Intro to Geometry Processing

Announcements

Assignment 8 due last night. Last one! Good job!

Tutorial on Friday for bonus homework assignment stuff and/or questions about theory for exam prep

Bonus assignment due Sunday 16 August

Final exam Saturday 22 August at 9pm (according to vote)

Course Evaluations

Computational Fabrication

Today:

General Overview

Geometry Processing course assignments

- Reconstruction
- Registration
- Smoothing
- Deformation
- Parameterization
- Curvature

Any Questions?

What is geometry processing?

birth

. . .

e.g., scan of a physical object or modeling in Maya

https://www.cs.toronto.edu/~jacobson/images/geometry-processing-in-the-wild-alec-jacobson.pdf

What is geometry processing?

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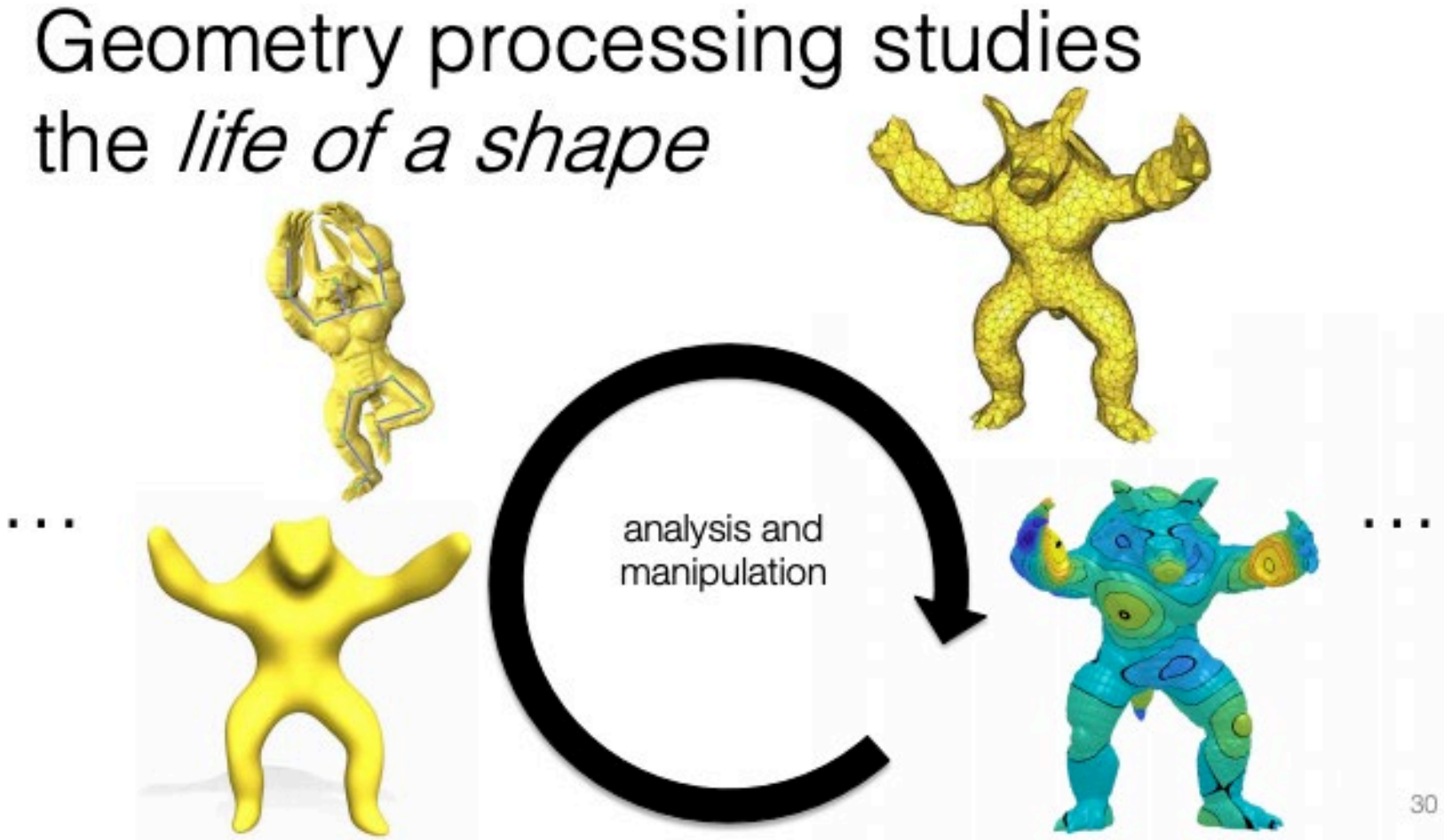

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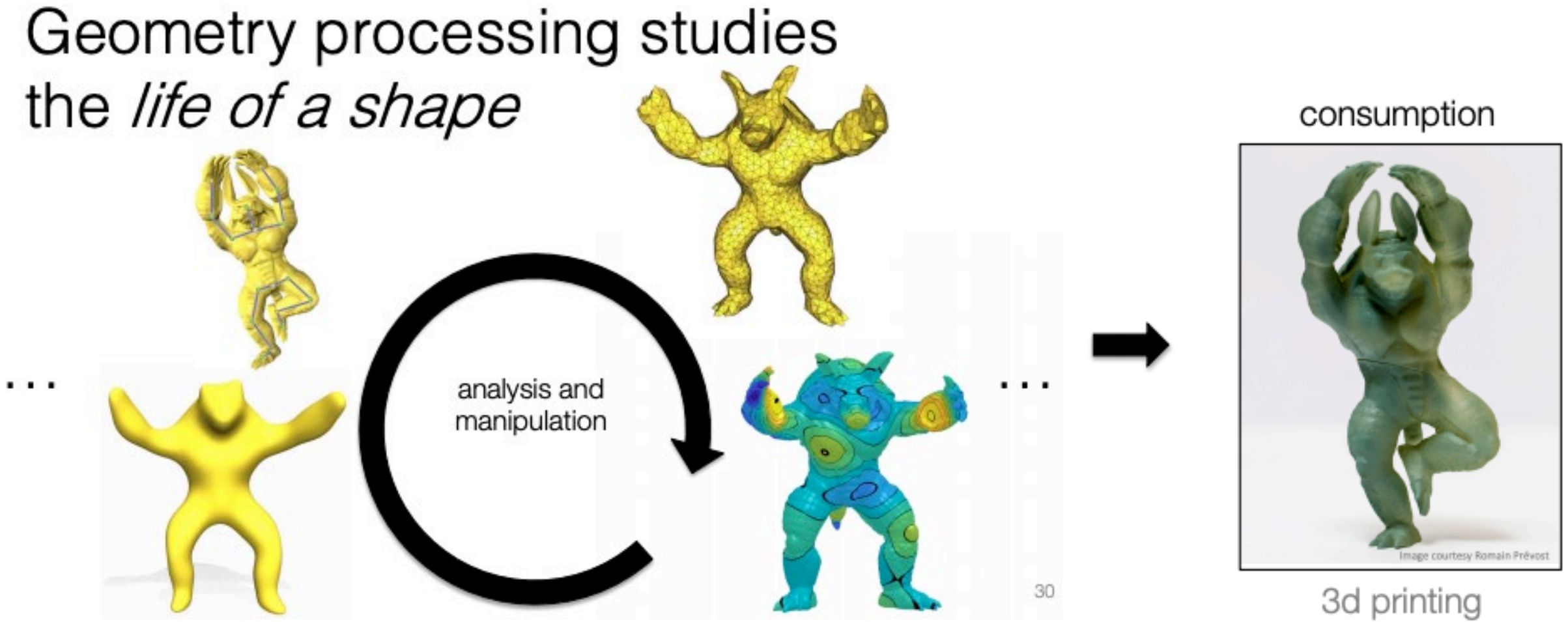
What is geometry processing?



