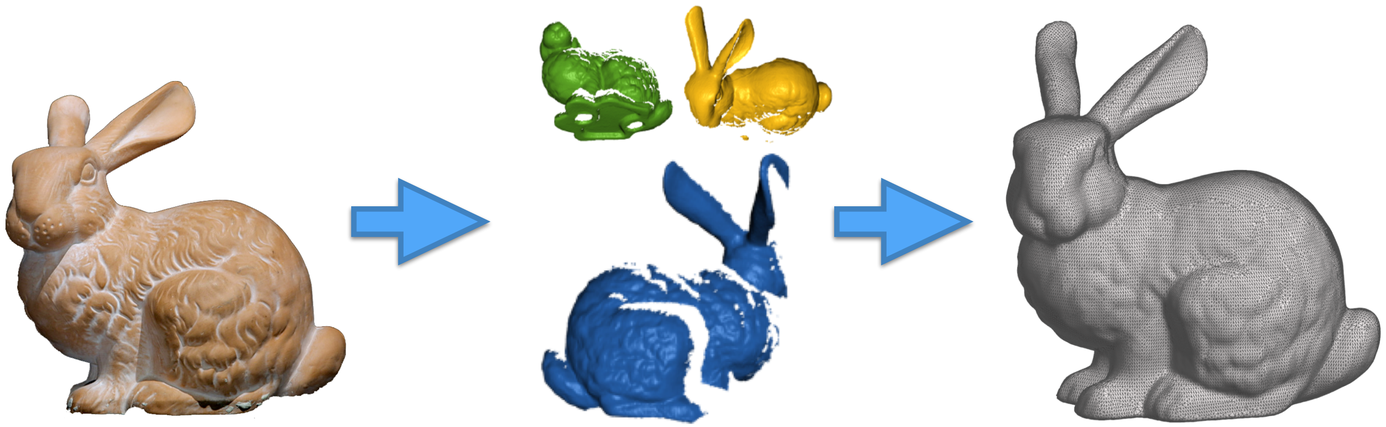

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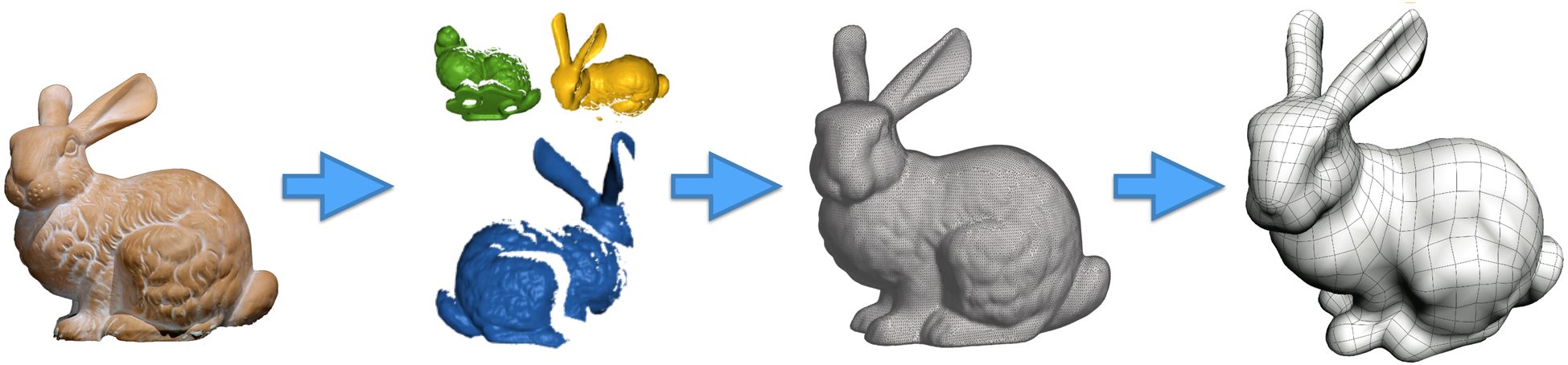

Physical Object

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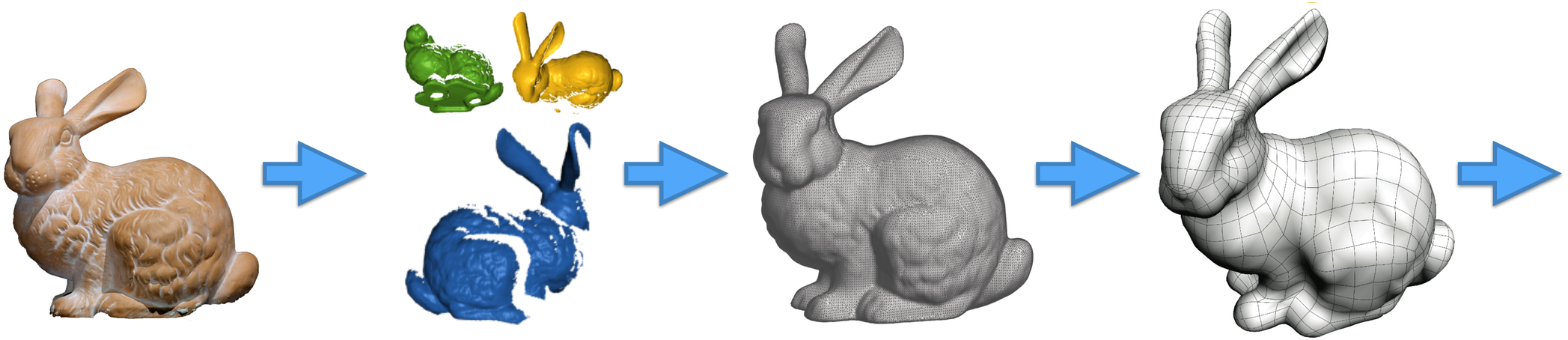
Structured Model

Geometric Computing



Physical Object

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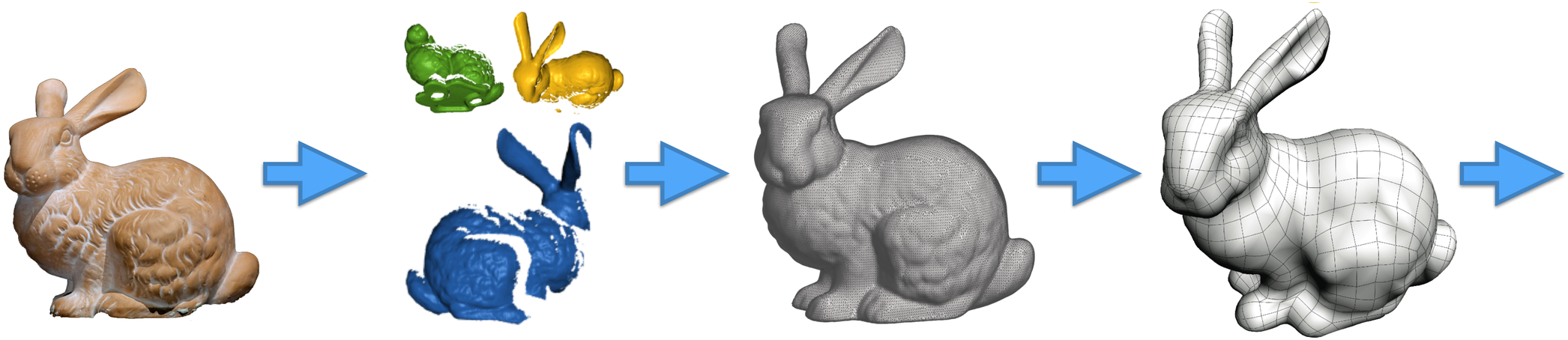
Applications

Geometric Computing

Animation



Physical Object

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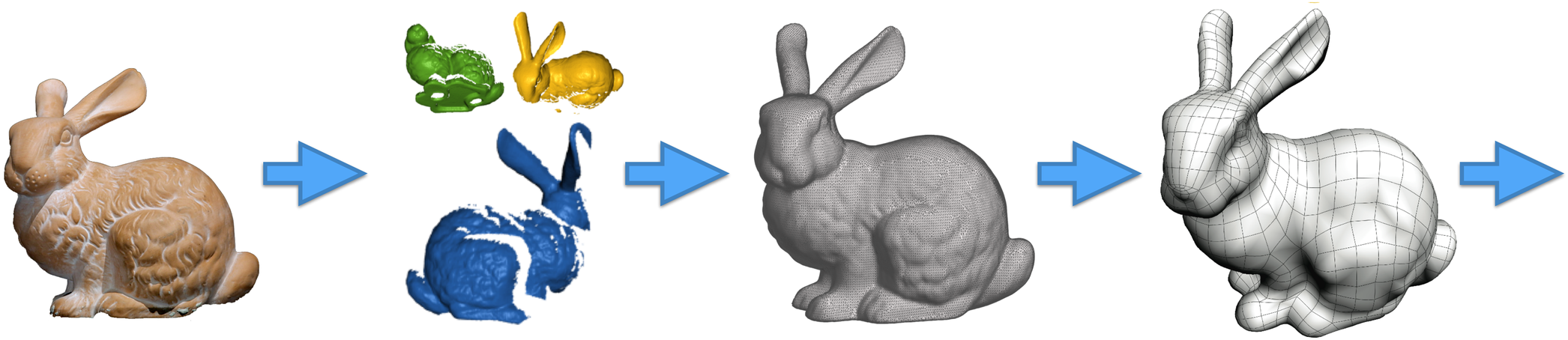
Applications

Geometric Computing

Animation

Physical Simulation



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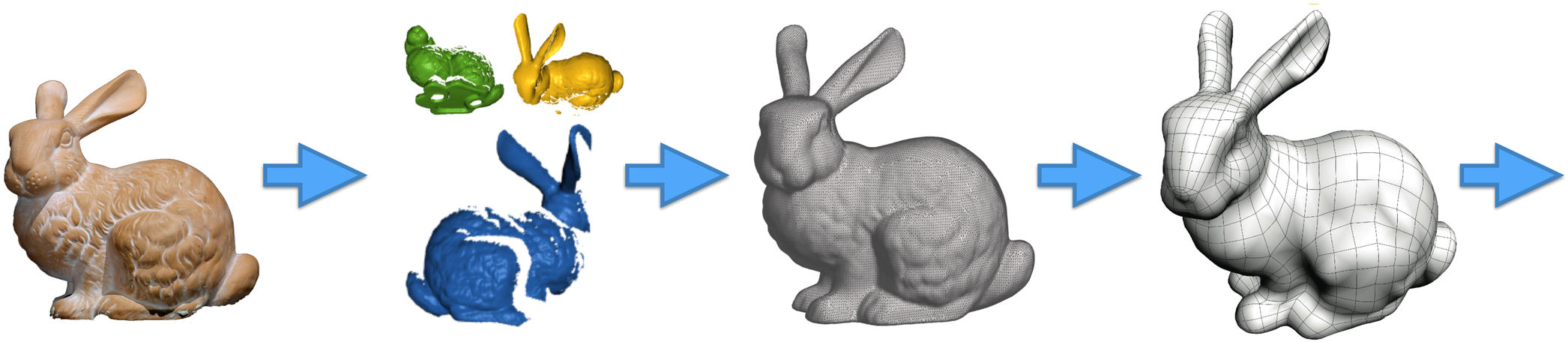


Physical Object

Range Images

Unstructured Model

Structured Model

Animation

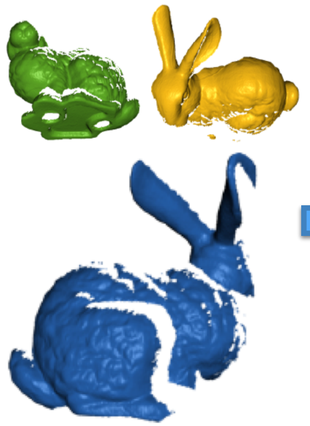
Physical Simulation

Fabrication

Applications

Geometric Computing

Physical Object



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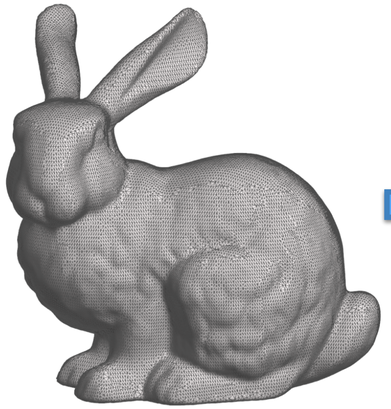

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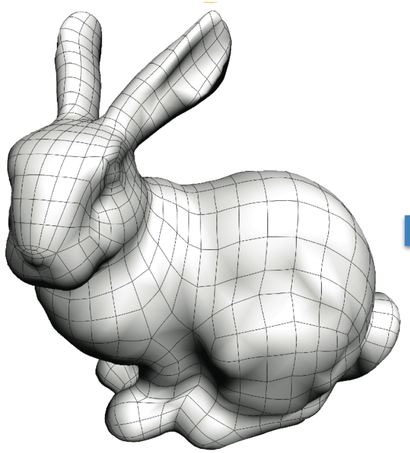


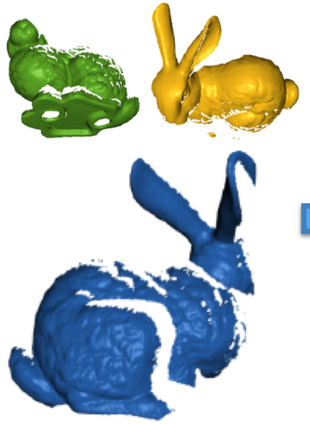
Structured Model

Applications

- **Animation**
- **Physical Simulation**
- **Fabrication**
- **Visual Effects**

Geometric Computing

Physical Object



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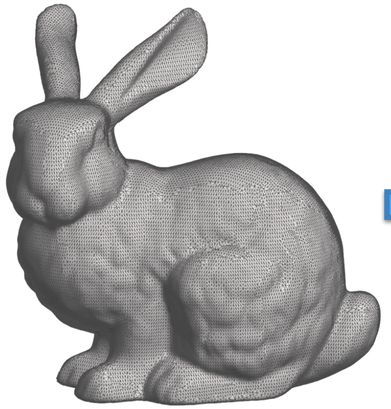

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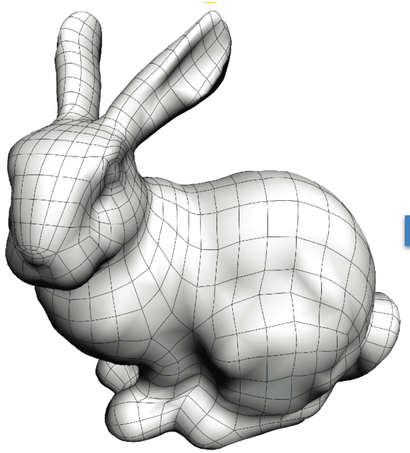


Structured Model

Animation

Physical Simulation

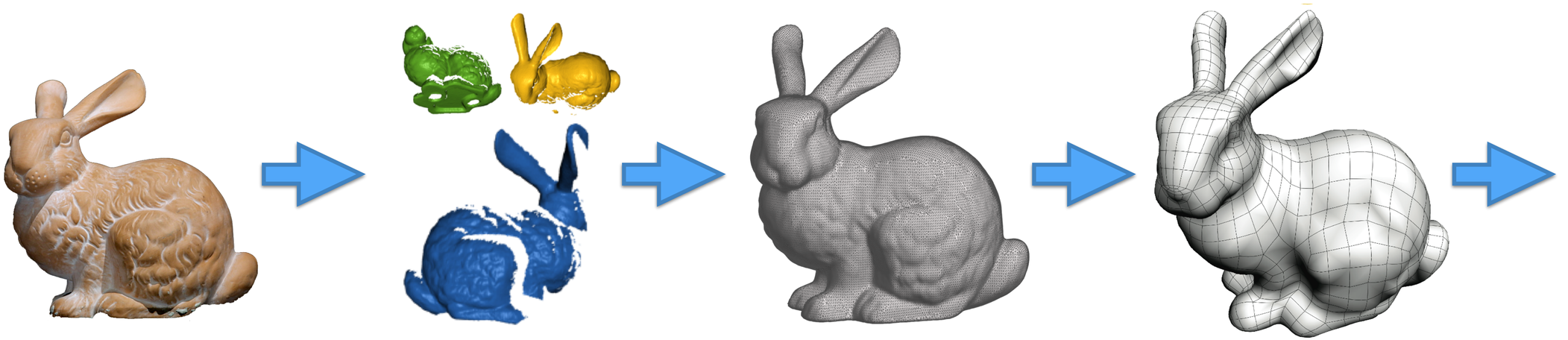
Fabrication

Visual Effects

Structural Analysis

Applications

Geometric Computing



Physical Object

Range Images

Unstructured Model

Structured Model

Animation

Physical Simulation

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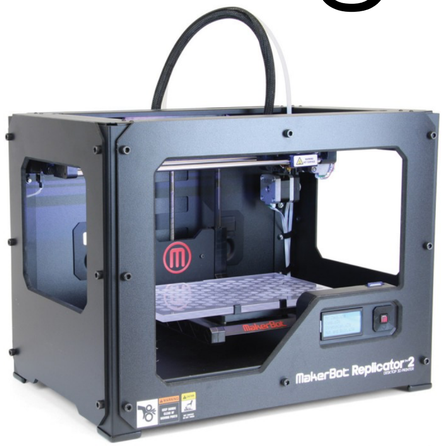
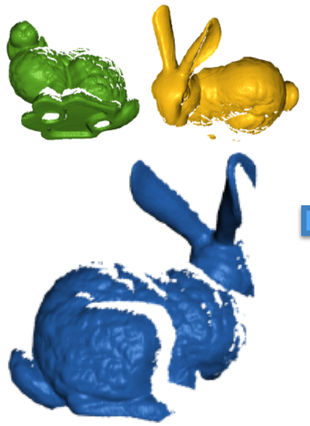


3D Printer

Physical Object



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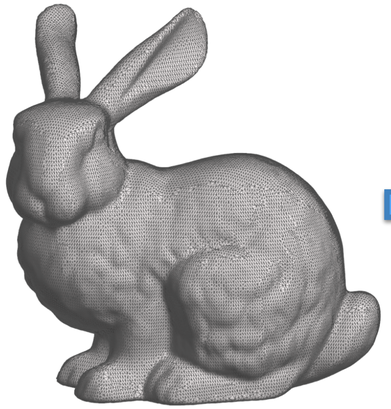

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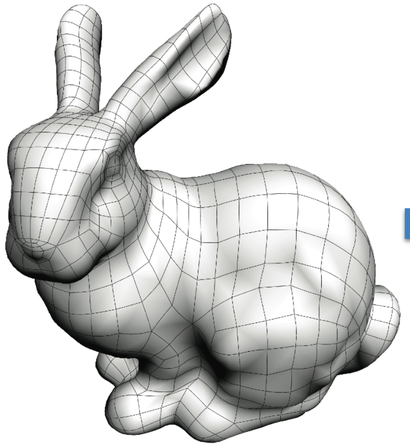


Structured Model

Animation

Physical Simulation

Fabrication

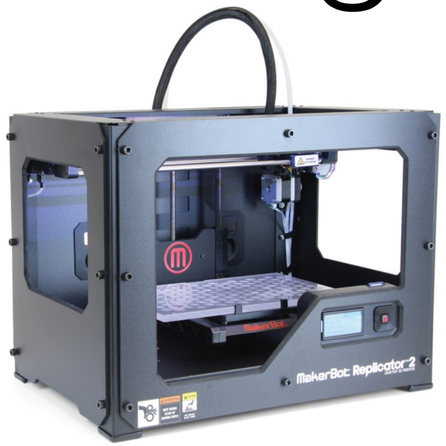
Visual Effects

Structural Analysis

Applications

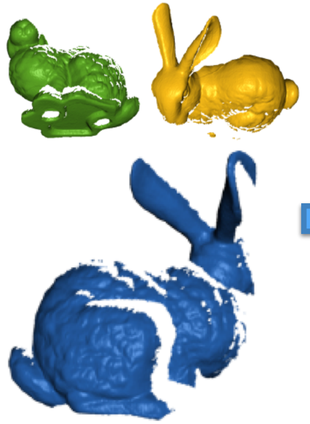
Geometric Computing

Physical Derived Object



3D Printer

Physical Object



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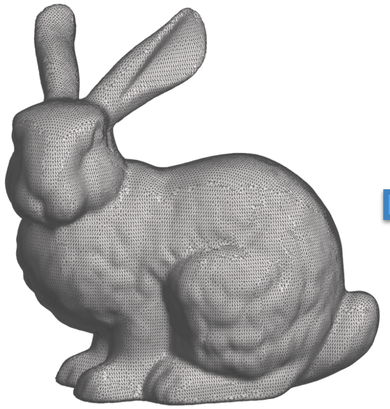

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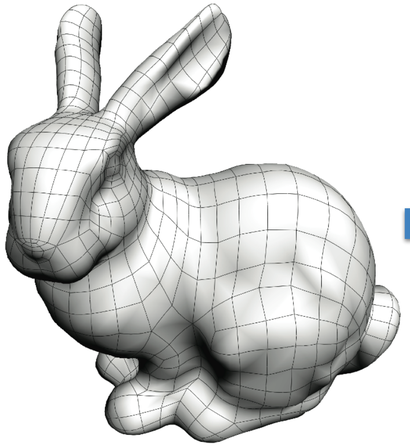

Structured Model

Animation

Physical Simulation

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Applications

Course Overview

- **Daniele:** Introduction to Geometric Computing with Jupyter
- **Sebastian:** Geometric Computing and Geometric Deep Learning
- **Teseo:** Mesh Generation and Numerical Simulation
- Q&A

Getting Started

- The libraries used in this course are implemented in C++ for efficiency reasons, but are exposed to python for ease of integration

- All libraries are available on conda, they can be installed with:

```
conda config --add channels conda-forge

conda install meshplot
conda install igl
conda install wildmeshing
conda install polyfempy
```

Libraries Overview

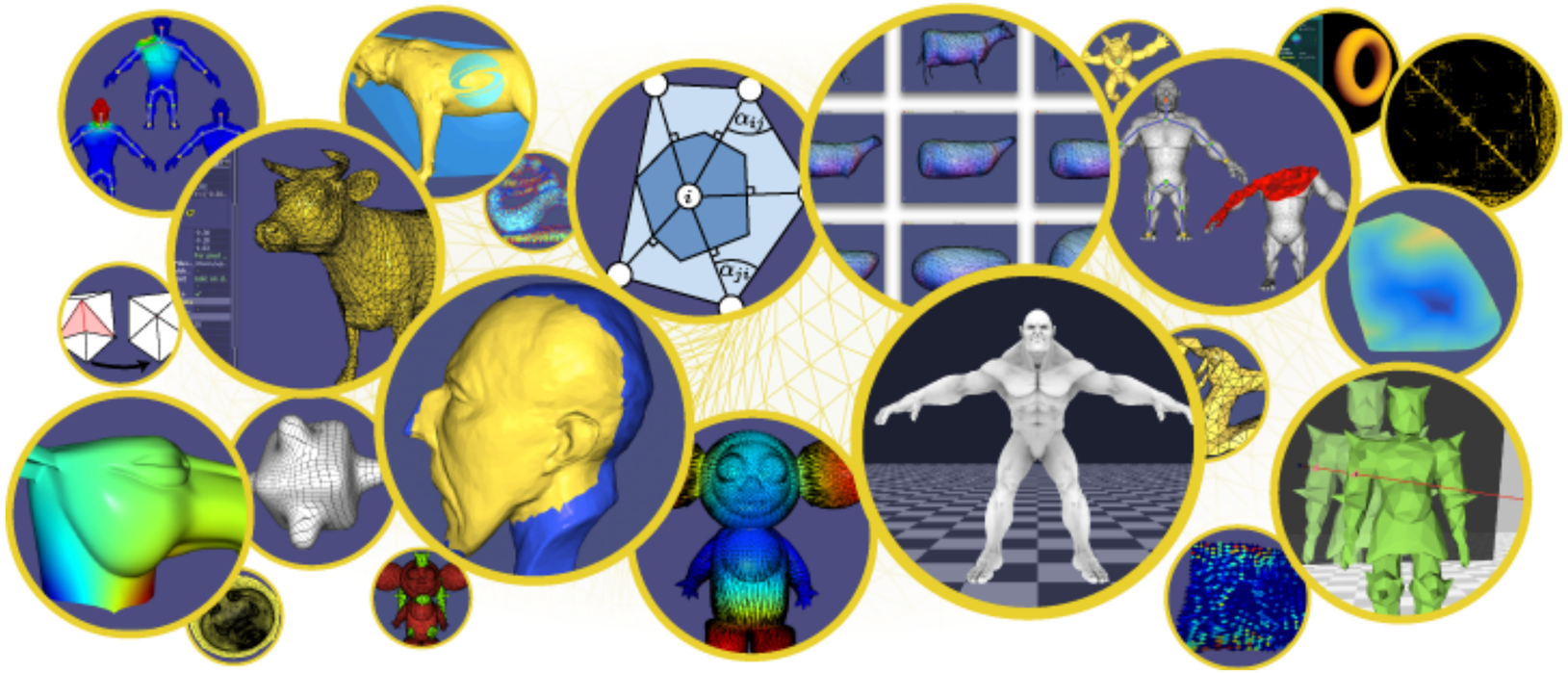
Cross Platform: Windows, MacOSX, Linux

MeshPlot

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

https://skoch9.github.io/meshplot/

Interactive Geometry Library (libigl)



https://libigl.github.io

Wild Meshing (TetWild)

https://wildmeshing.github.io

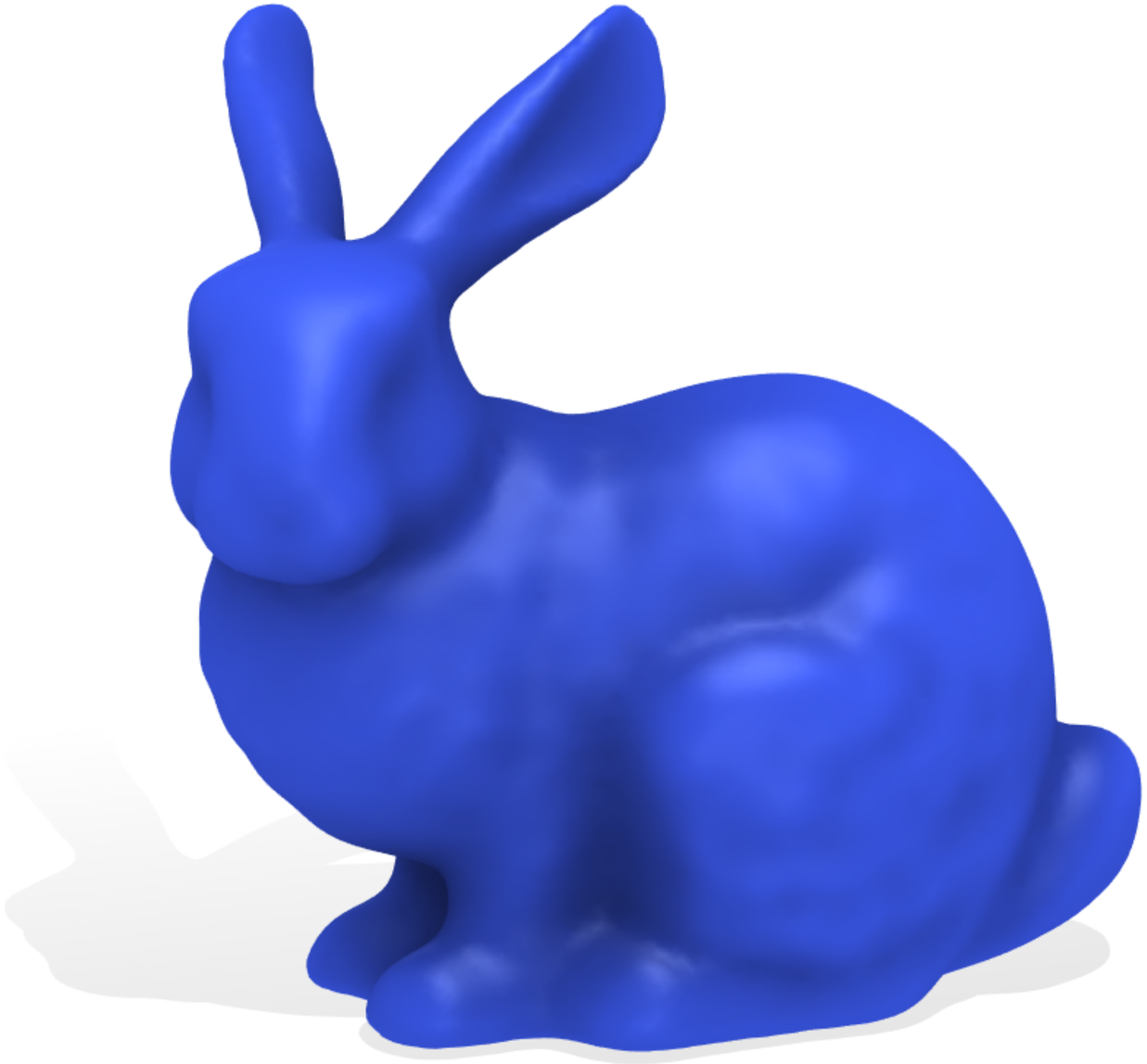
PolyFEM

https://polyfem.github.io

Data Structures (or lack thereof)

Acknowledgement: Alec Jacobson

Triangle meshes discretize surfaces…



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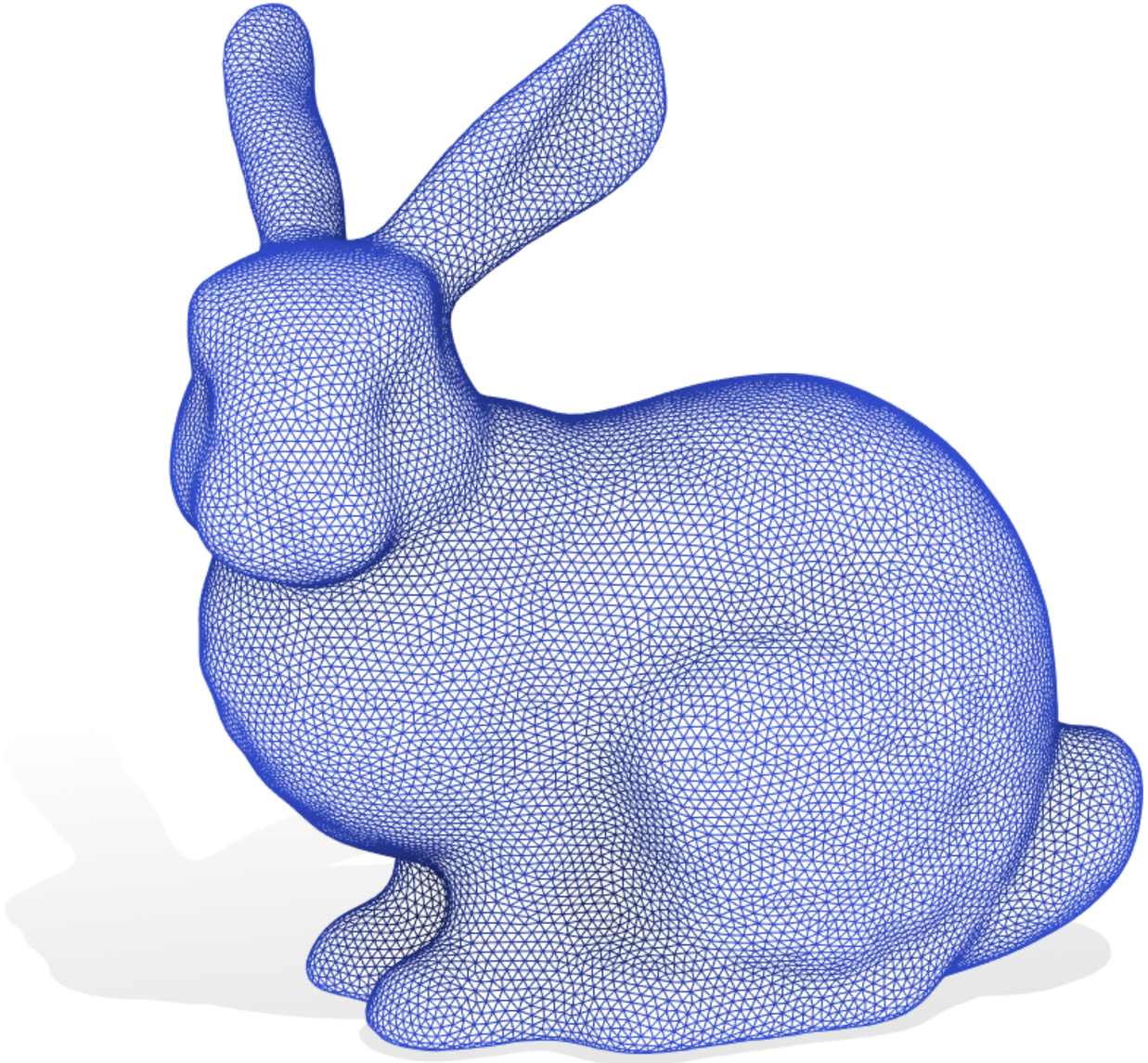

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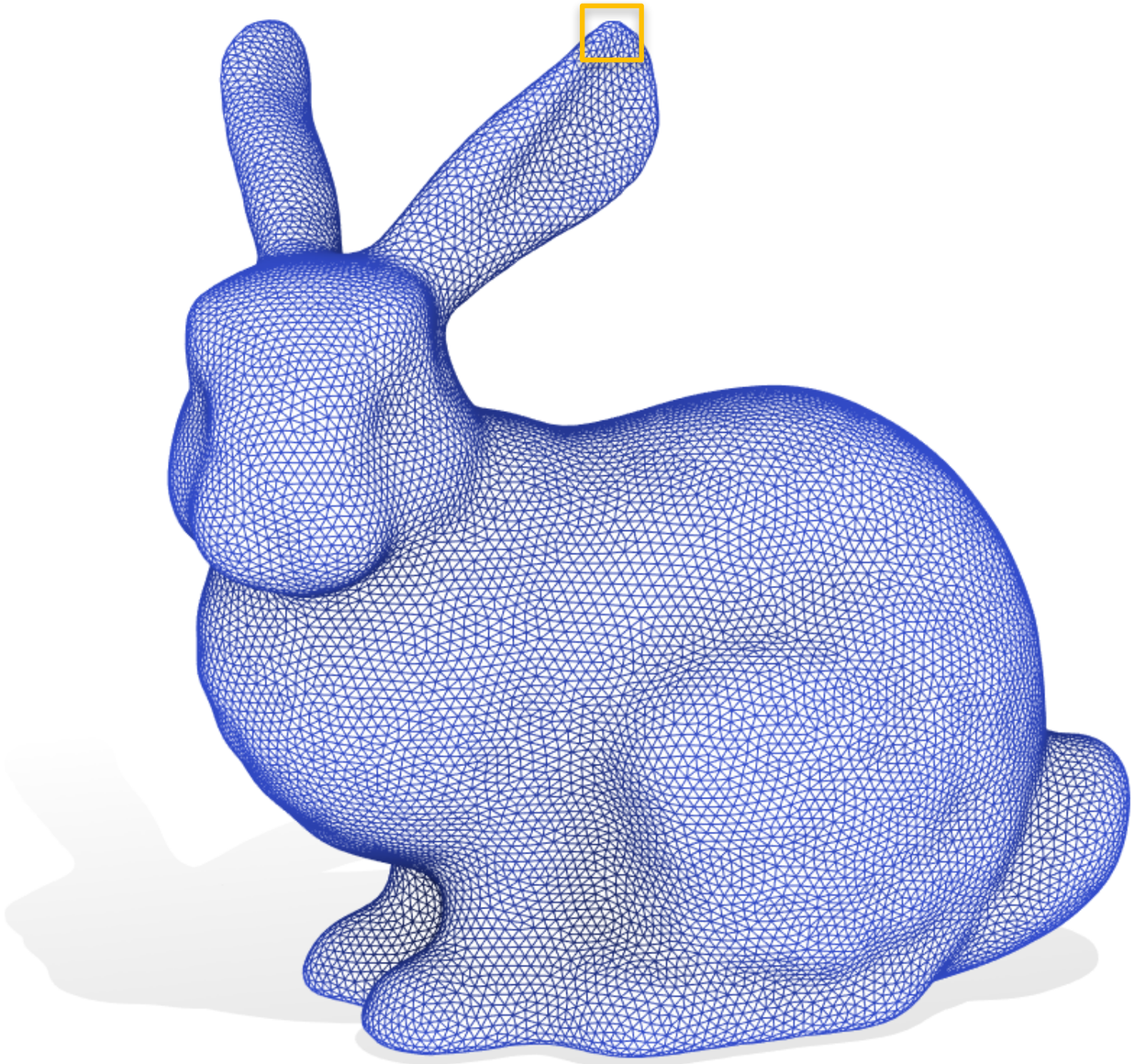