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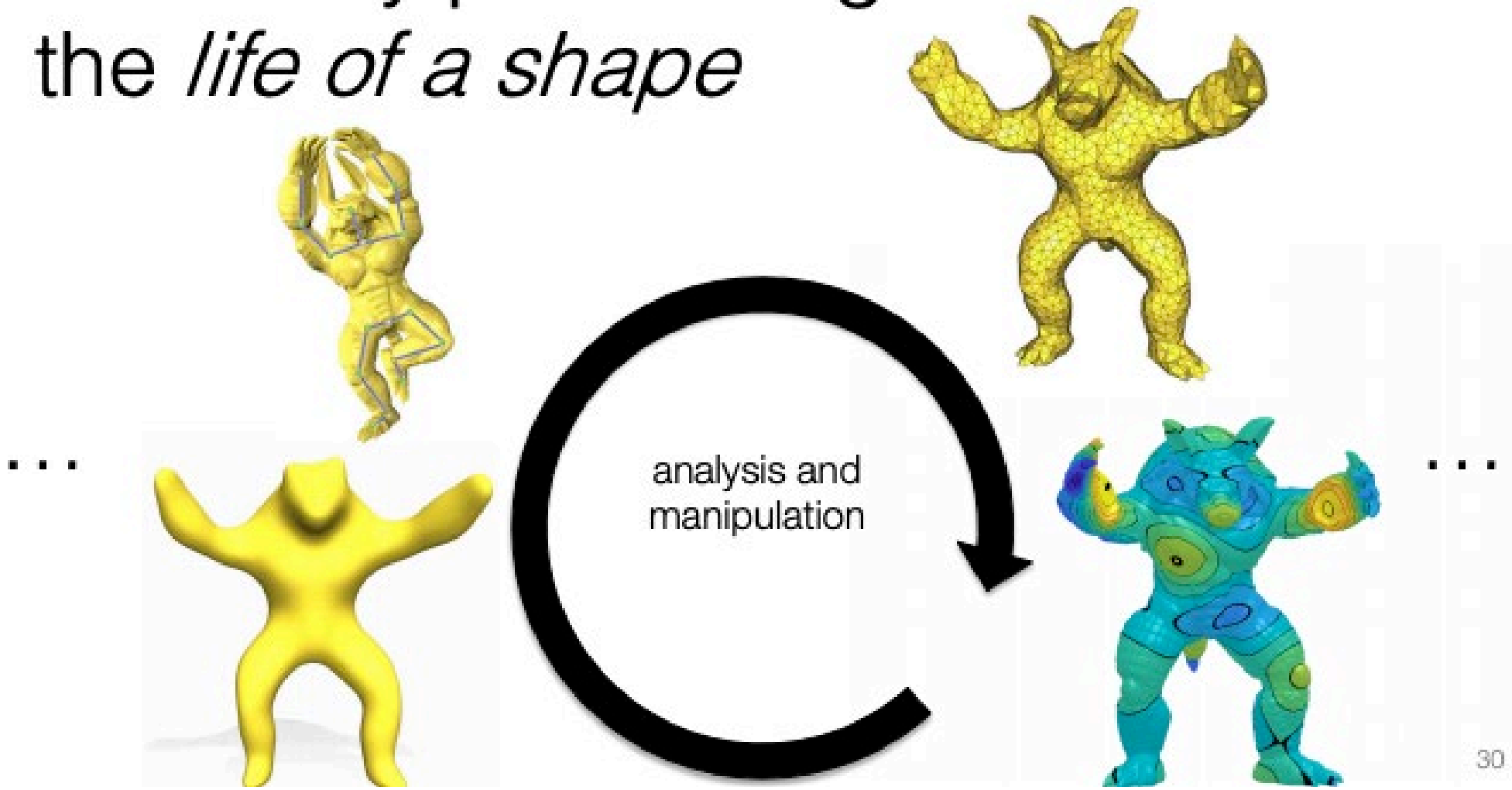
What is geometry processing?

Geometry processing studies
the *life of a shape*



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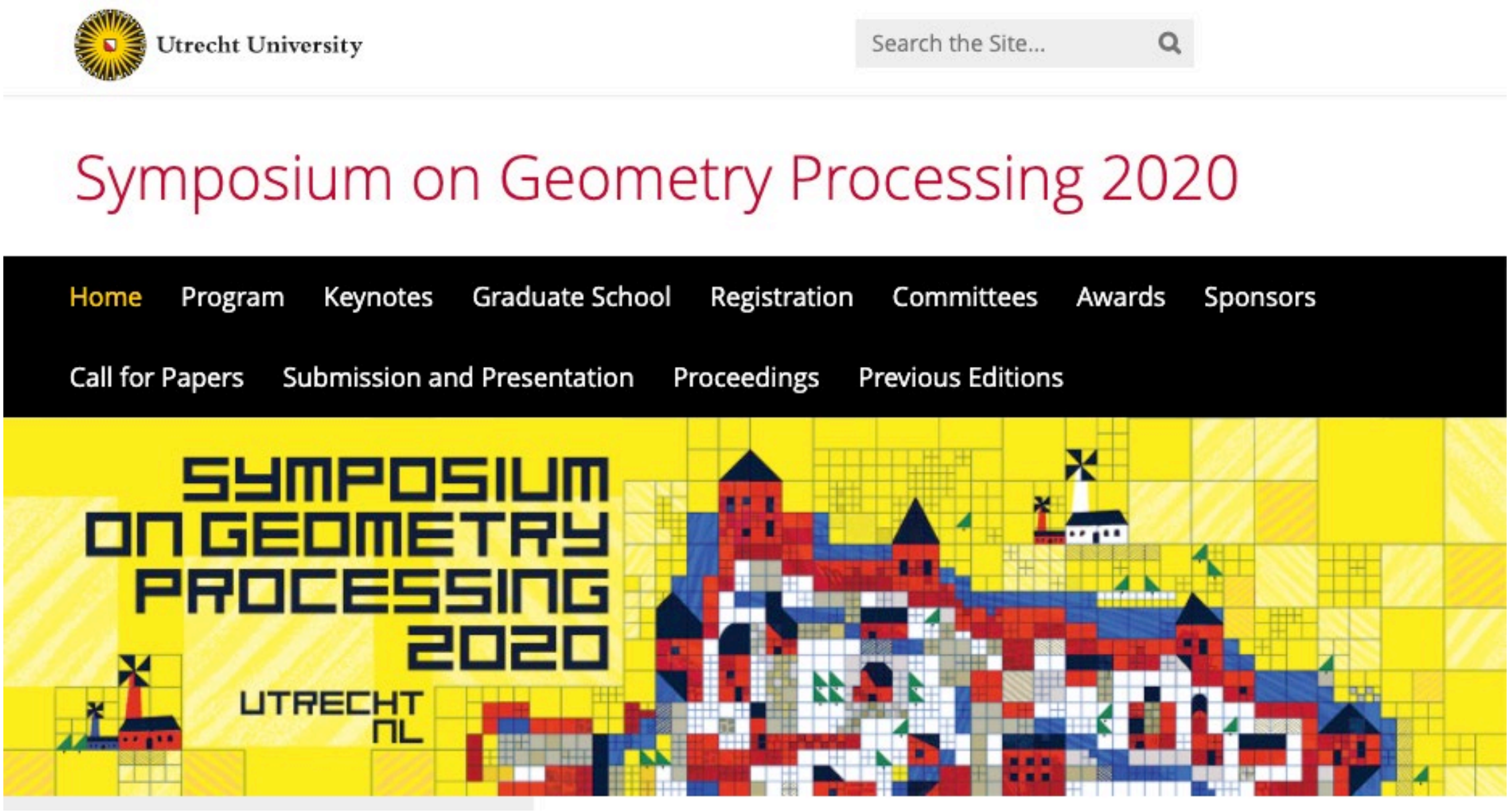
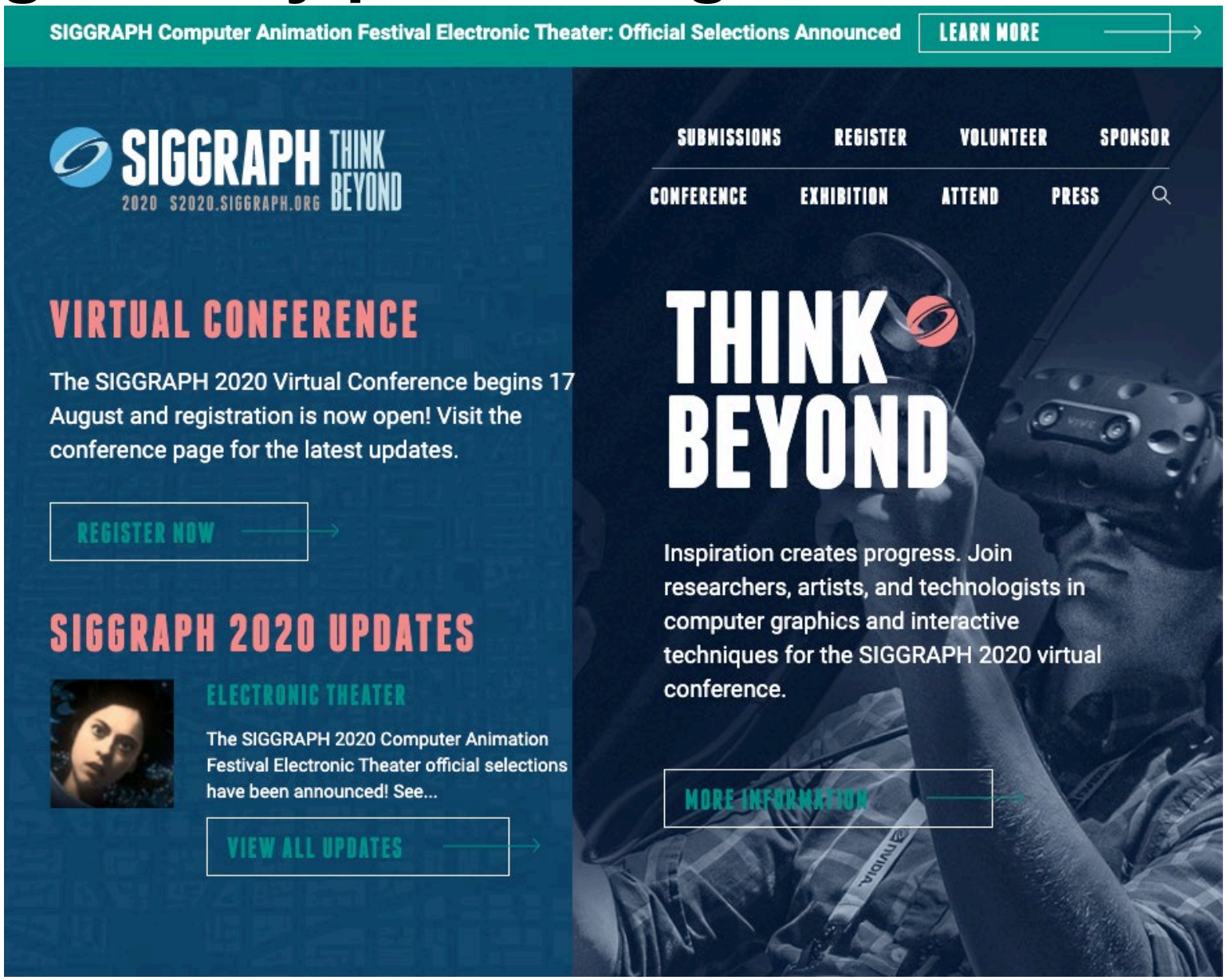