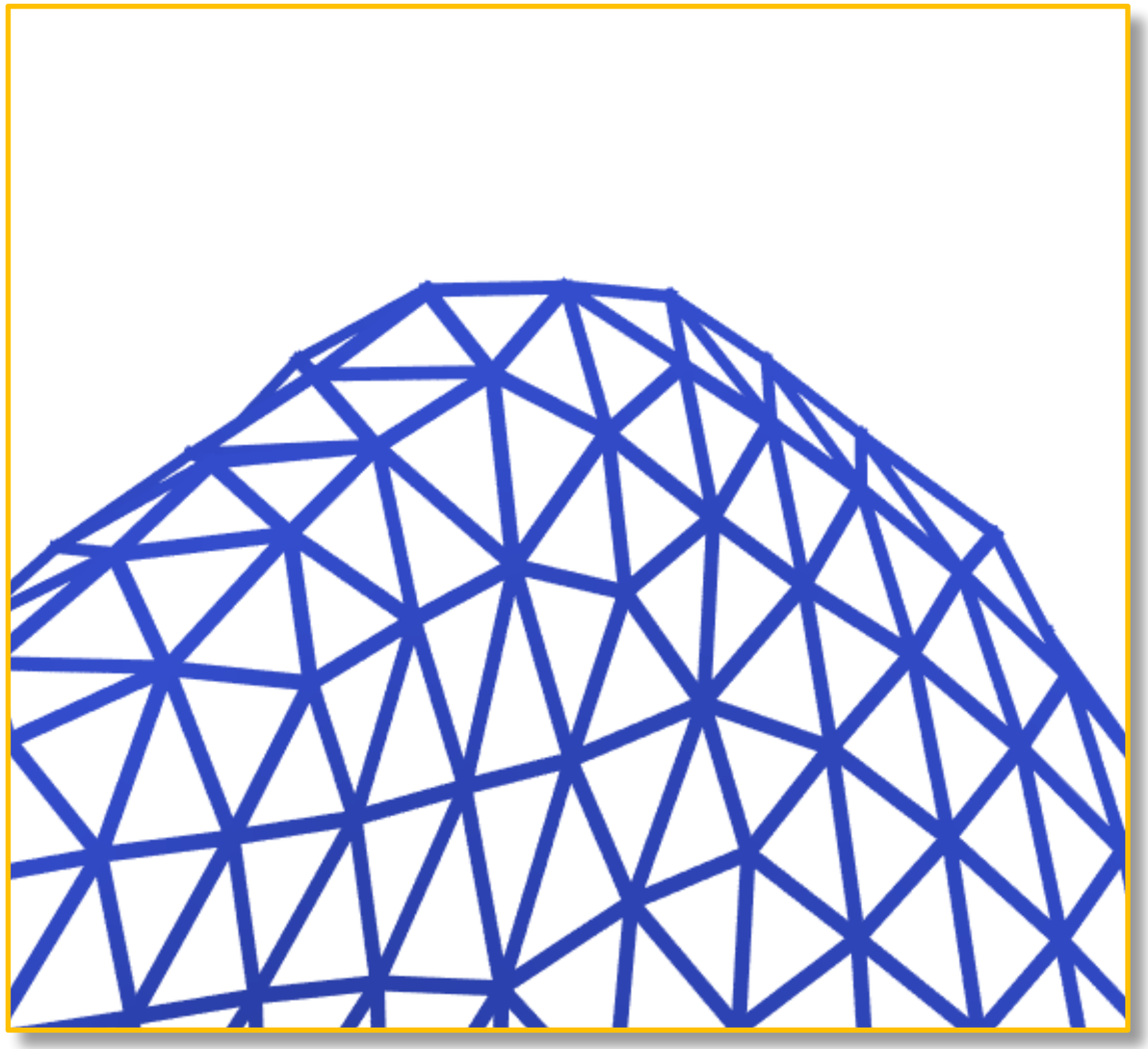

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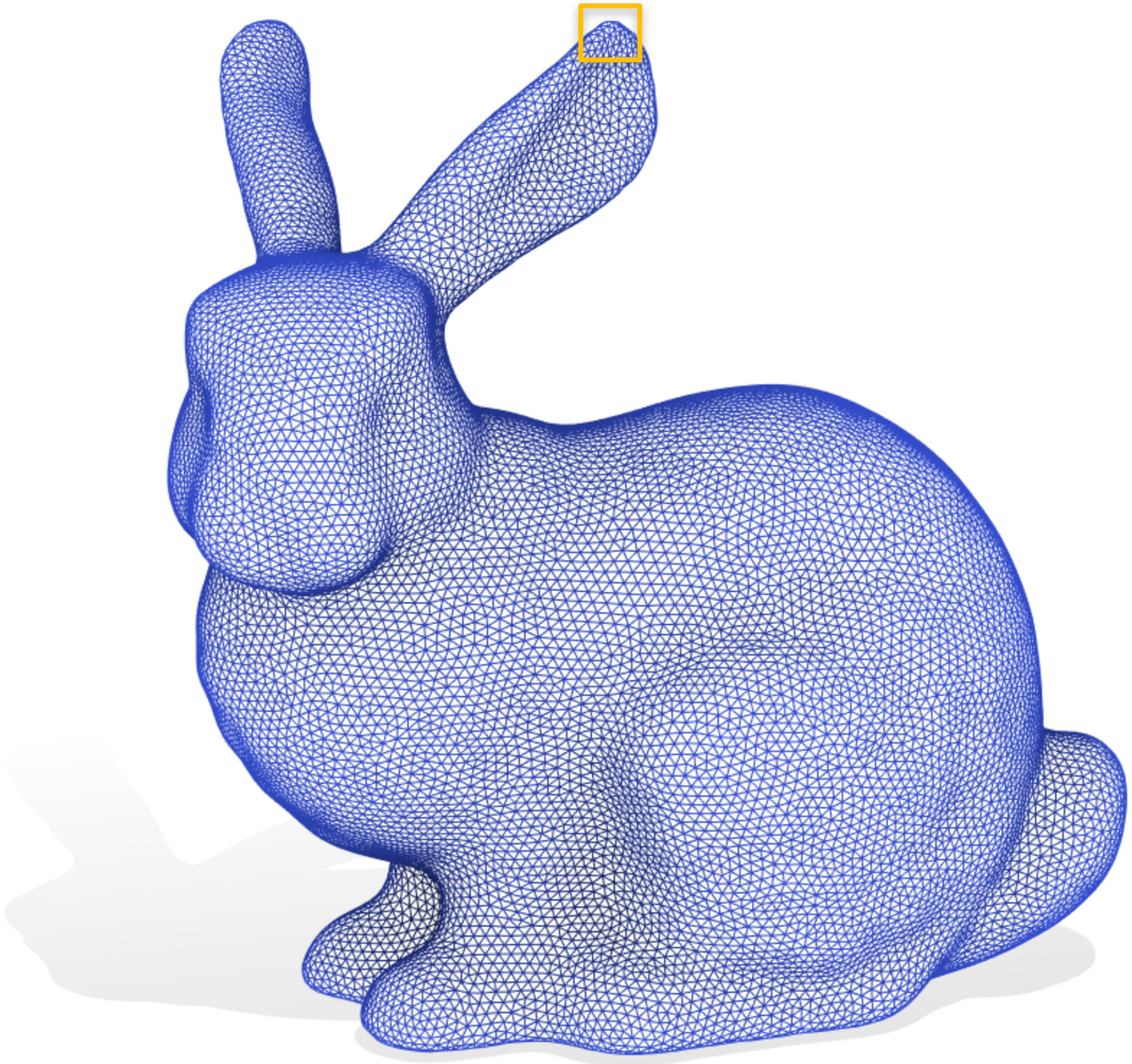

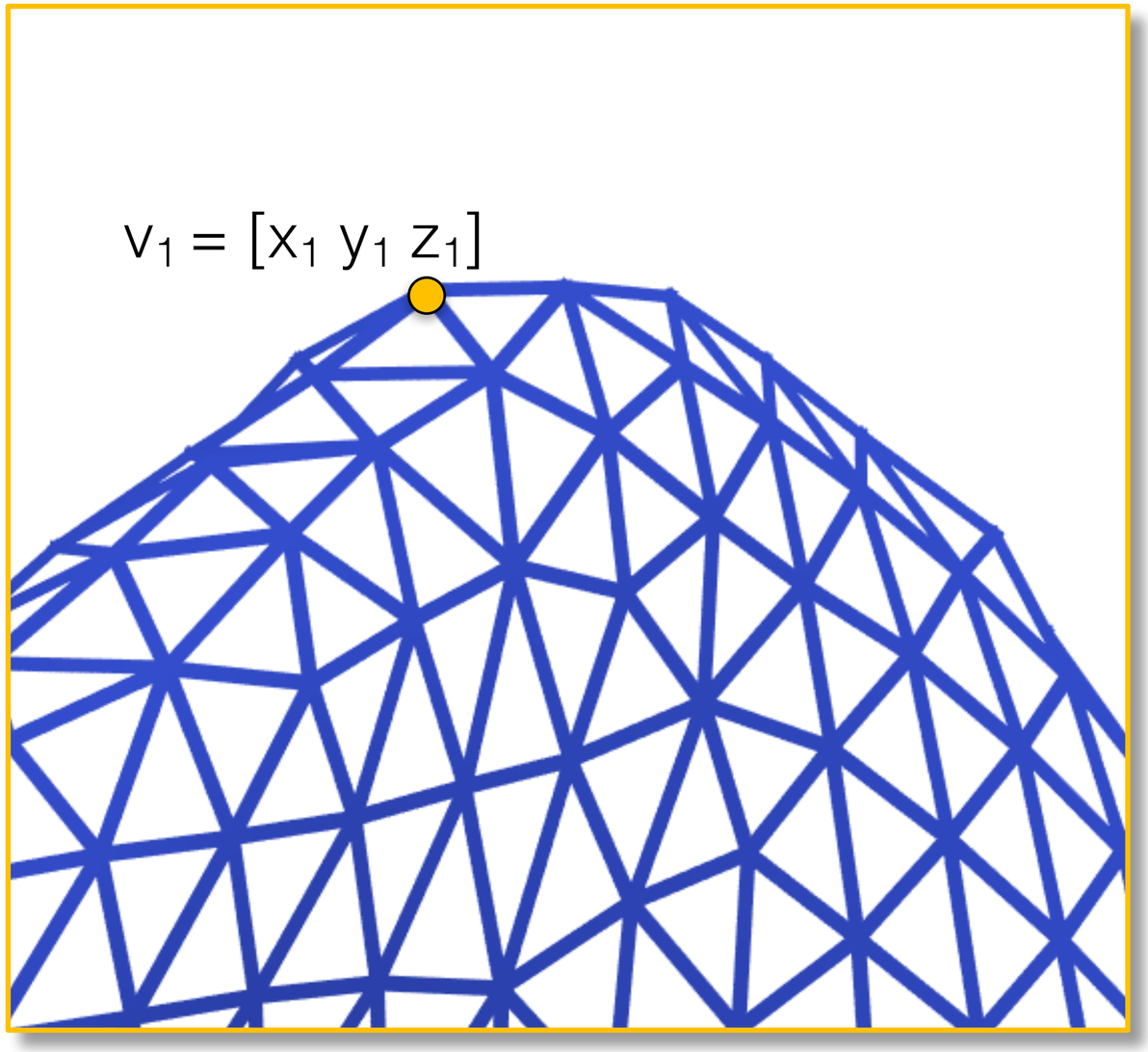

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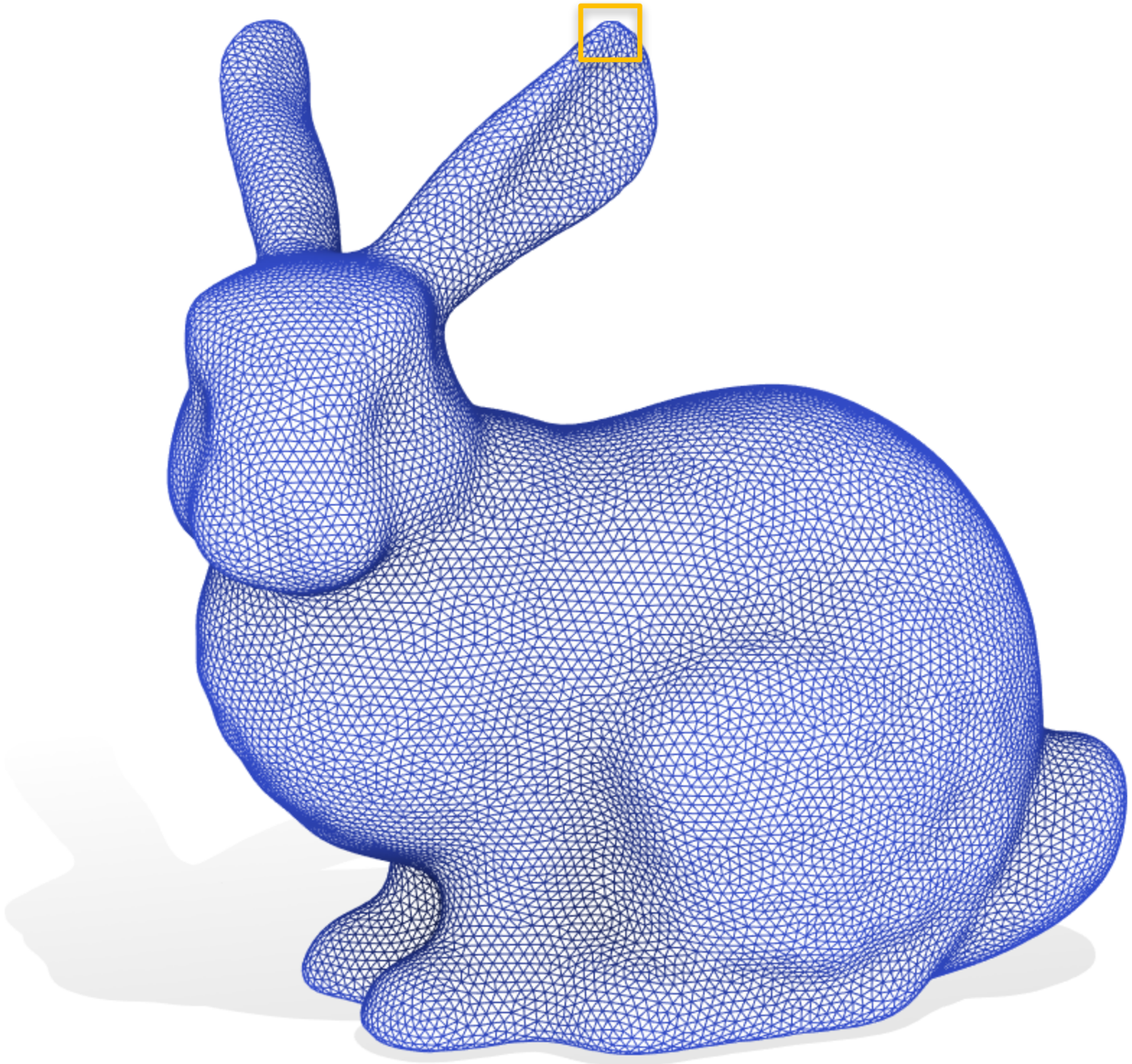