https://sgp2020.sites.uu.nl/

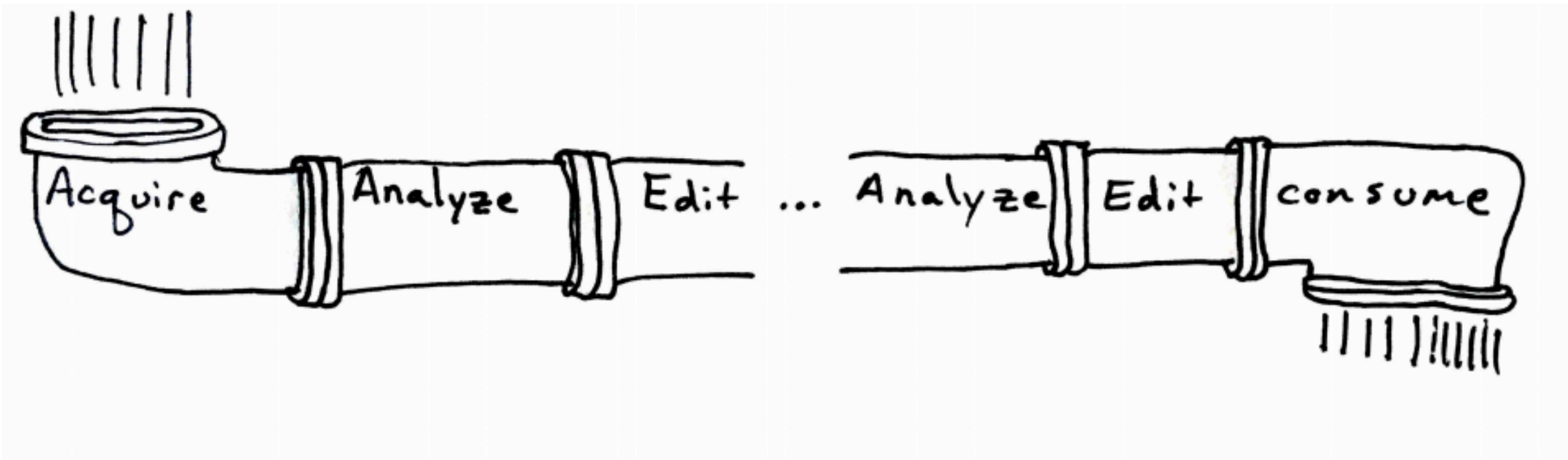
What is geometry processing?



https://s2020.siggraph.org/

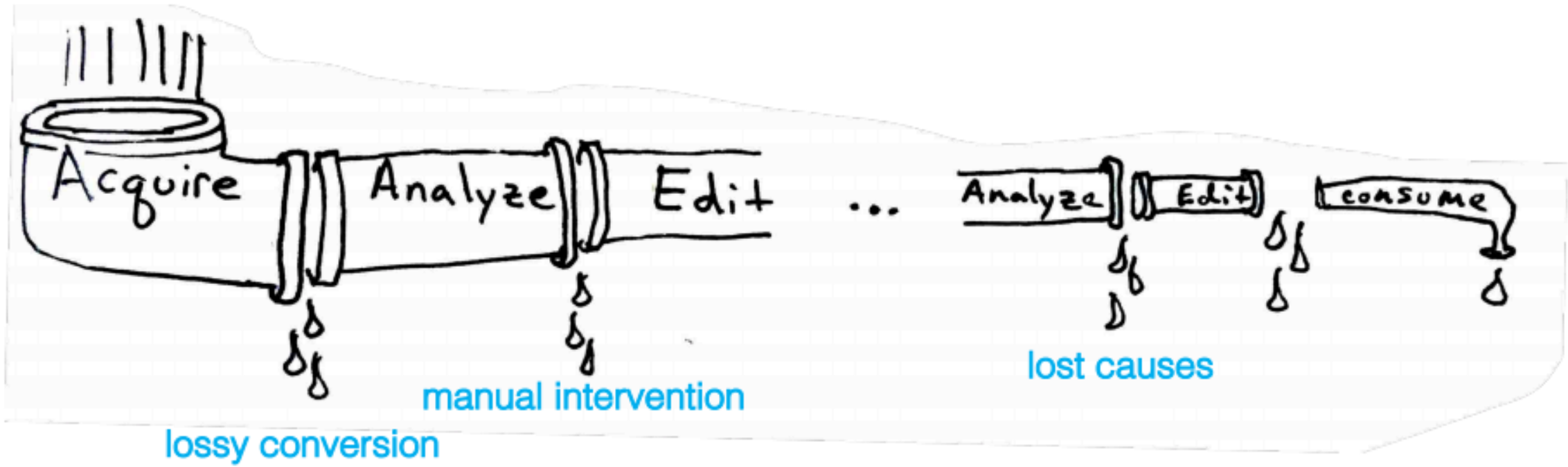
In practice

Traditionally we think of the geometry processing *pipeline*…



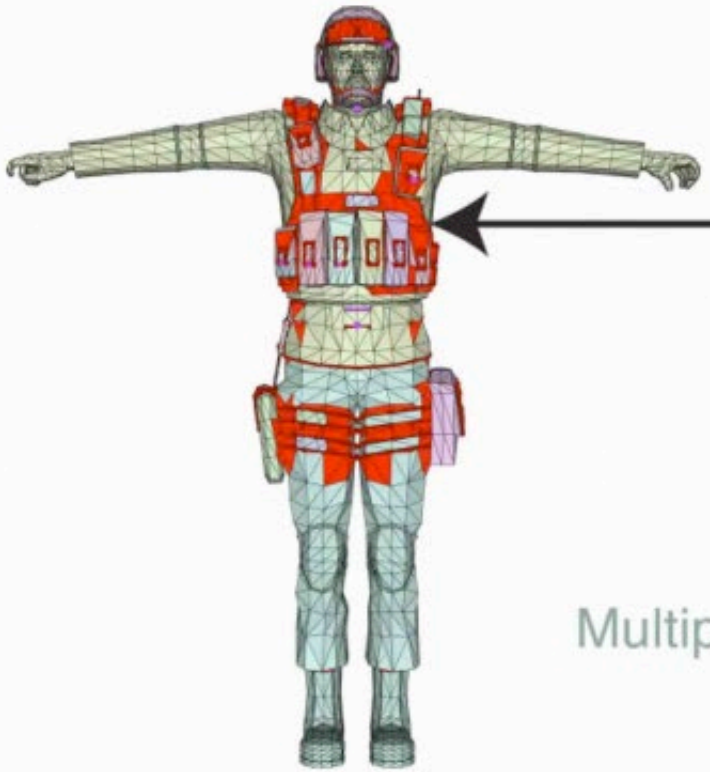
In practice

… in the *wild* this pipeline is leaky

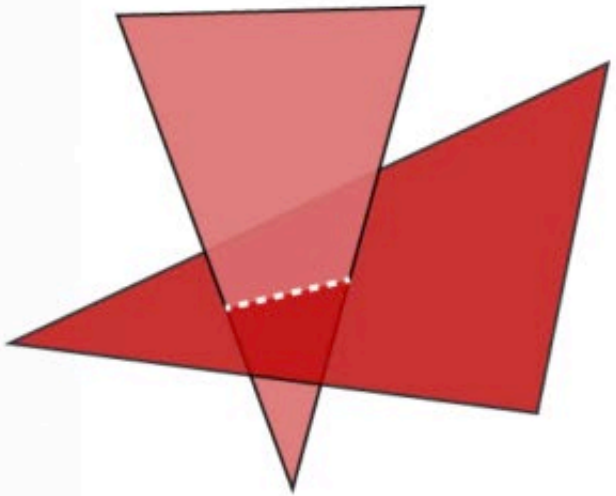


In practice, we want algorithms that work on any mesh, even yucky ones

Good enough for visualization does not imply good enough for admit geometric computation