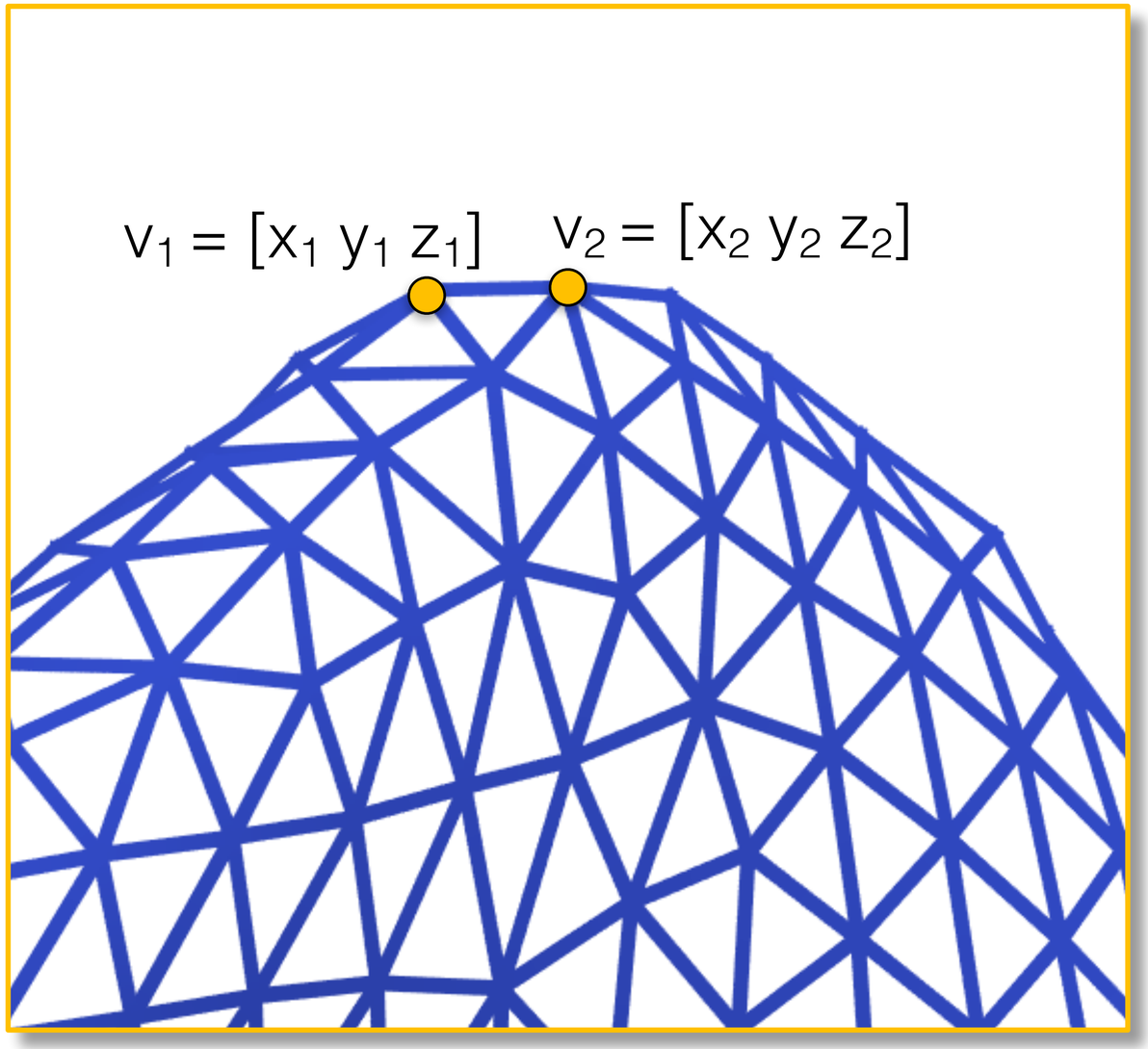

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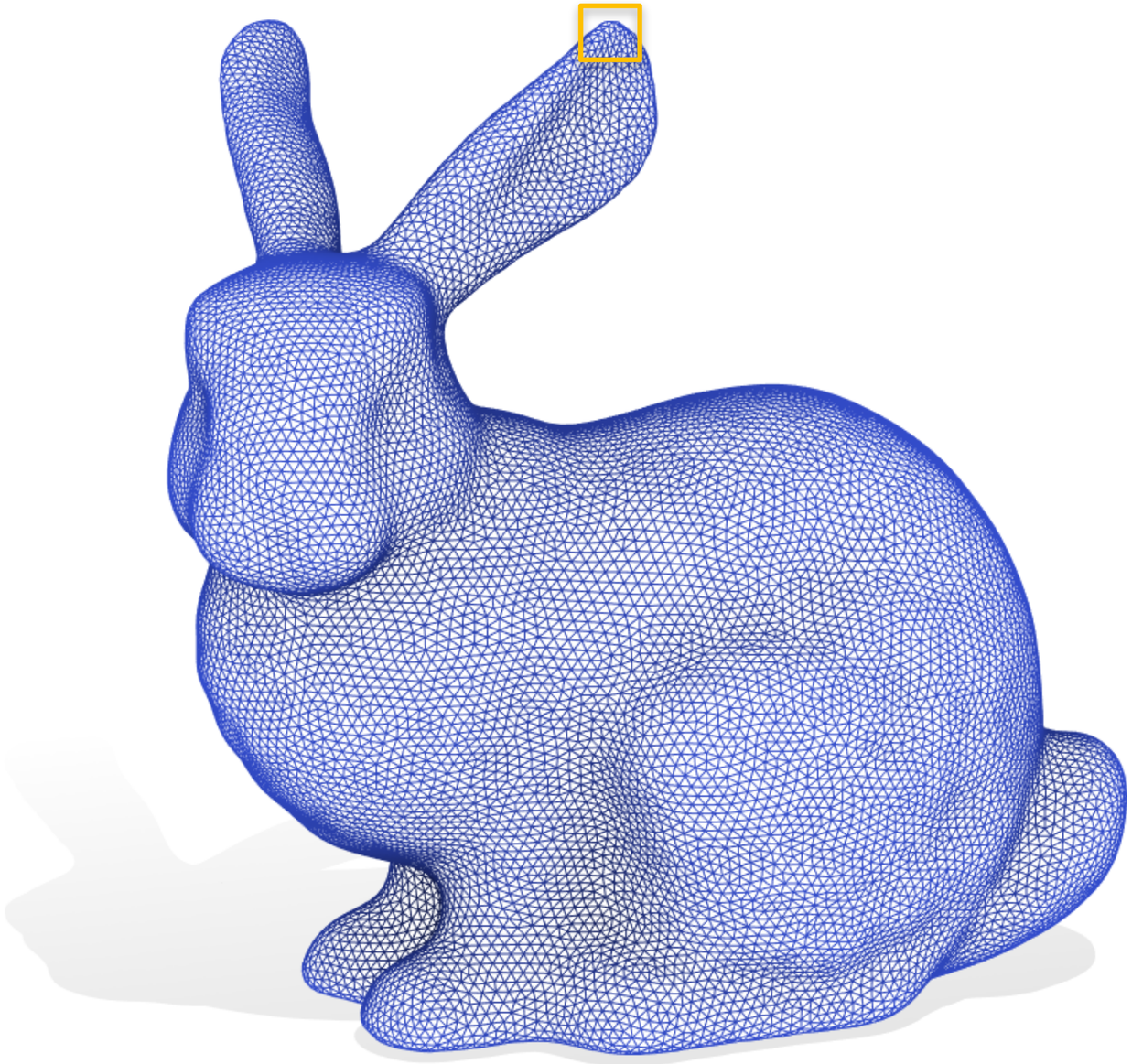

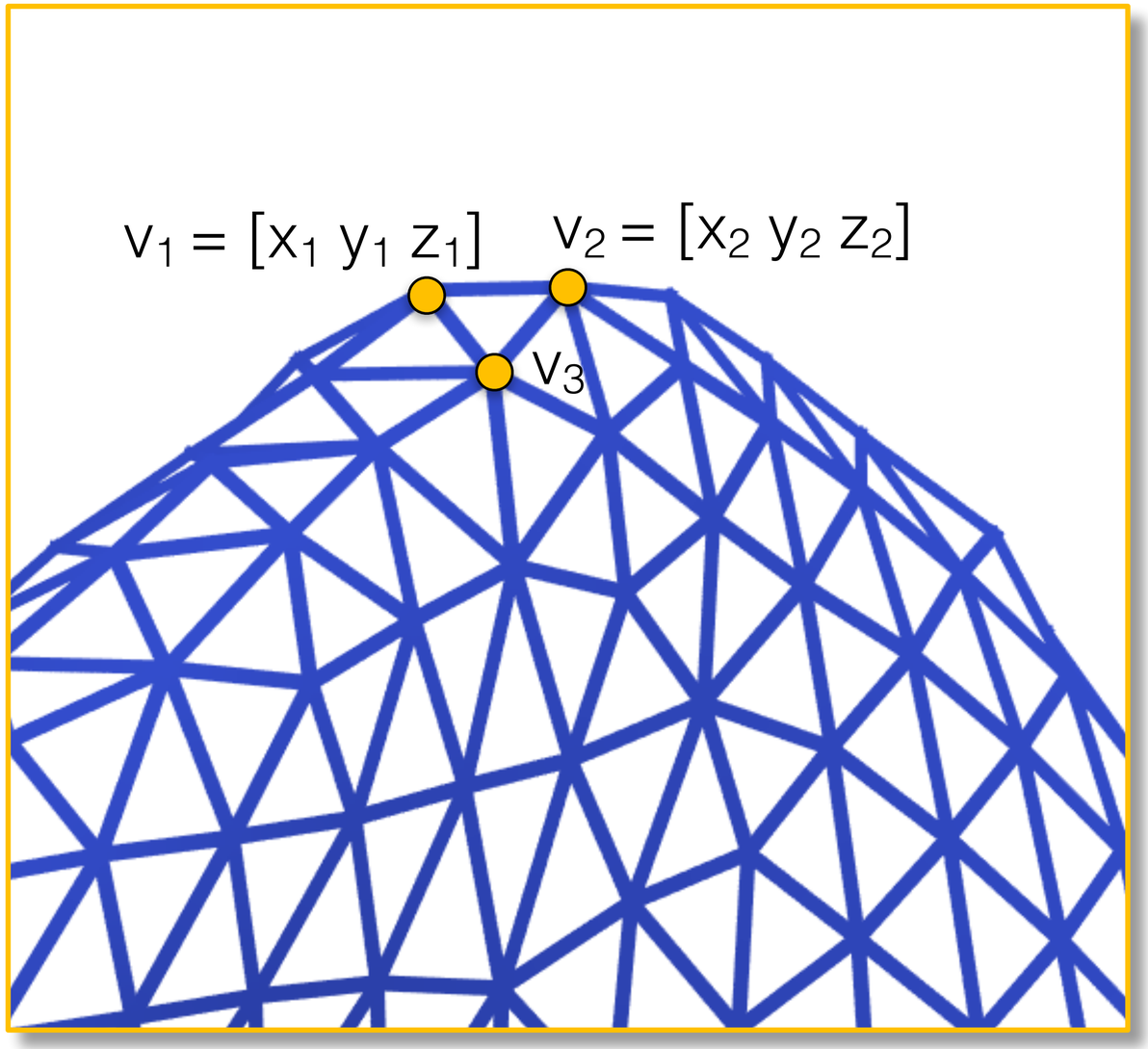

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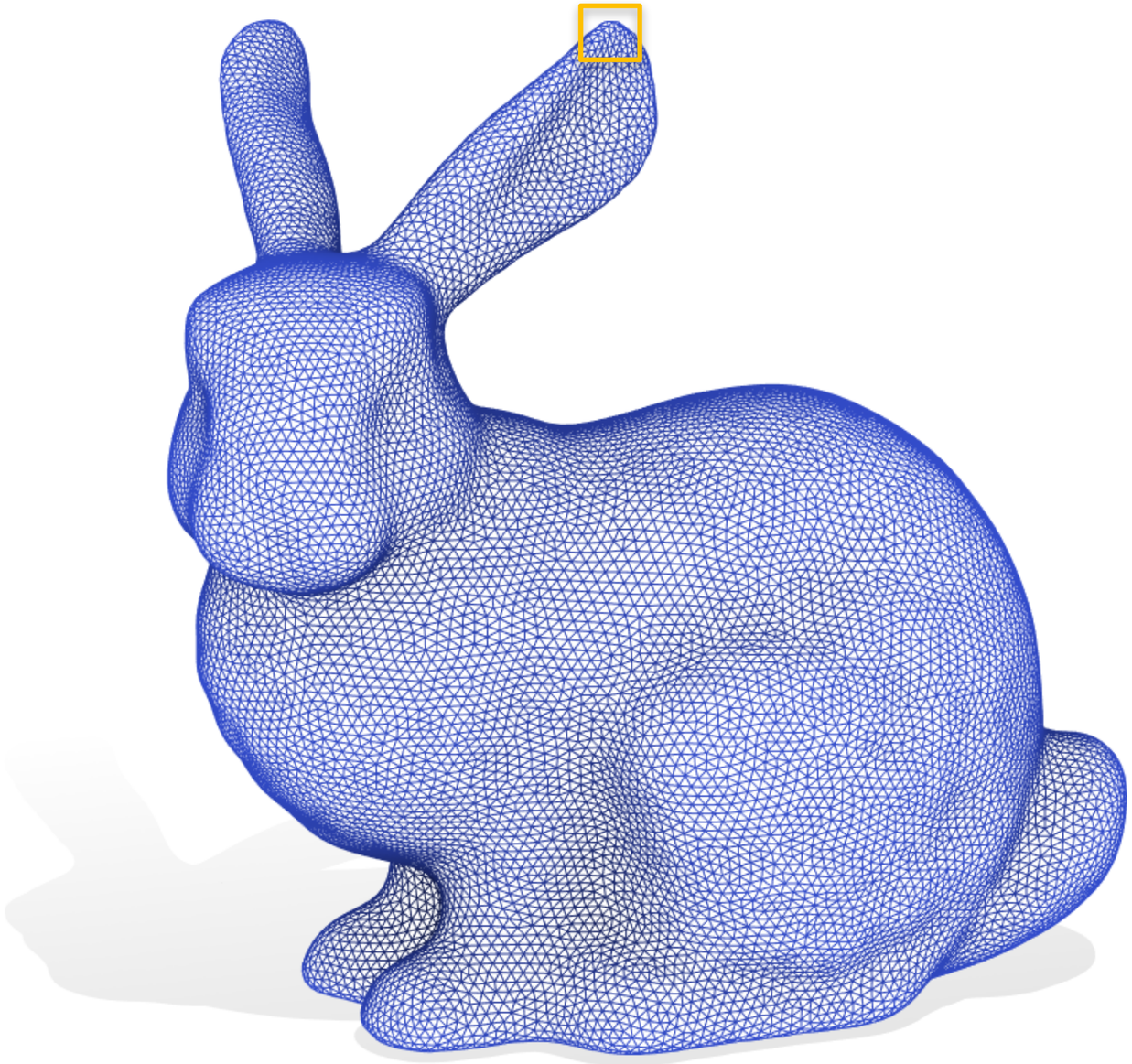