Self-intersections



Multiple connected components

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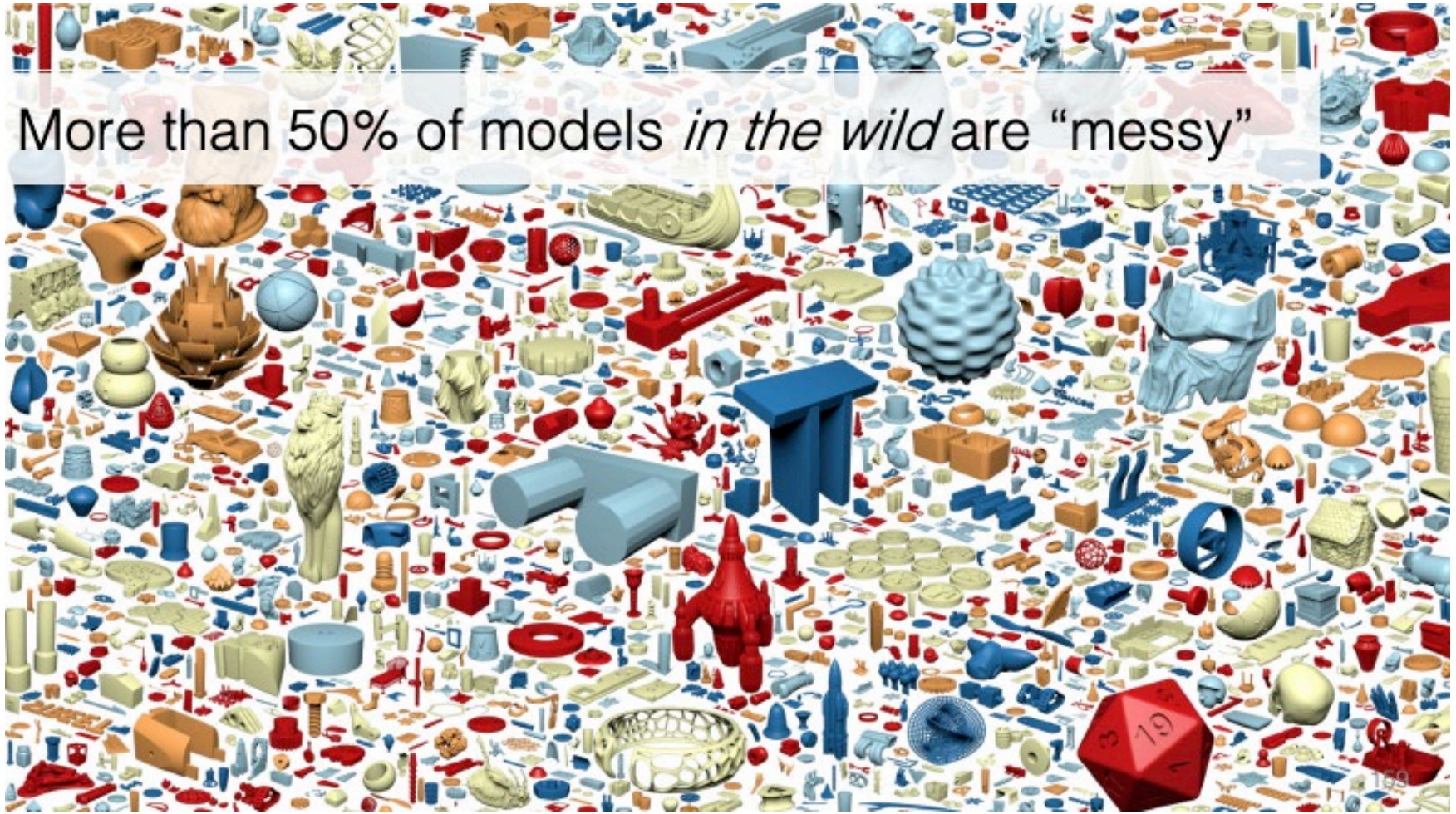

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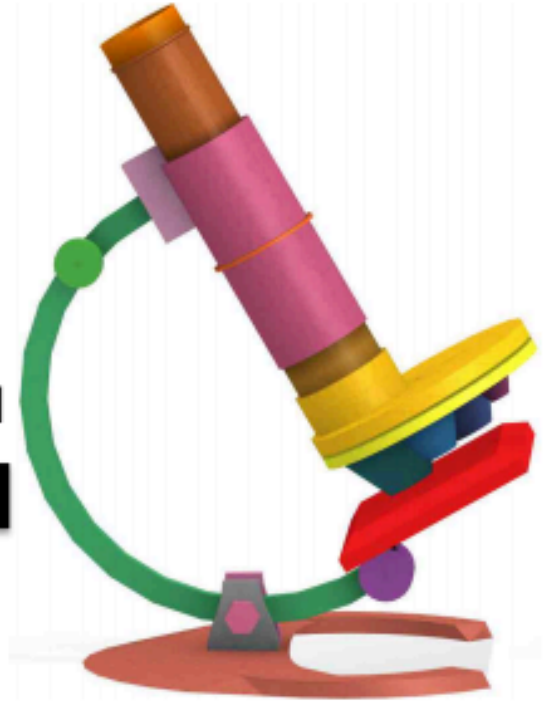
Isolating subproblems from full pipeline can make robustness harder

Discretize volume and use finite element method



Solve heat equation on this microscope modeled as union of 24 overlapping parts

http://dgp.toronto.edu/~sgsellan/pdf/overlapping.pdf

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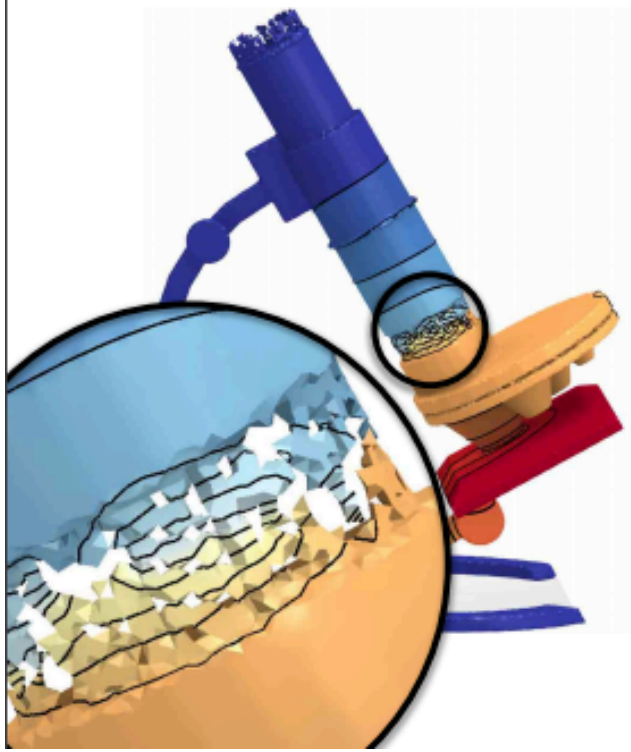

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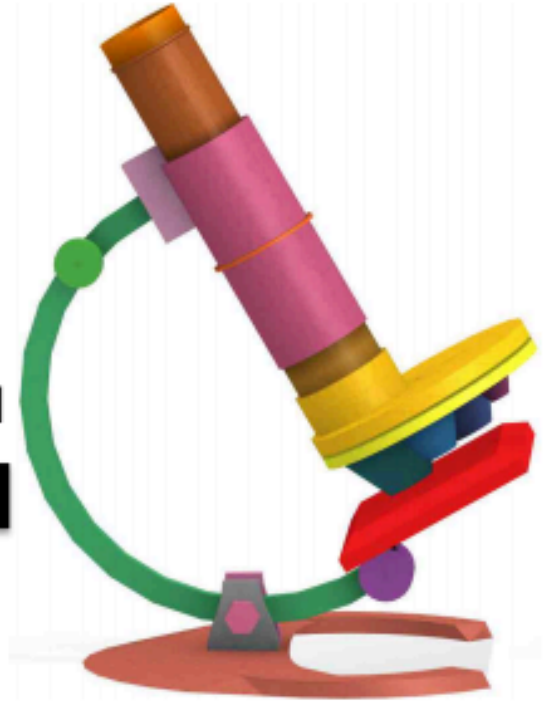

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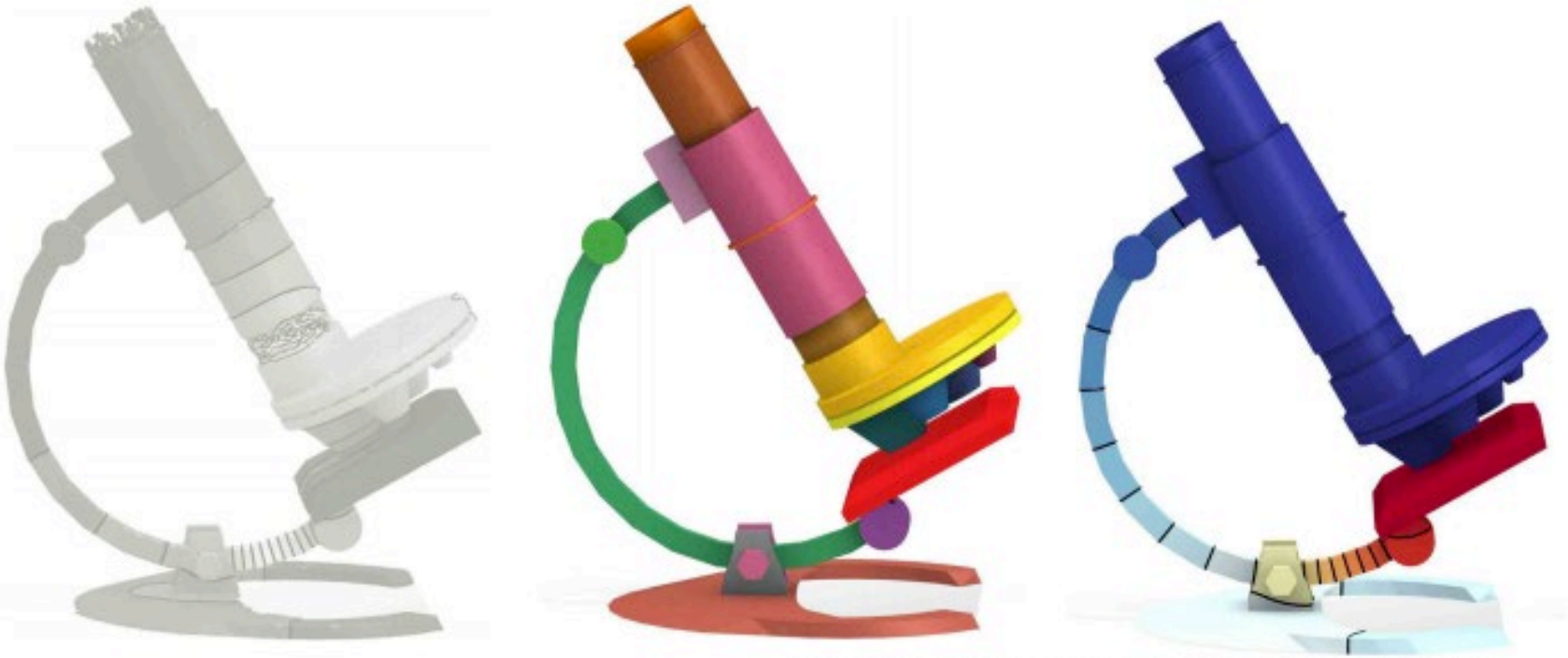