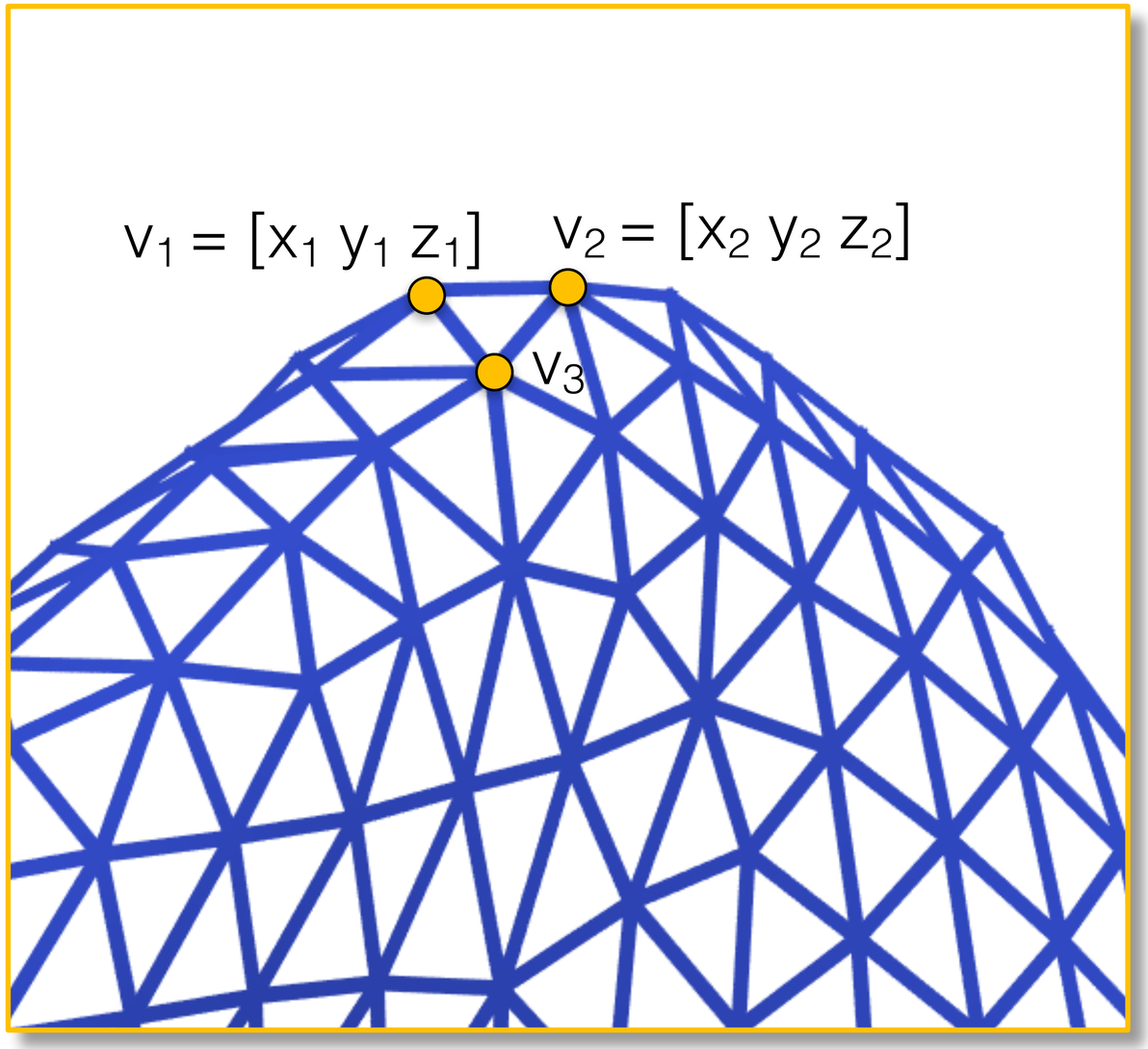

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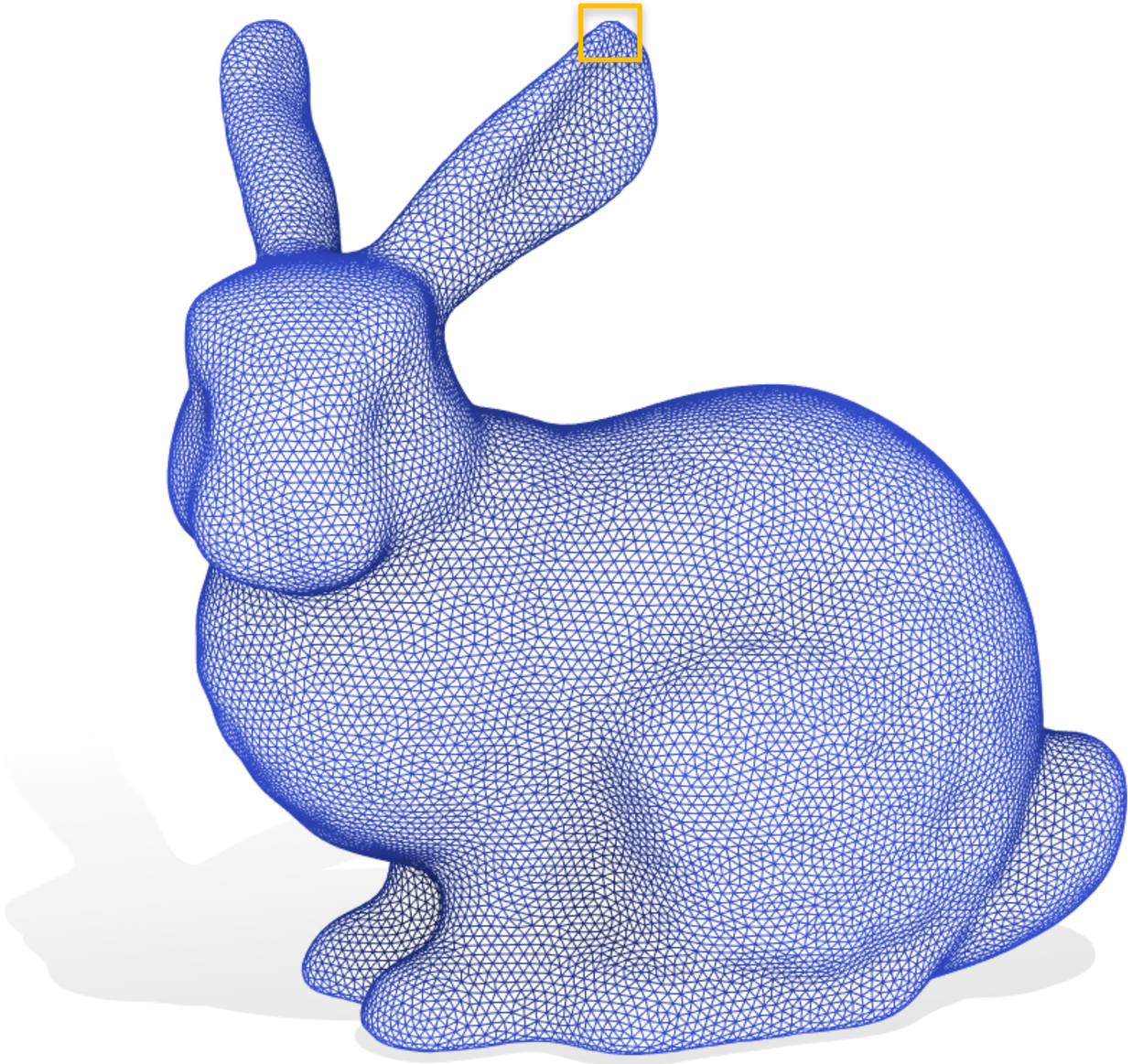

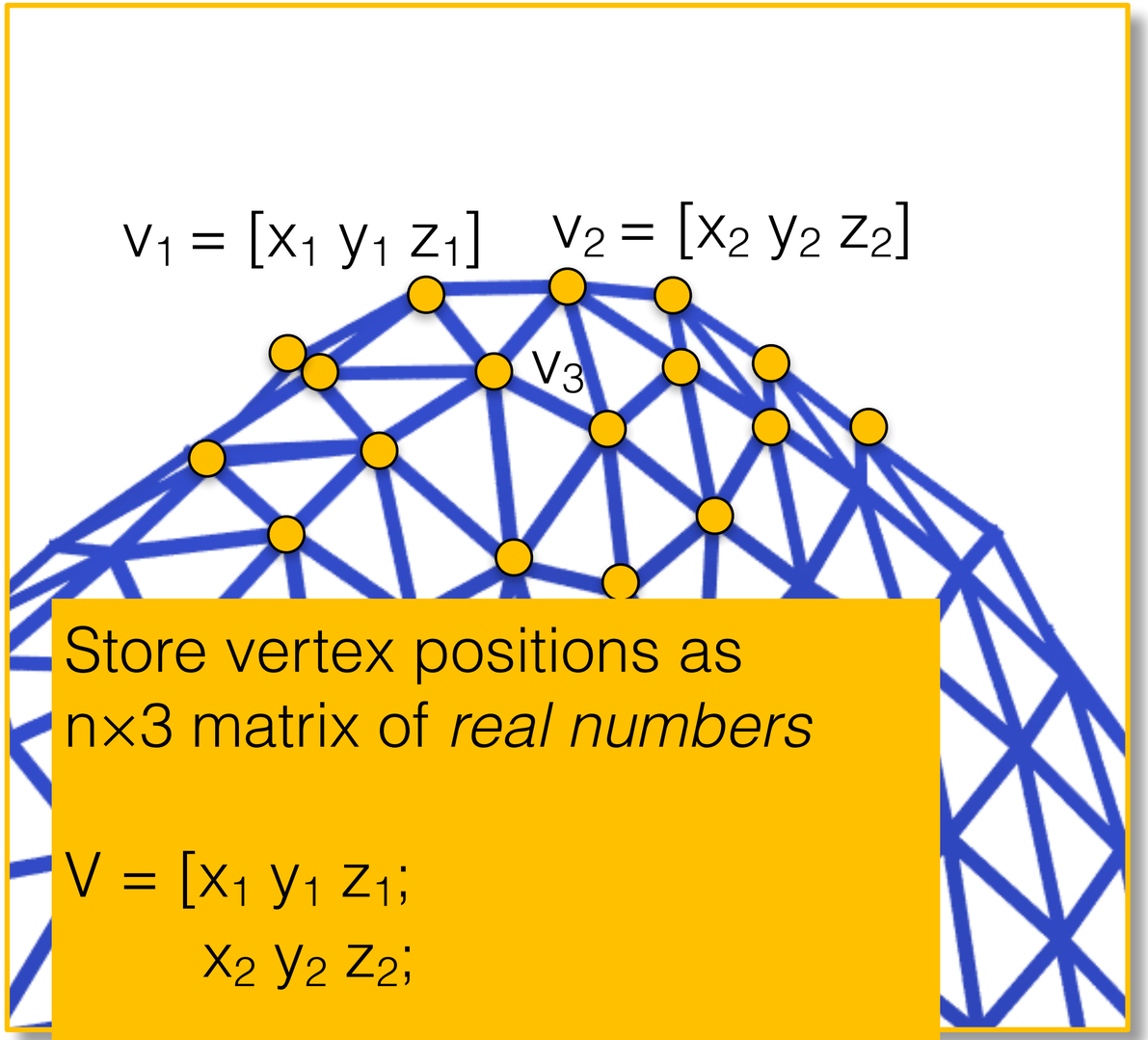

Store vertex positions as
n×3 matrix of *real numbers*

$V = [x_1\ y_1\ z_1;$
$x_2\ y_2\ z_2;$
…
$x_n\ y_n\ z_n]$

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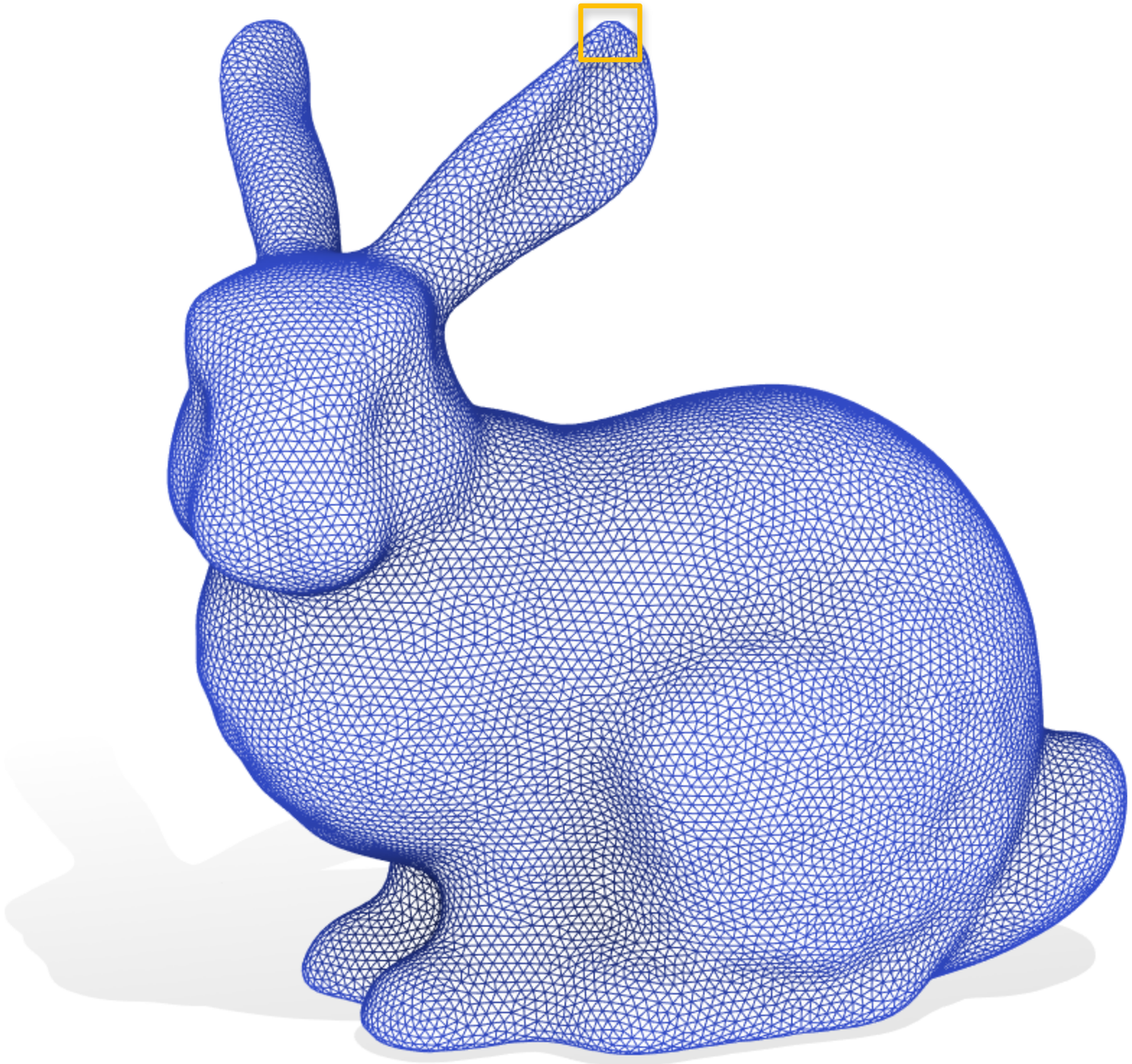

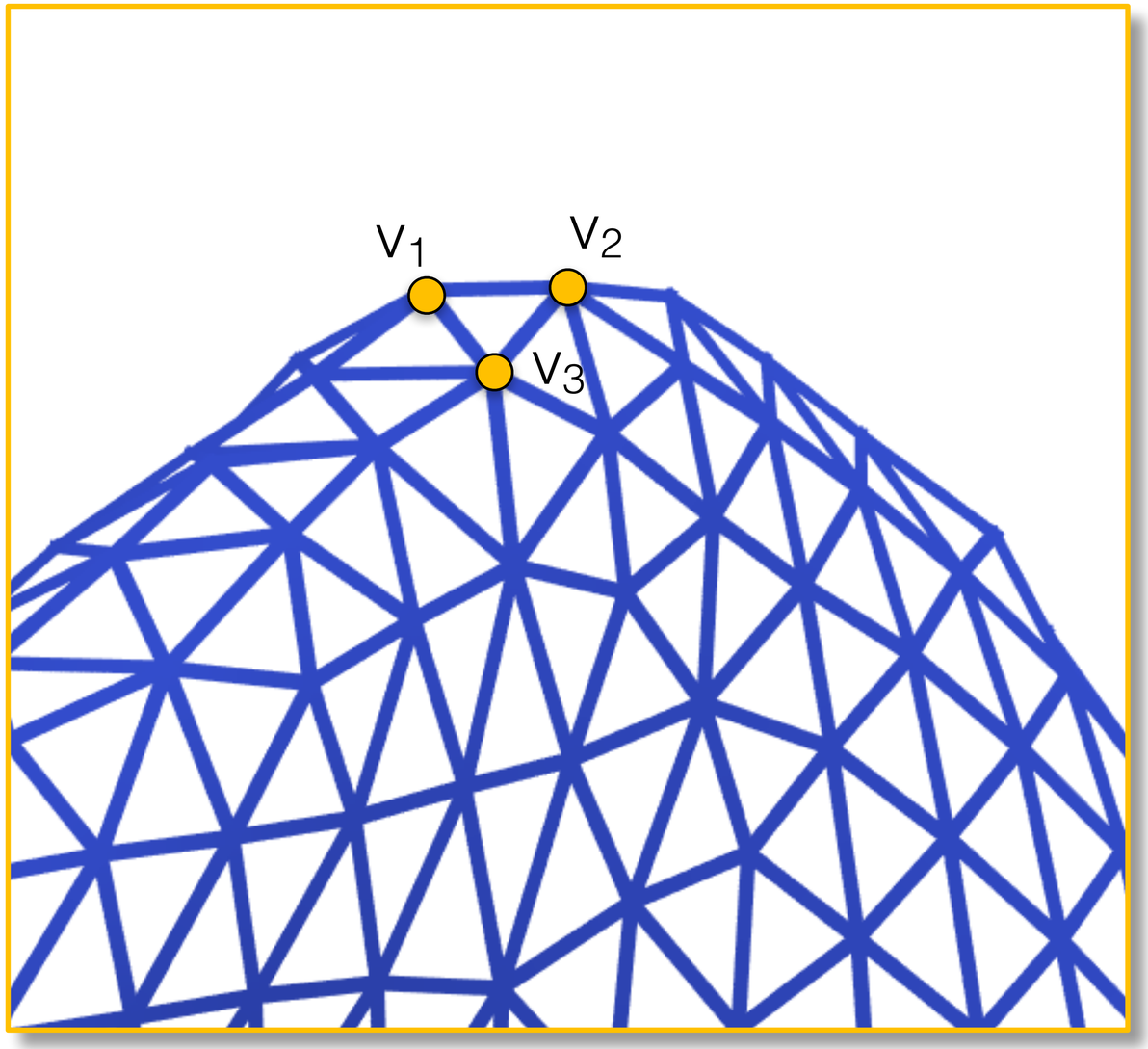

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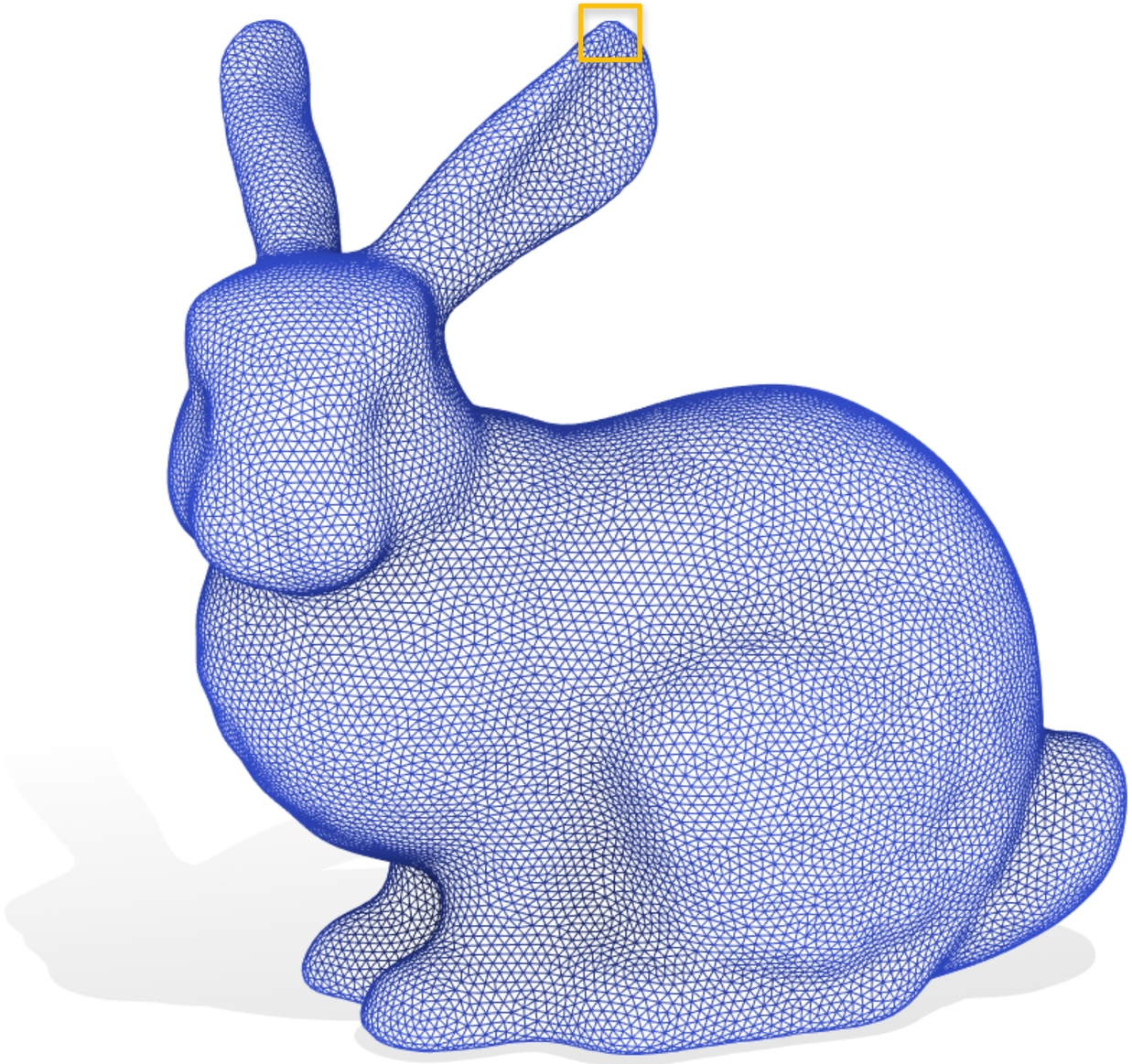