"Solid Geometry Processing on Deconstructed Domains"
[Sellán, Cheng, Ma, Dembowski, & J. 2019]

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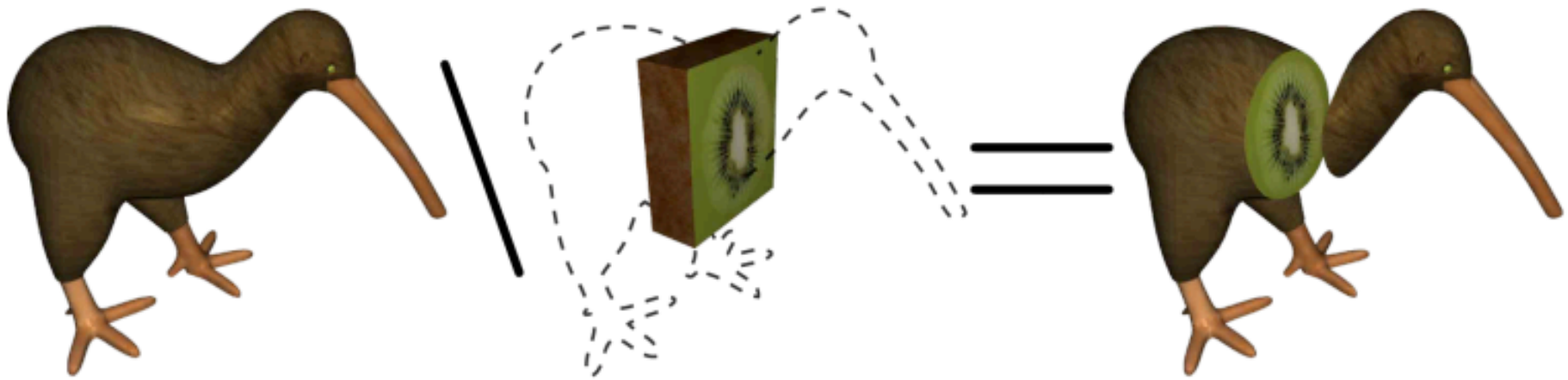
Novel Boolean algorithm accepts
all piecewise-constant winding number meshes



"Mesh Arrangements for Solid Geometry" [Zhou, Grinspun, Zorin, & J. 2016]

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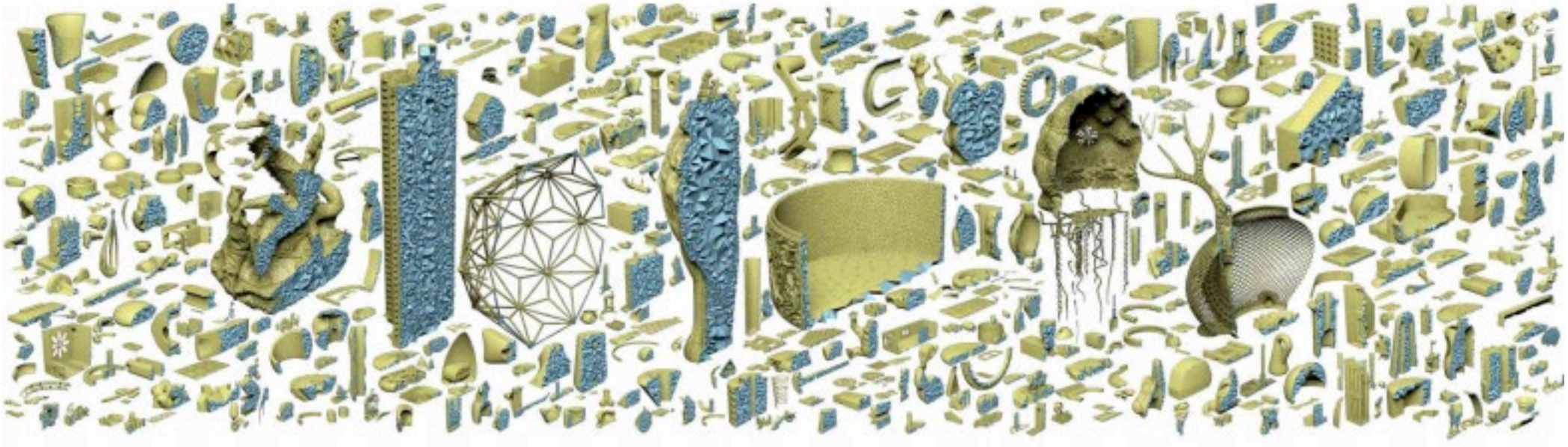
Validate in the wild on 10,000 models



mesh entire convex hull
conform to surface up to small *epsilon*
extract interior via generalized winding number

"Tetrahedral Meshing in the Wild" [Hu, Zhou, Gao, J., Zorin, Panozzo 2018]

Course Structure (at least when I took it)

Lectures on math and algorithms – on the board

- Mostly discuss first the problem in the continuous setting (energies, operators)
- Then sometimes move onto the discrete analog (matrices, usually sparse)
- Read papers + README to implement assignments
- PDEs experience is “not required” but ***very*** useful

7 assignments
Course project
Course participation – contribute to the geometry processing Wikipedia article

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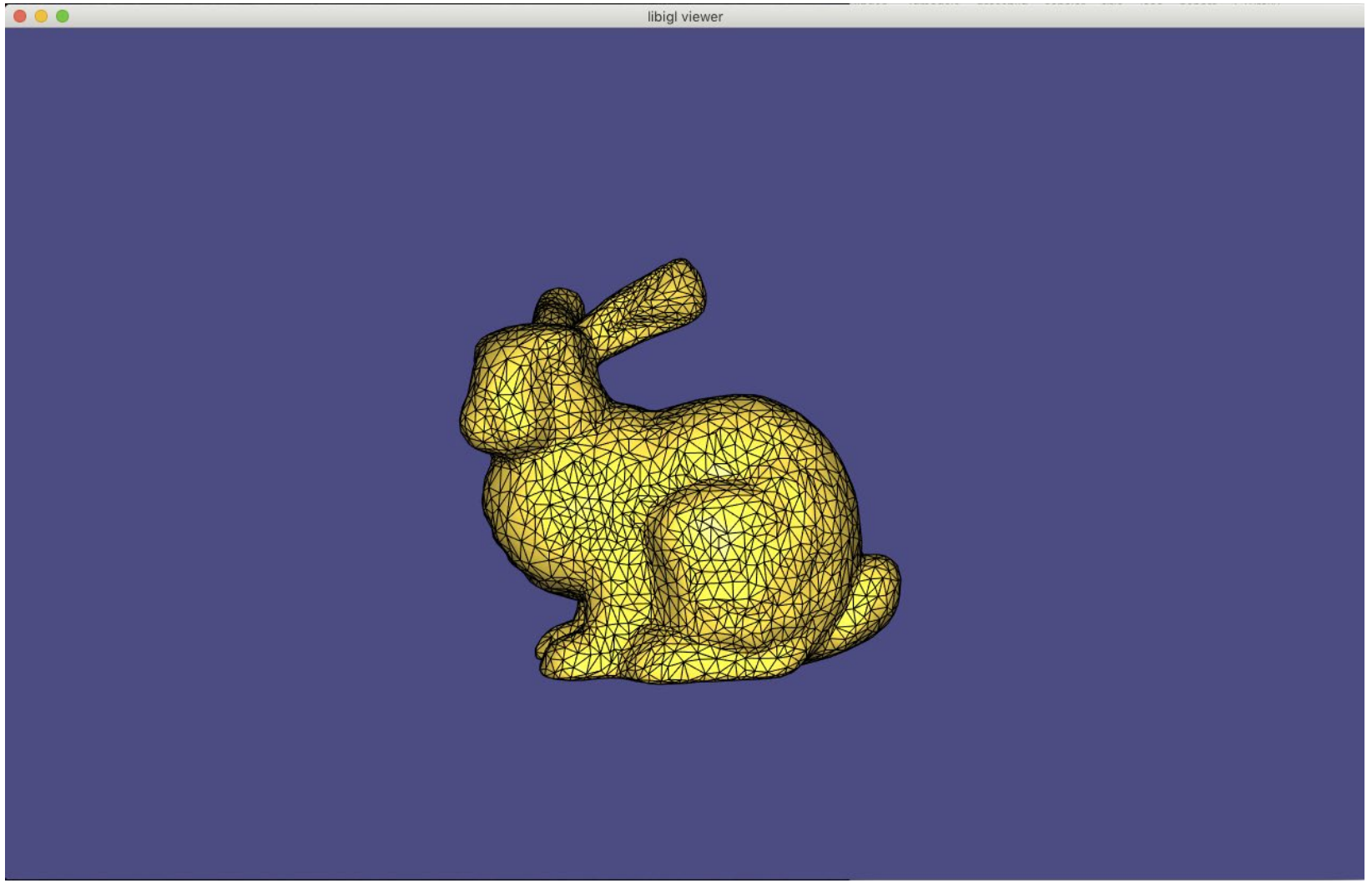
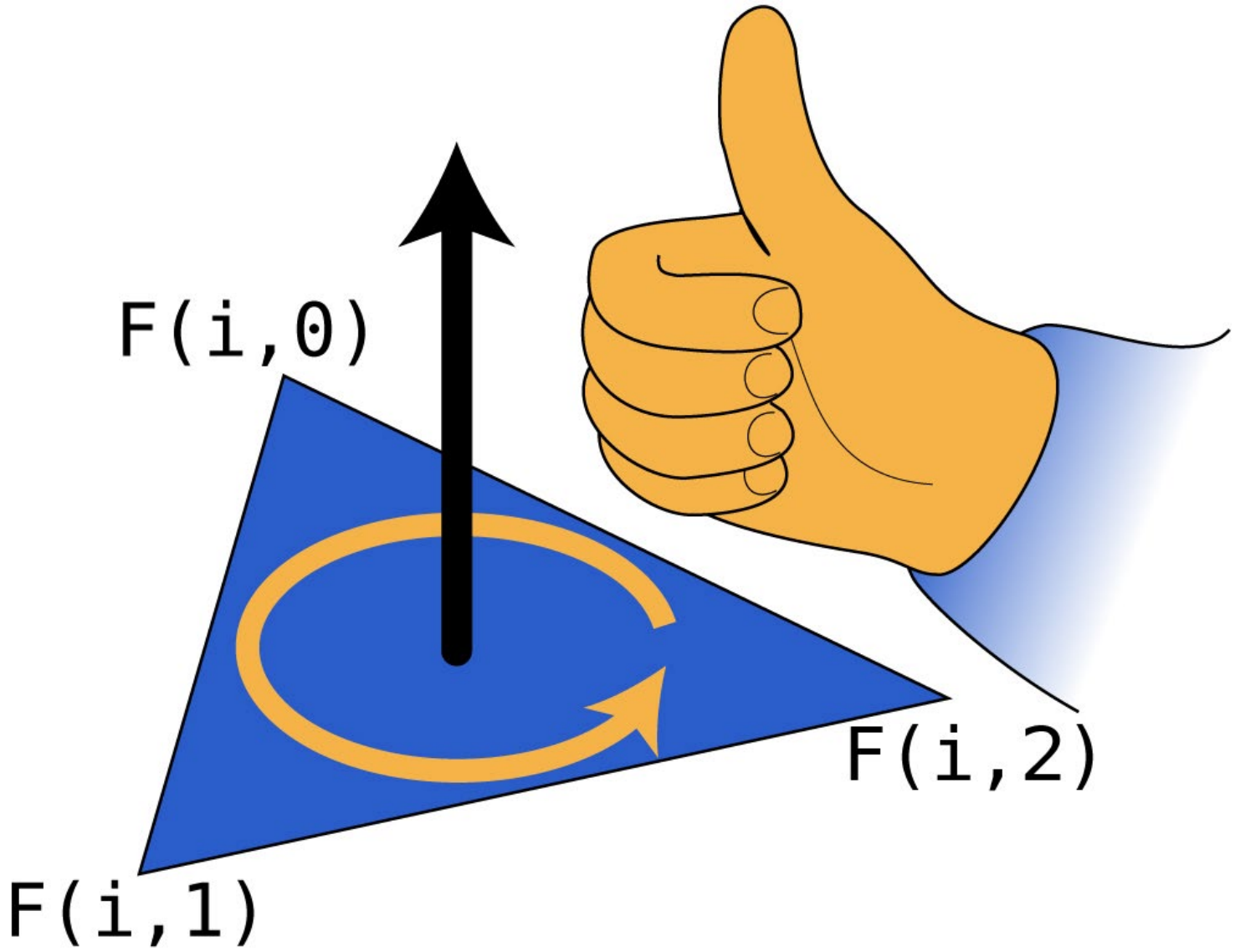
Fundamentals

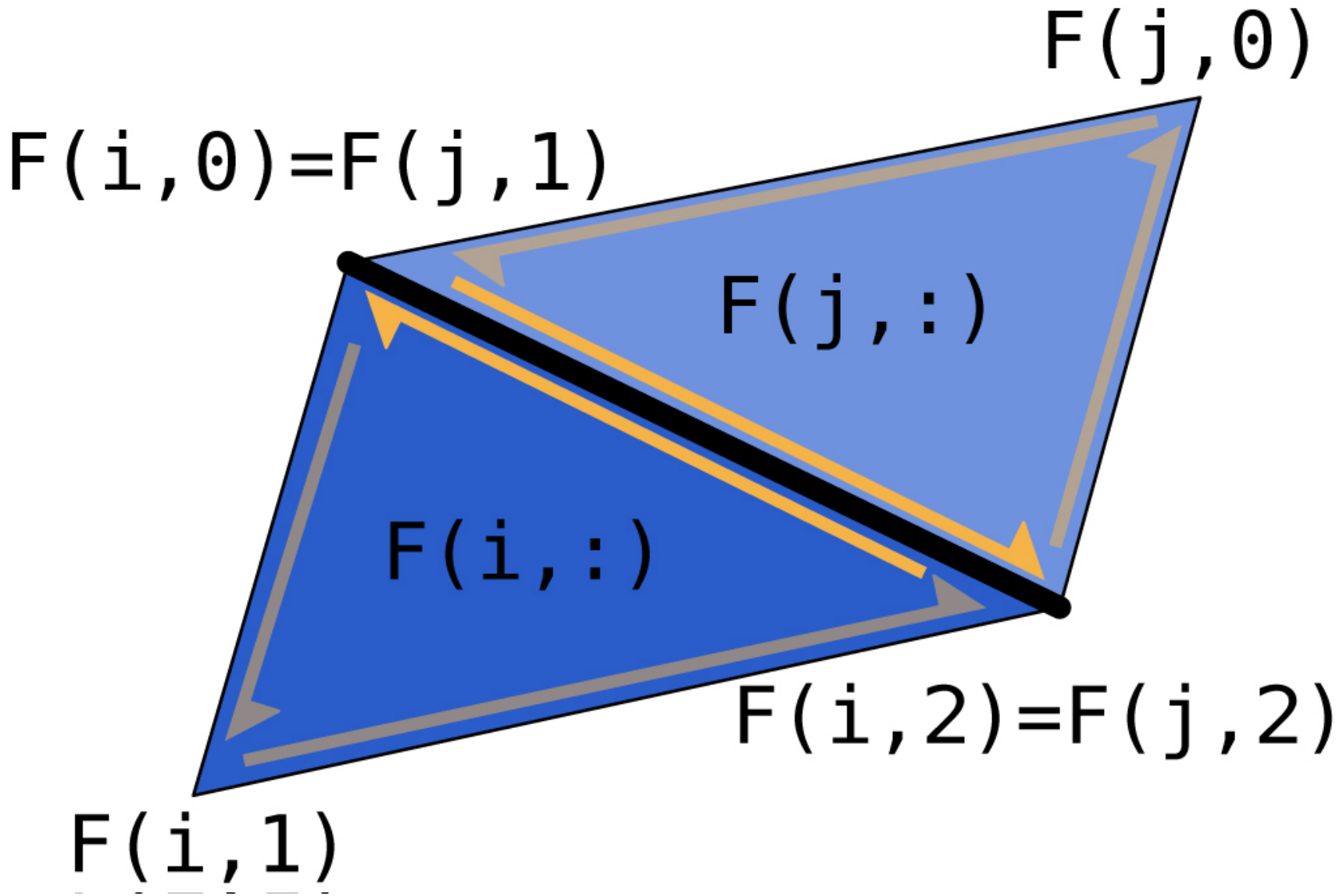


https://github.com/alecjacobson/geometry-processing-introduction

Fundamentals



Fundamentals



Assignments

Reconstruction

Given a point cloud (this type of data can come from 3D scanning

Make an “explicit surface representation” (mesh)

Poisson surface reconstruction
http://hhoppe.com/poissonrecon.pdf

Registration

Align one surface with another

Compute Hausdorff distance – a scalar that measures how poorly the surfaces are matched

Each iteration estimate R and T that will align each point to its match

Iterative closest point method
https://en.wikipedia.org/wiki/Iterative_closest_point