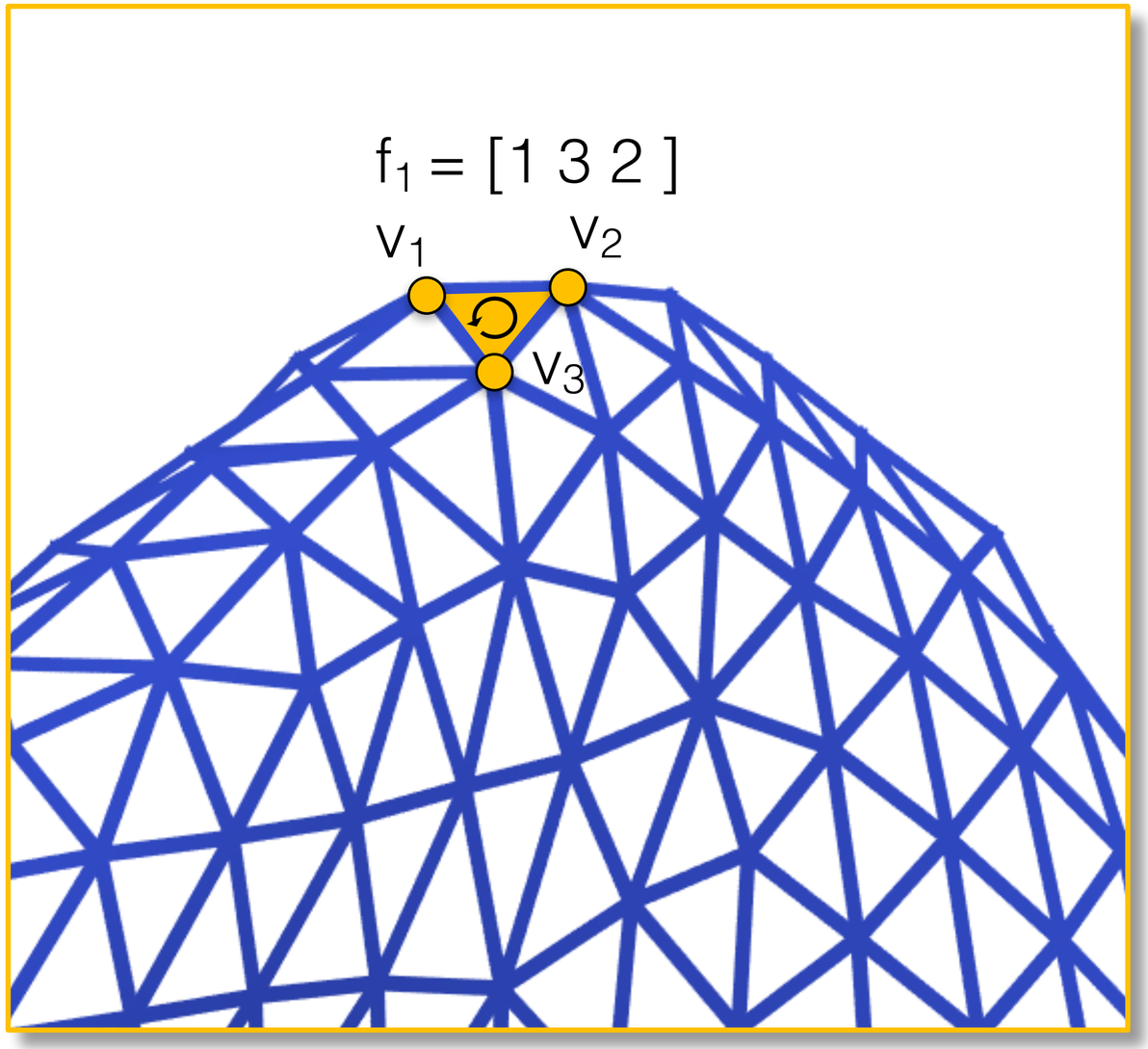

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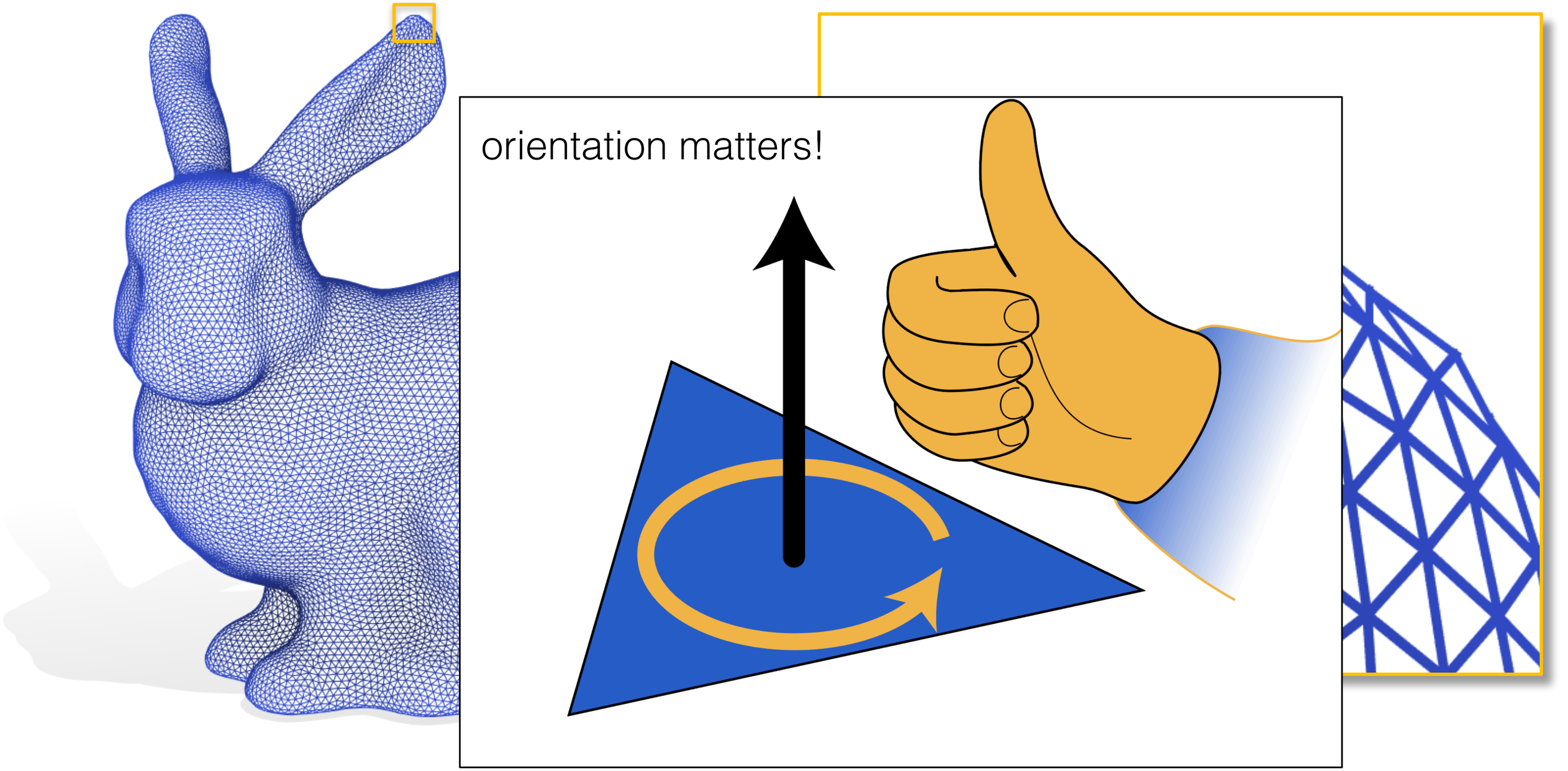

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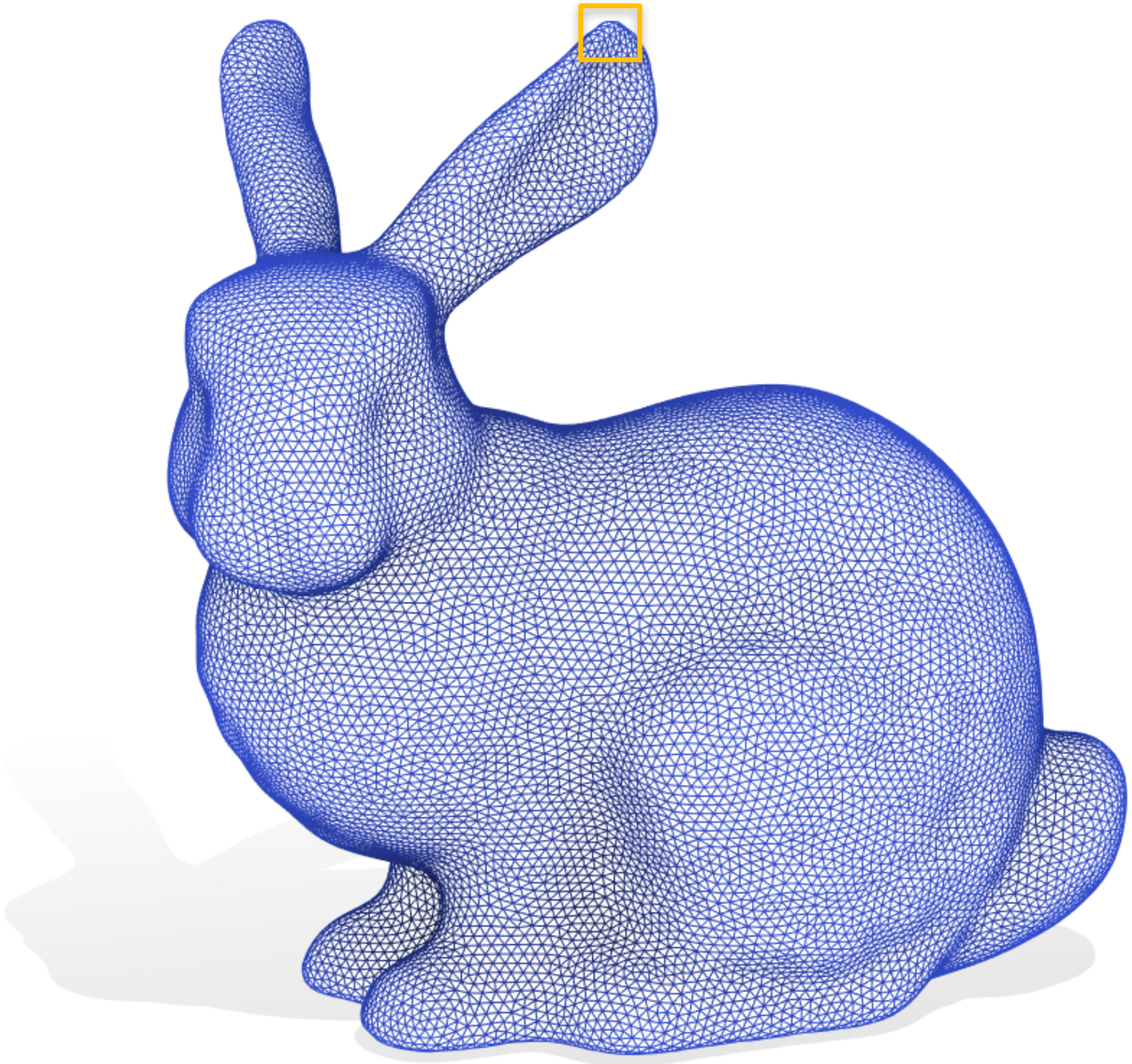