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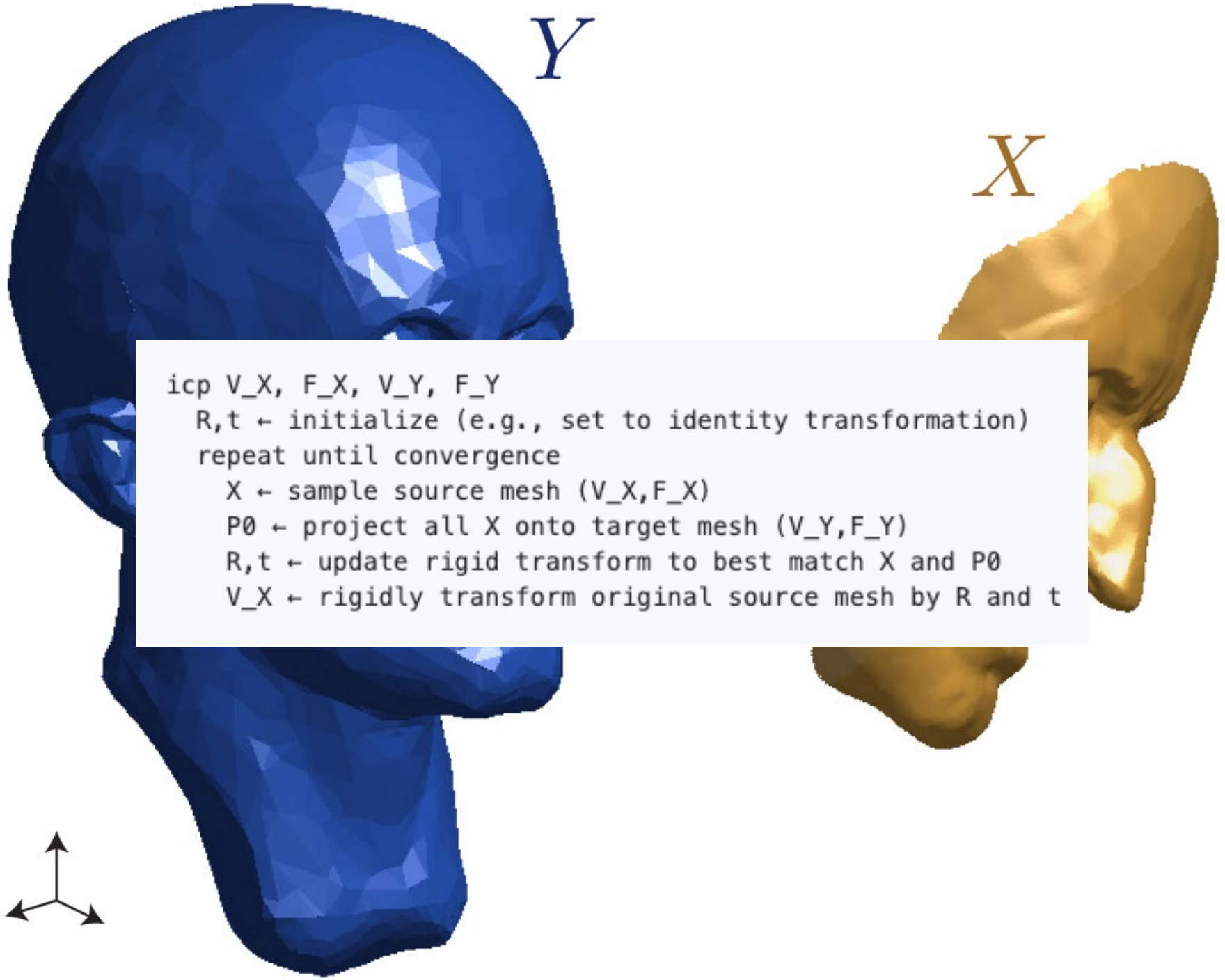



```
icp V_X, F_X, V_Y, F_Y
  R,t ← initialize (e.g., set to identity transformation)
  repeat until convergence
    X ← sample source mesh (V_X,F_X)
    P0 ← project all X onto target mesh (V_Y,F_Y)
    R,t ← update rigid transform to best match X and P0
    V_X ← rigidly transform original source mesh by R and t
```

Smoothing

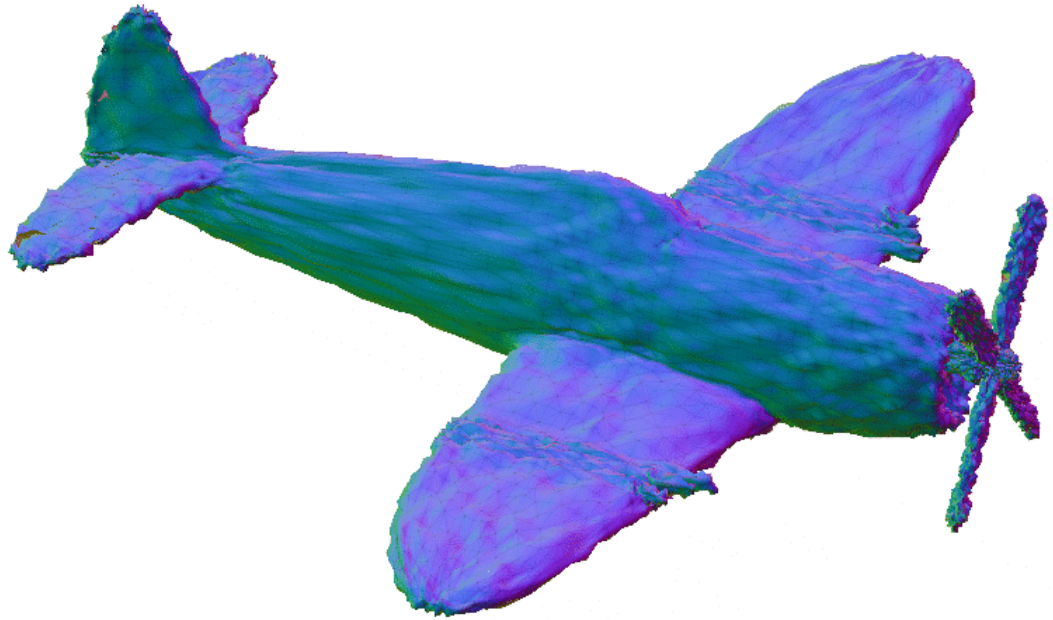
Given noisy data (signal) on a surface

Denoise

Surface fairing

Smoothing using the Laplacian
http://ddg.cs.columbia.edu/SGP2014/LaplaceBeltrami.pdf

Smoothing



Deformation

Given a mesh, place “handles”

When a handle is moved, deform the mesh

ARAP (As rigid as possible)

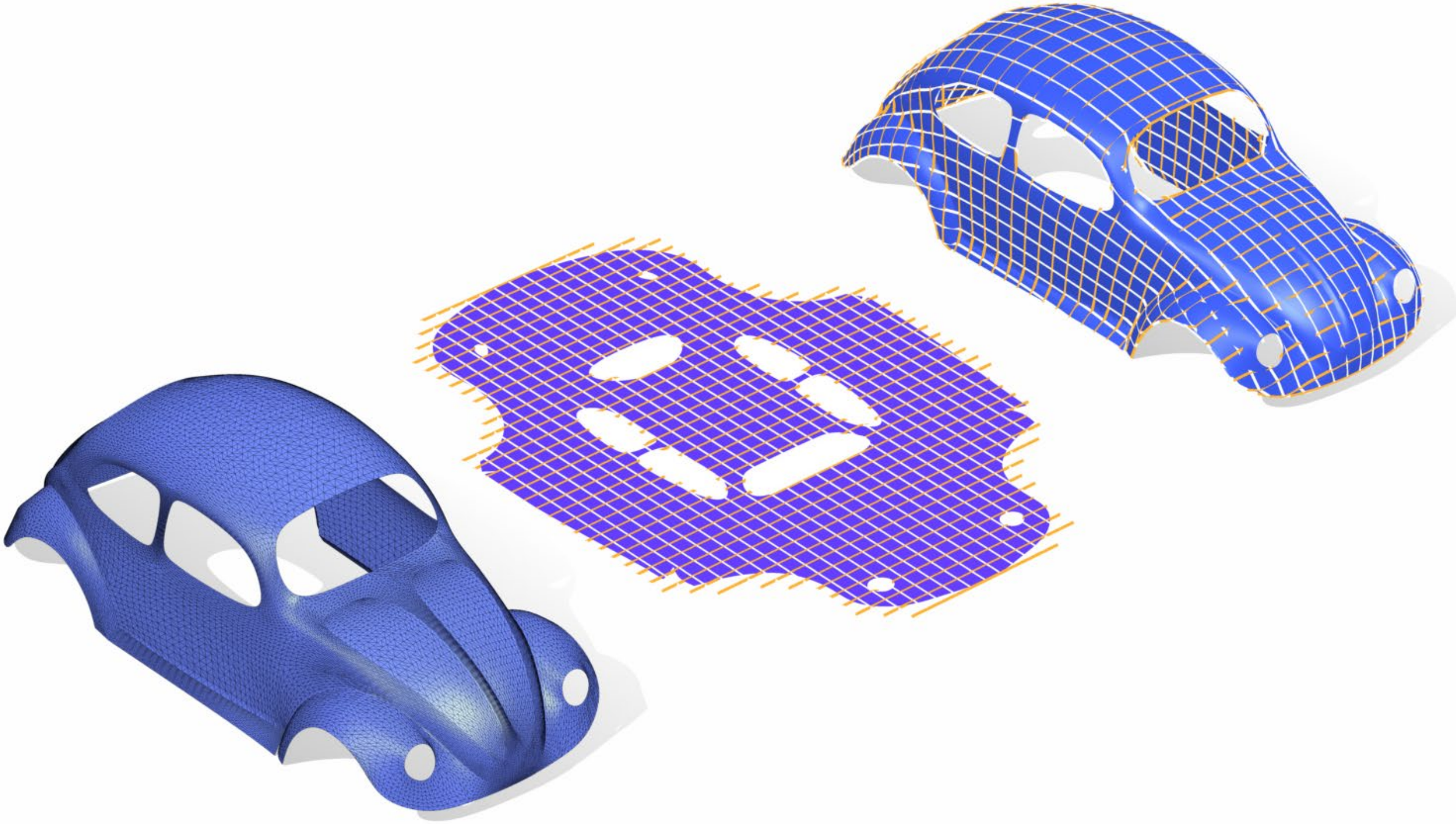
Alternate between finding optimal rotations and optimal vertex positions
http://sites.fas.harvard.edu/~cs277/papers/sorkine_asrigid.pdf

Parameterization

How do you flatten a shape?

Called parameterization because 2D coordinate system can be interpreted as a parameterization of the 3D surface

What does this remind you of?
https://dl.acm.org/doi/10.1145/566654.566590



Curvature

Local info about a shape

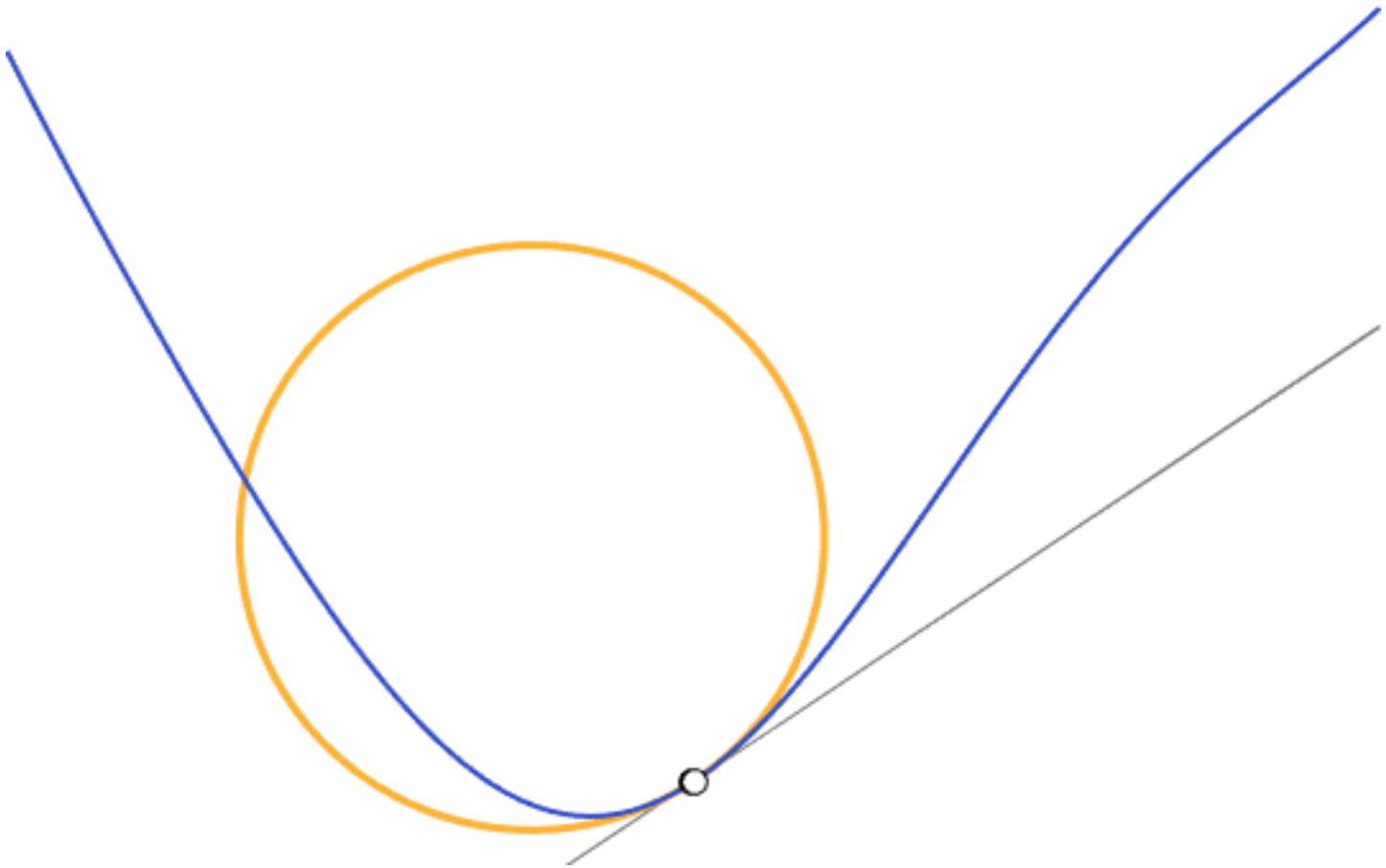
Compute difference curvature quantities

Useful for

- define energies
- salient points
- provide constraints for remeshing

https://en.wikipedia.org/wiki/Curvature#Precise_definition

Curvature



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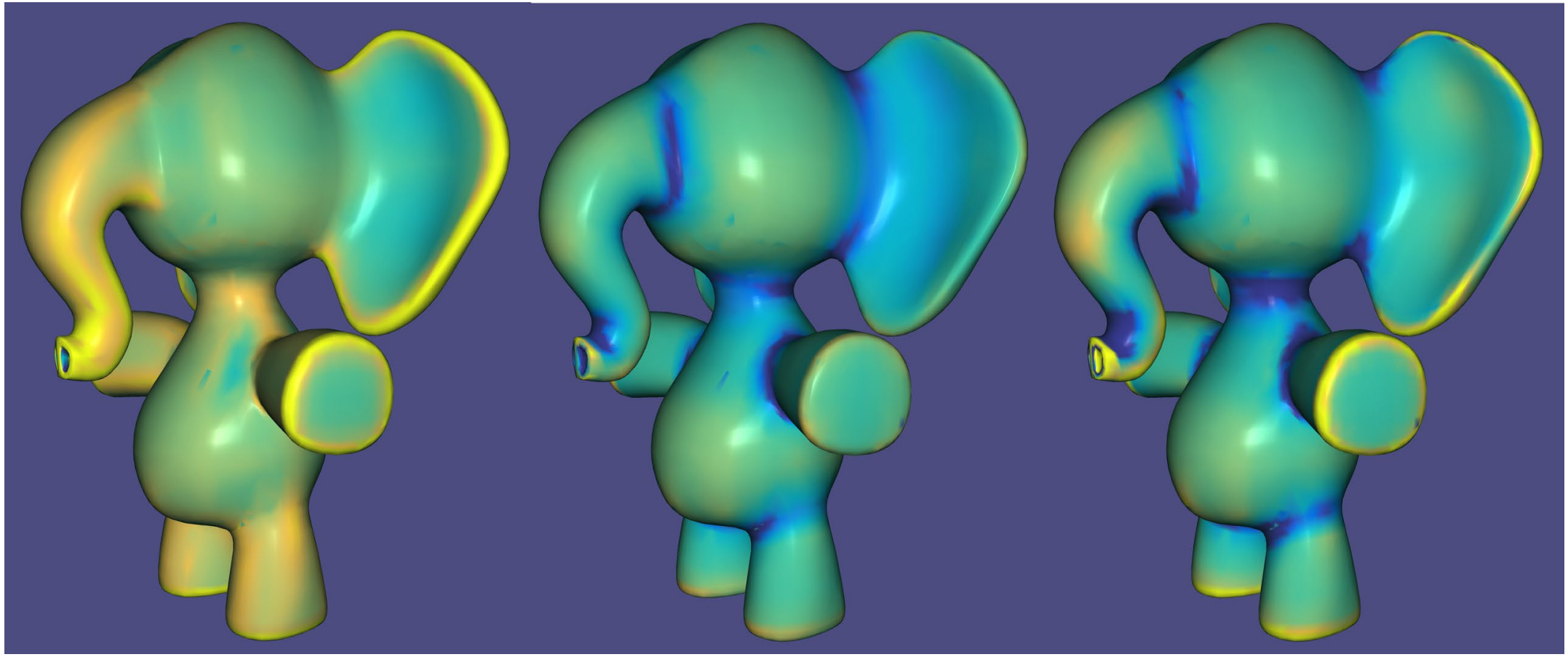

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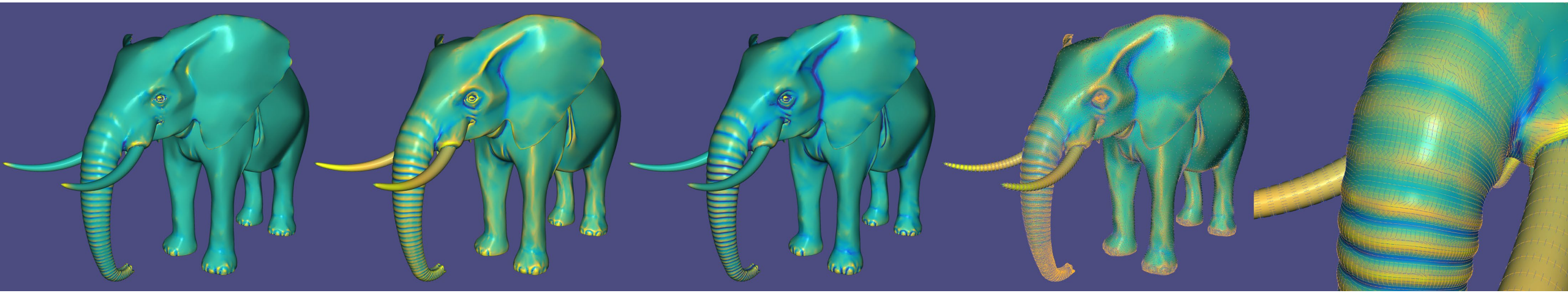

Done for Today