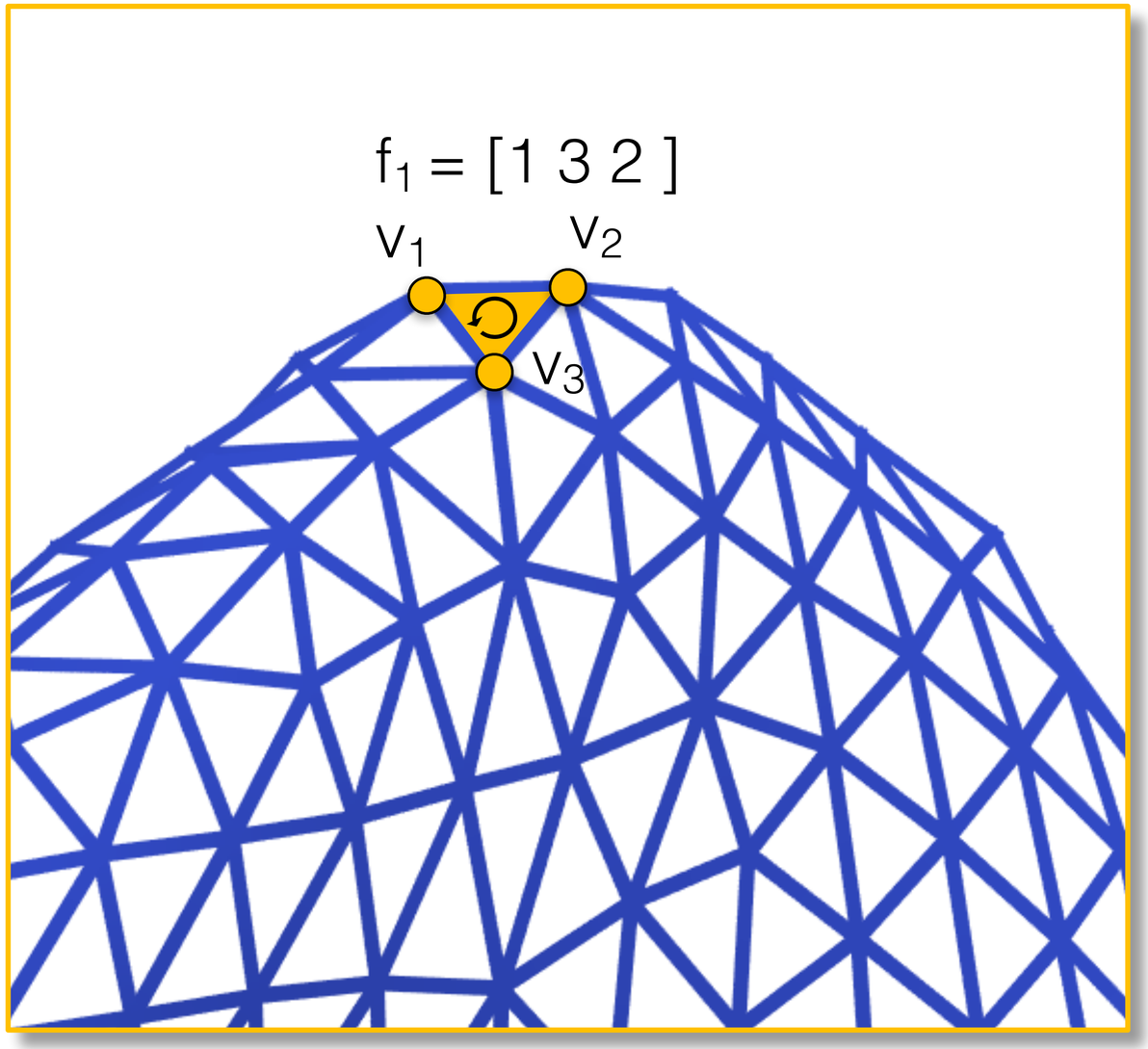

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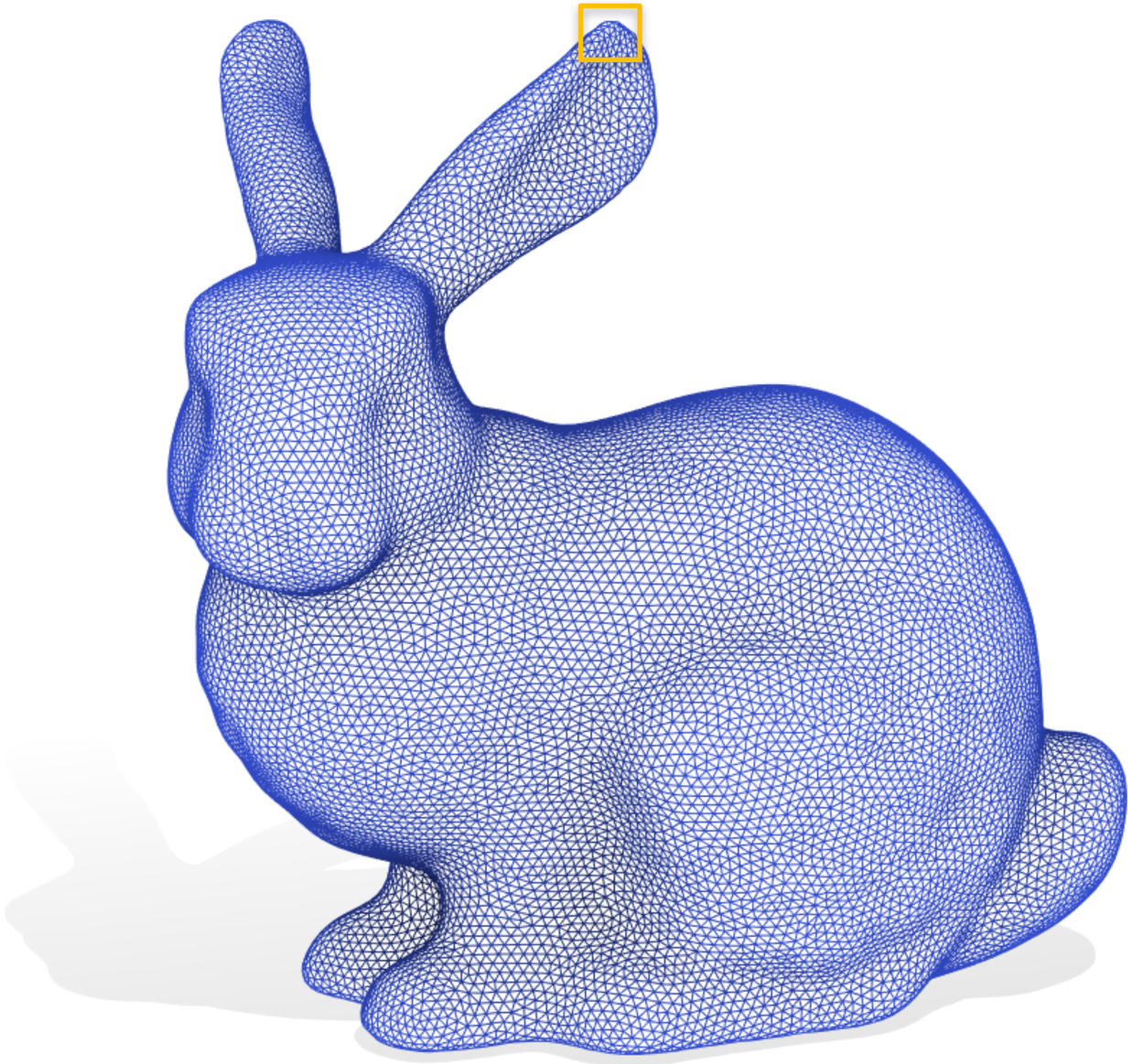
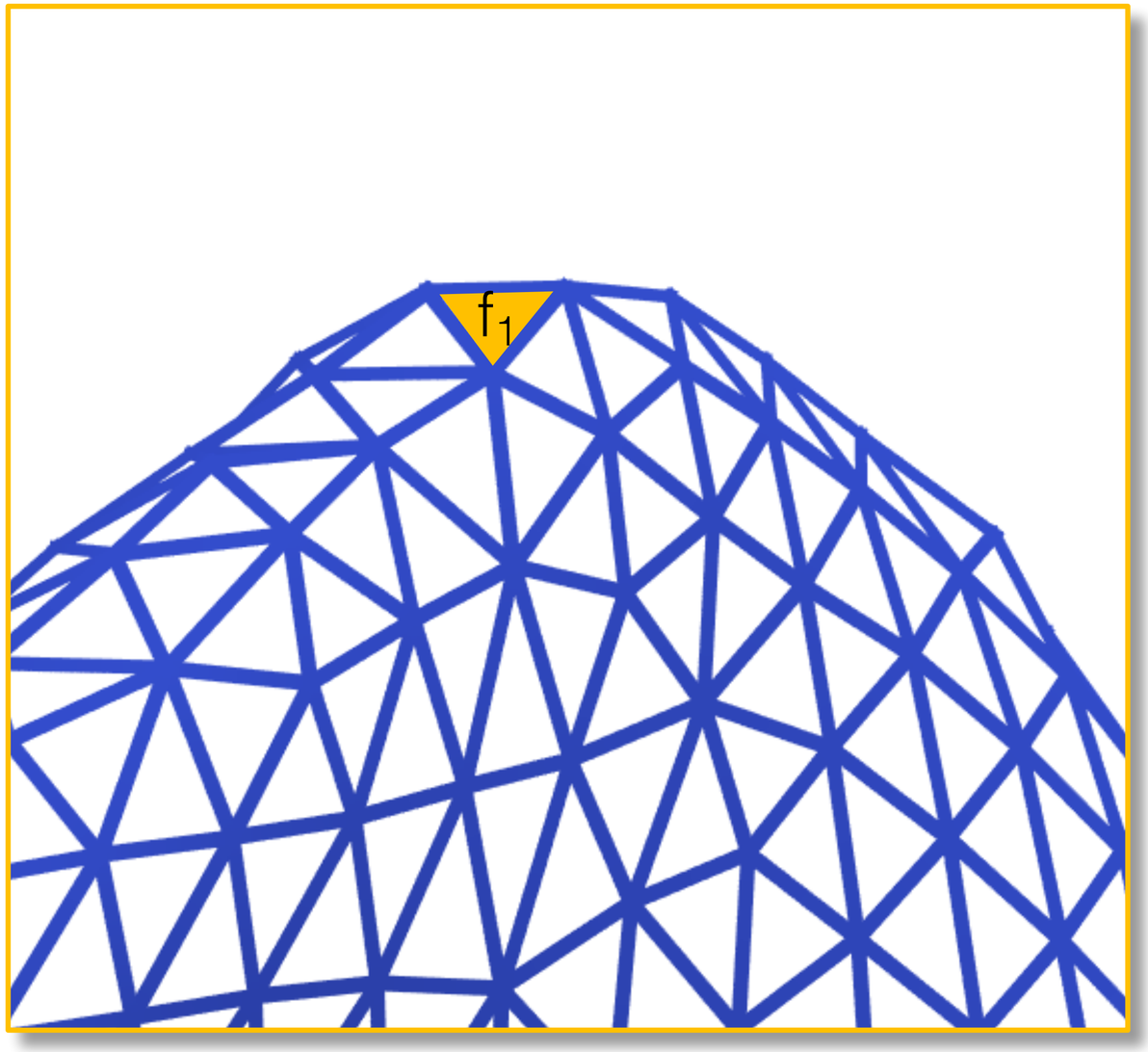
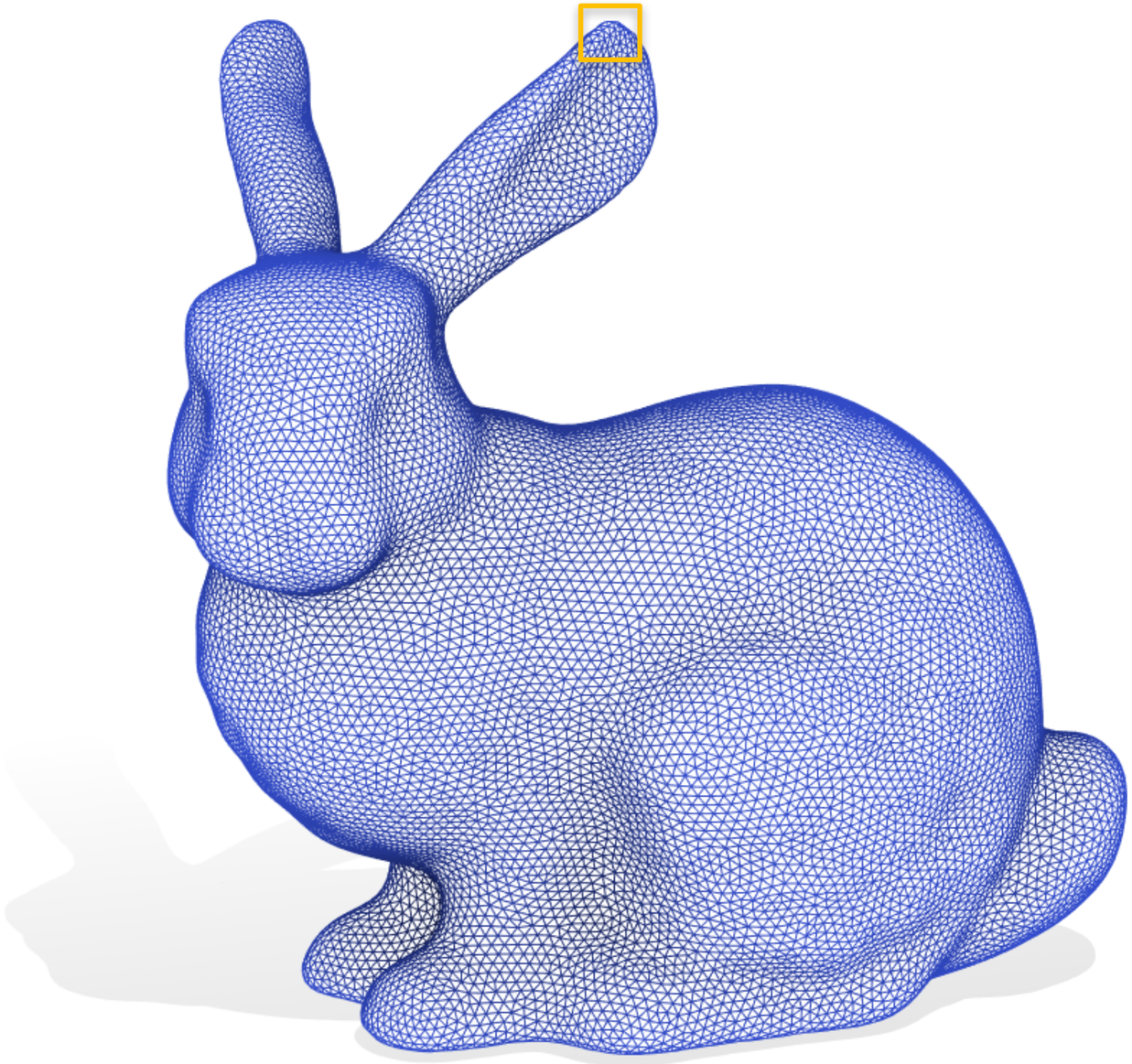
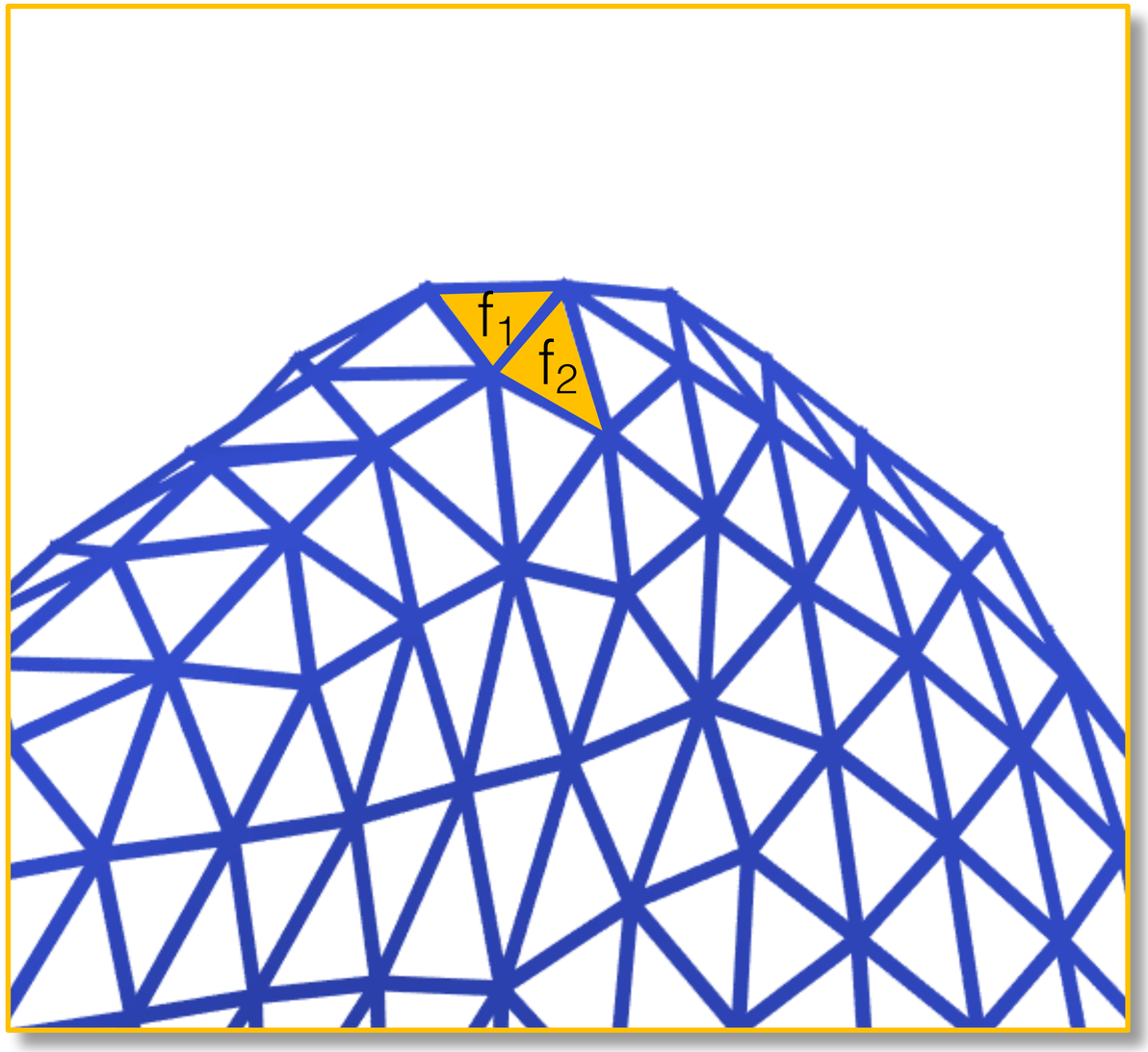


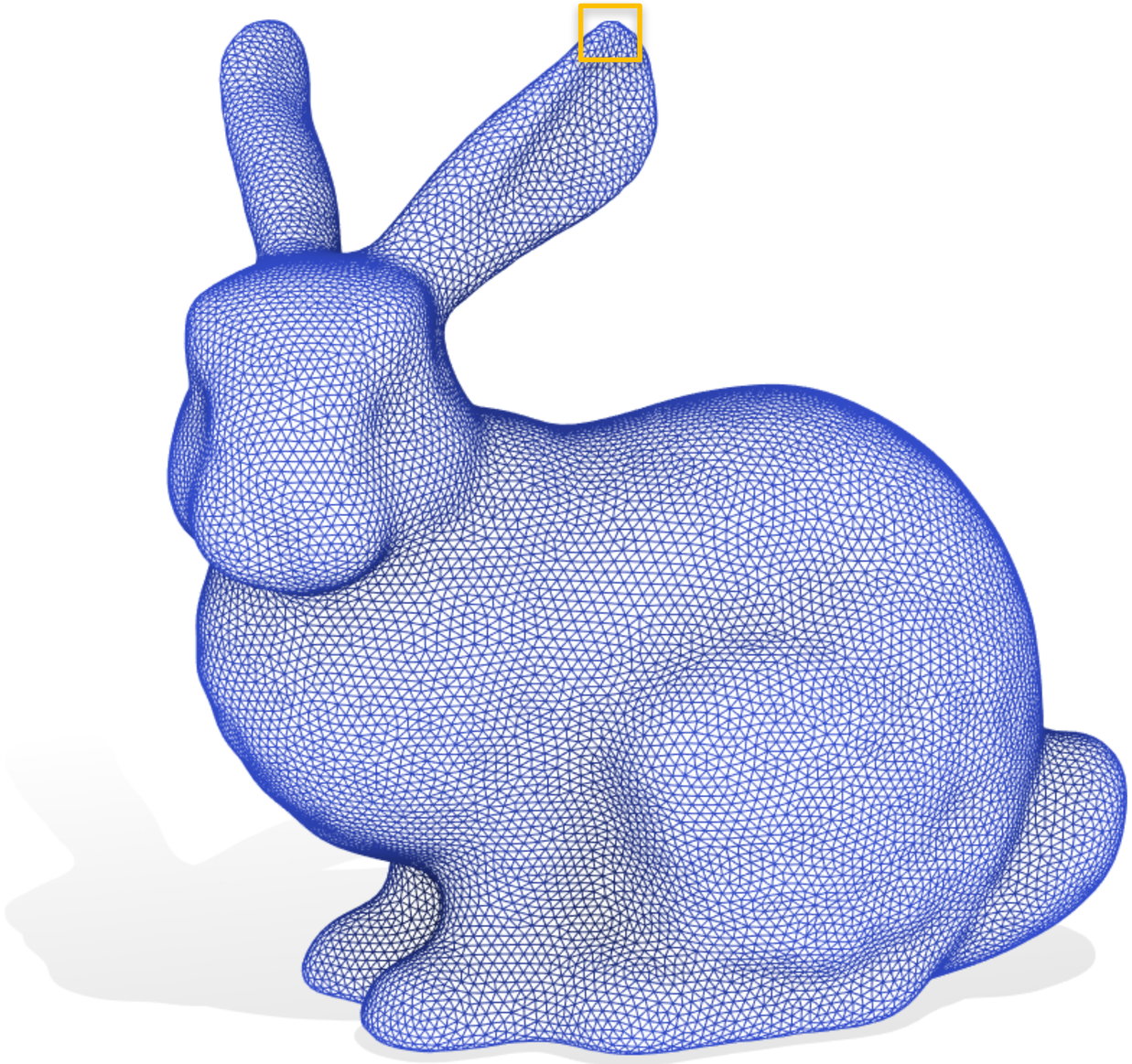


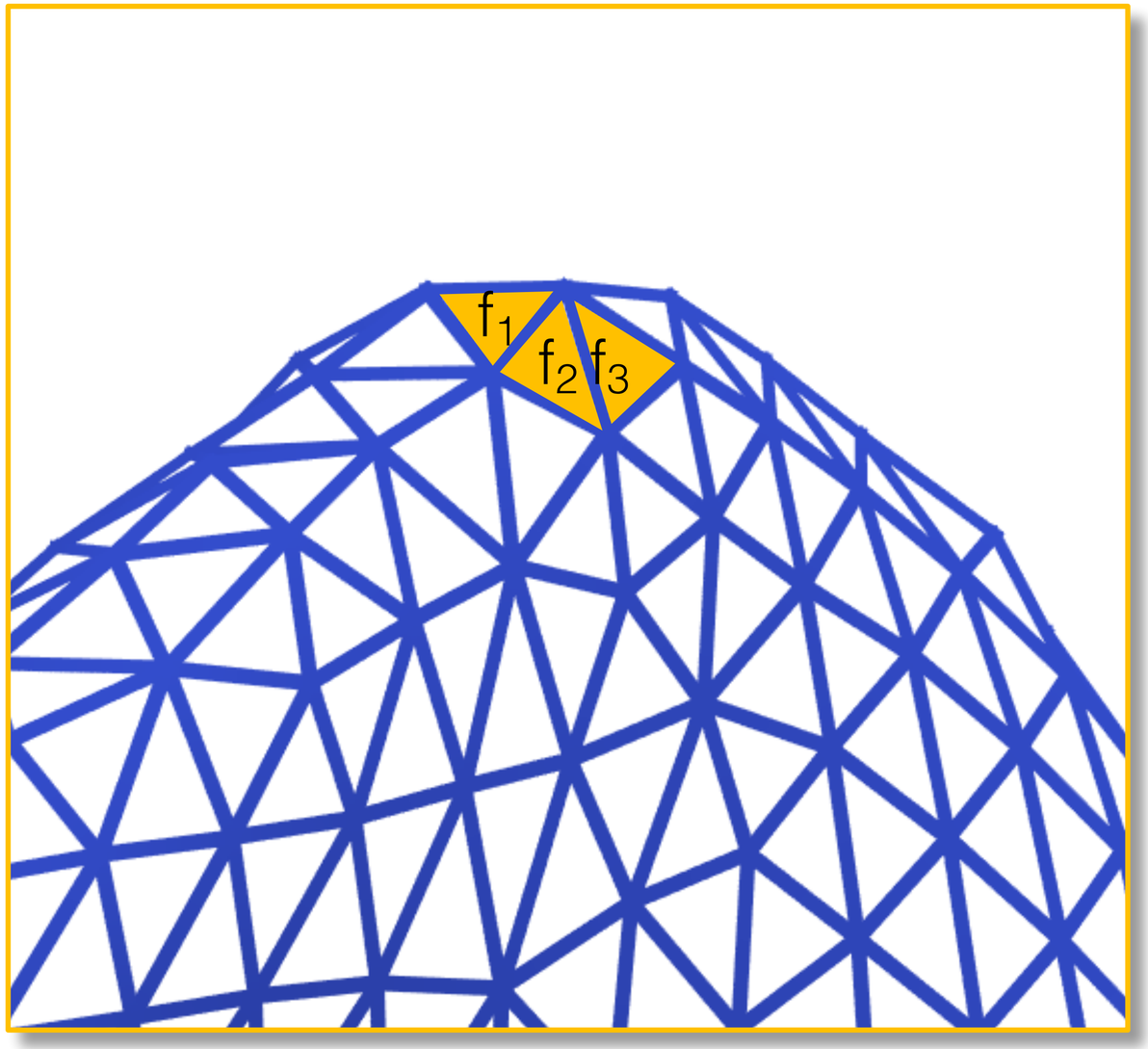
Triangle meshes discretize surfaces…



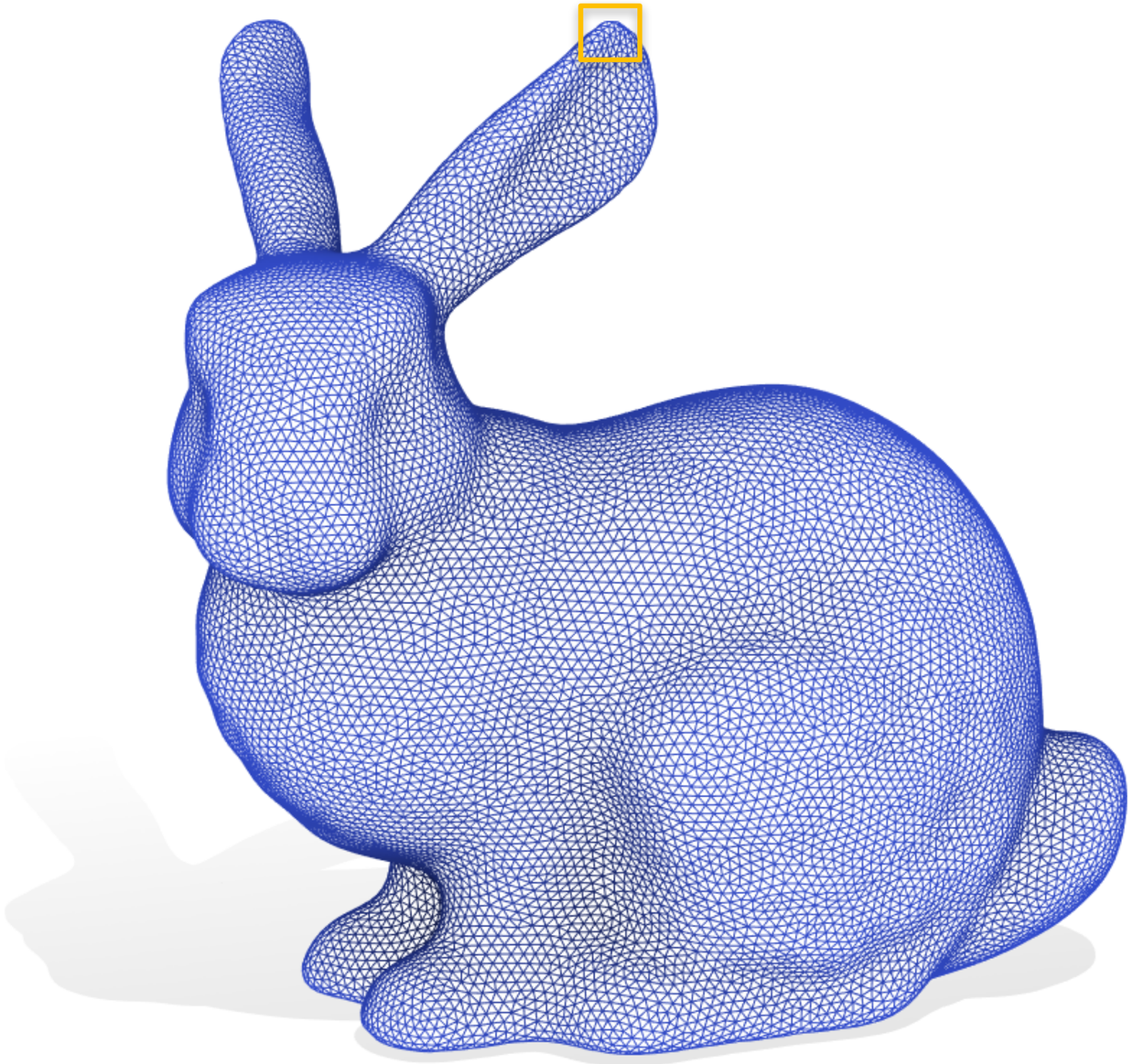


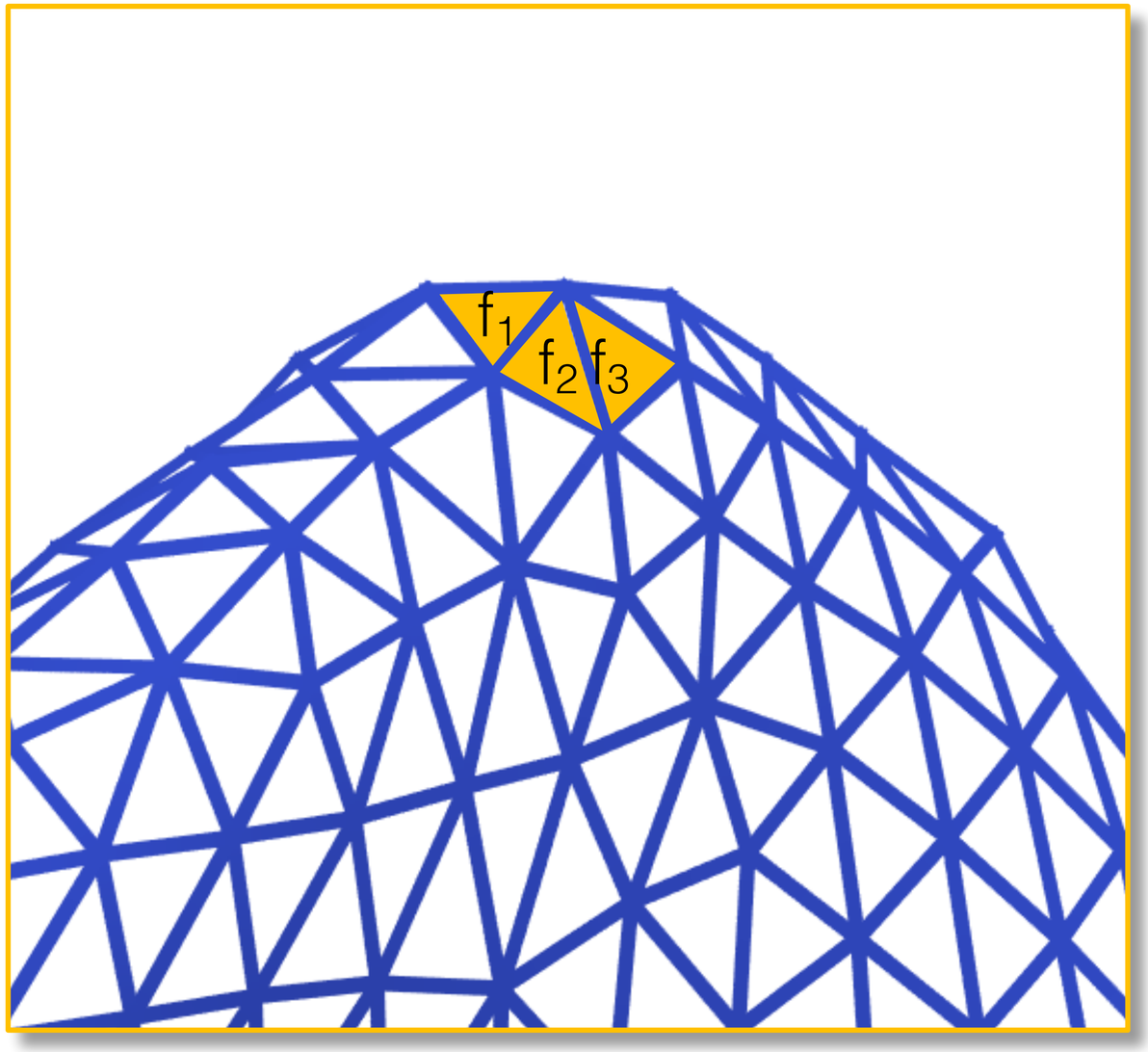
Triangle meshes discretize surfaces…



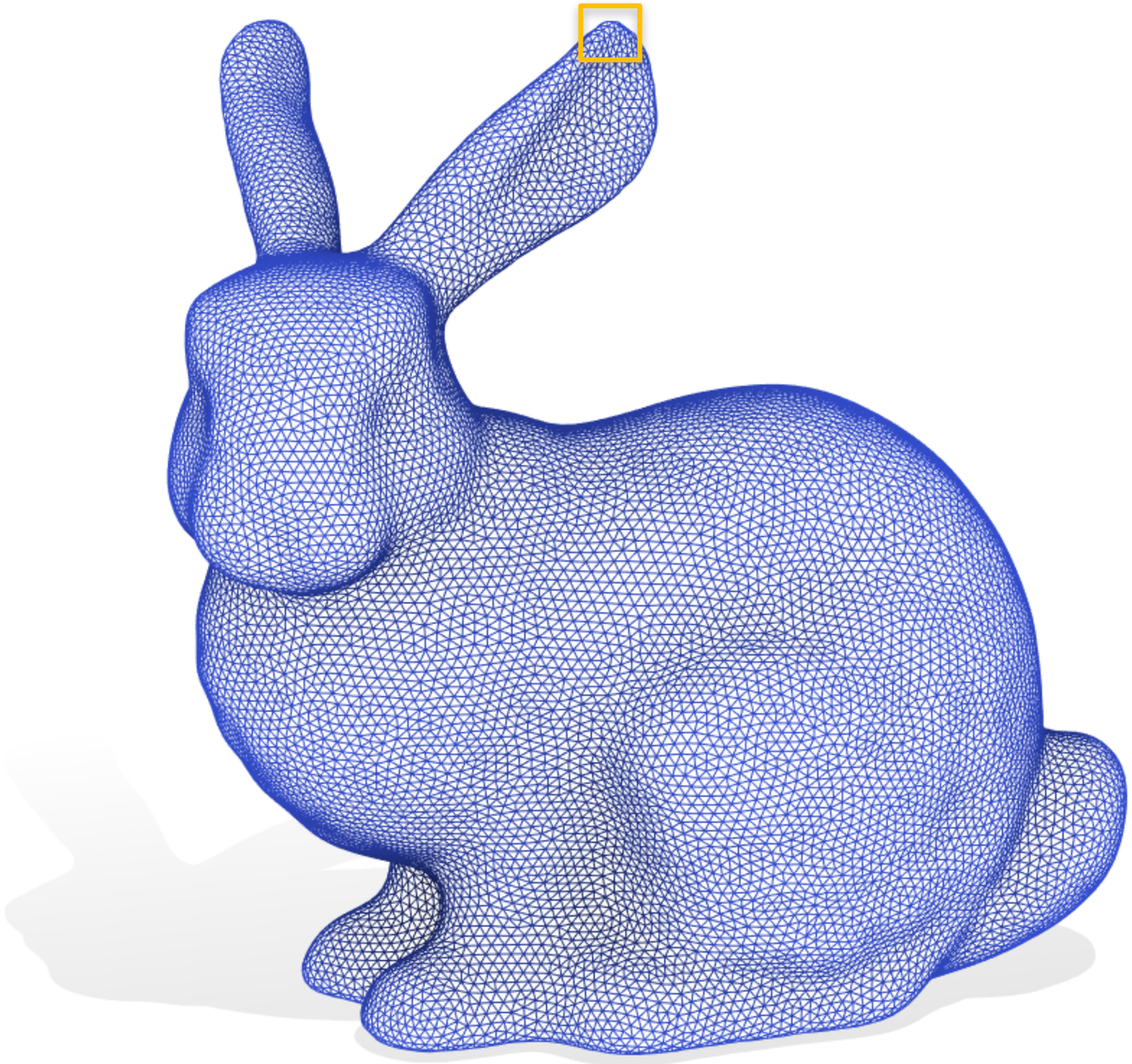


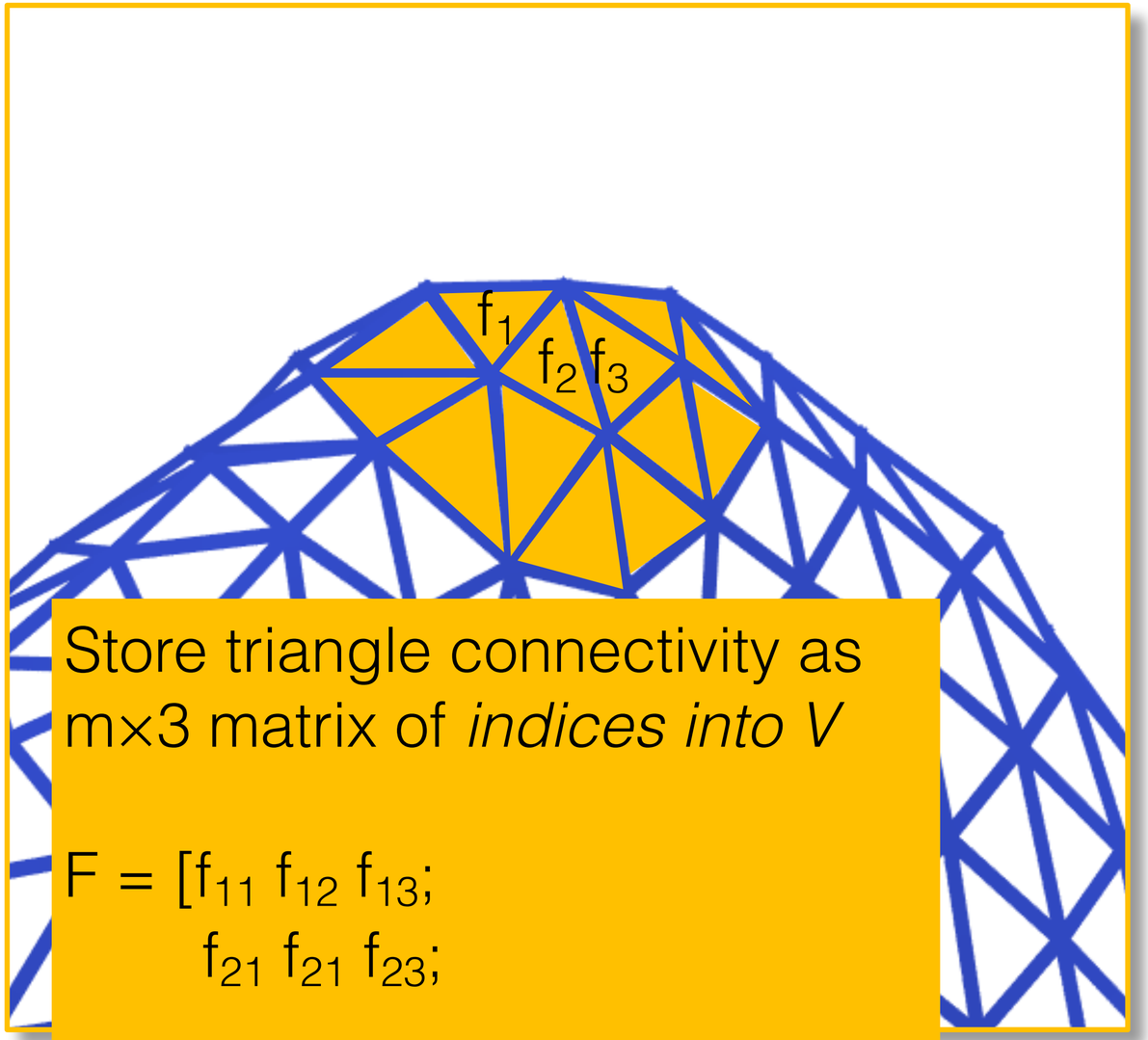
Triangle meshes discretize surfaces…





Triangle meshes discretize surfaces…





Store triangle connectivity as m×3 matrix of *indices into V*

$F = [f_{11}\ f_{12}\ f_{13};$
$f_{21}\ f_{21}\ f_{23};$
…
$f_{n1}\ f_{n2}\ f_{n3}]$

Why RAW matrices?

- Memory efficient and cache friendly
- Indices are simpler to debug than pointers
- Trivially copied and serialized
- **Interchangeable** with other libraries: **numpy**, pyTorch, Tensorflow, Scipy, MATLAB, OpenCV

Getting Started

Binder Demo