

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

What is geometry processing?

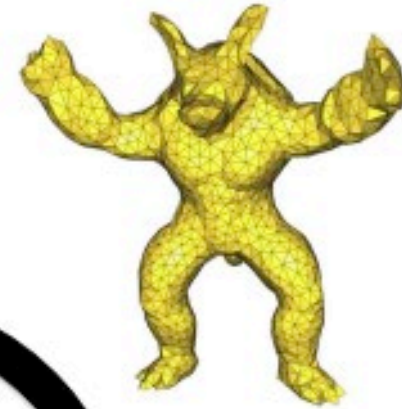
Geometry processing studies
the *life of a shape*



t or modeling in Maya



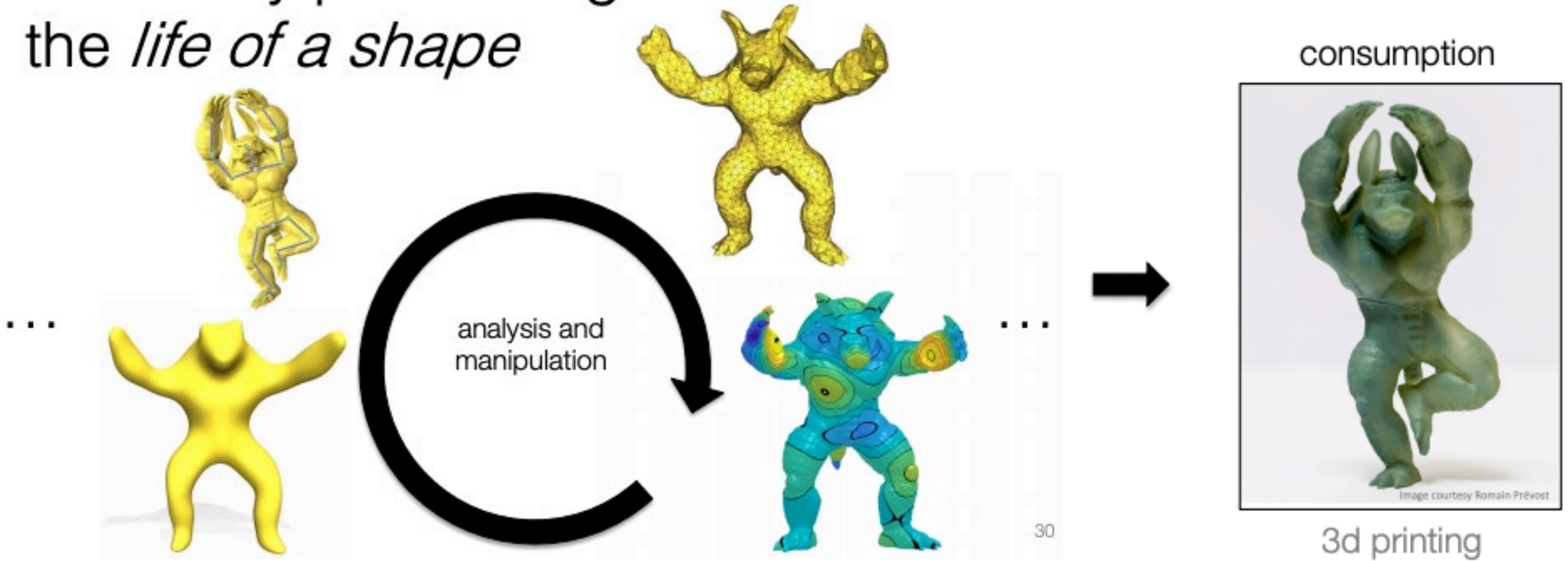
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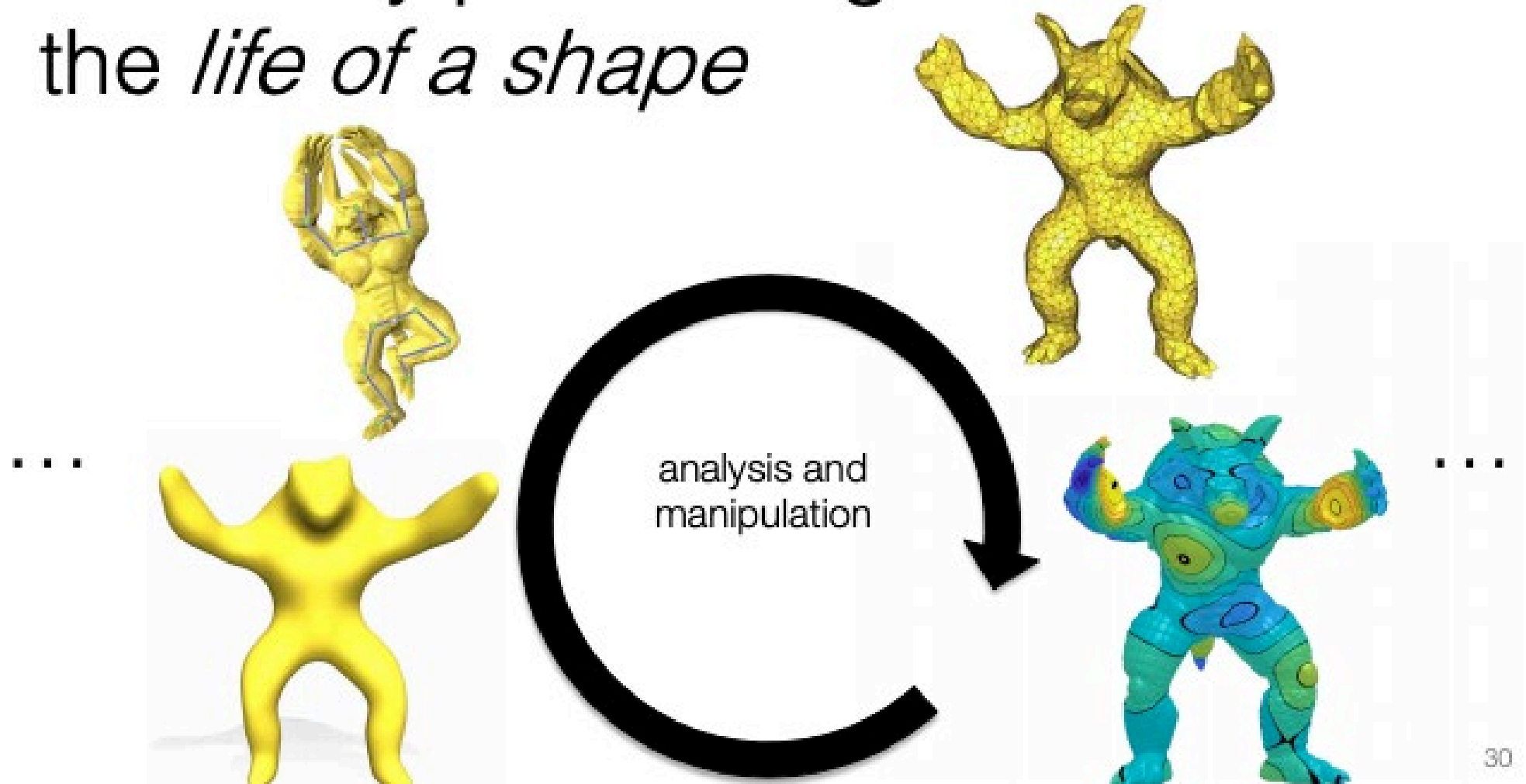
What is geometry processing?

Geometry processing studies
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What is geometry processing?

Geometry processing studies
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What is geometry processing?



Utrecht University

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Symposium on Geometry Processing 2020

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

What is geometry processing?

The screenshot shows the SIGGRAPH 2020 website. At the top, a teal banner reads "SIGGRAPH Computer Animation Festival Electronic Theater: Official Selections Announced" with a "LEARN MORE" button. Below this, the left sidebar has a dark blue background with the SIGGRAPH logo and "THINK BEYOND 2020" text. It features a "VIRTUAL CONFERENCE" section with a "REGISTER NOW" button and a "SIGGRAPH 2020 UPDATES" section with a "VIEW ALL UPDATES" button. The main content area on the right has a dark background with a person wearing a VR headset. It includes a navigation menu with links for SUBMISSIONS, REGISTER, VOLUNTEER, SPONSOR, CONFERENCE, EXHIBITION, ATTEND, and PRESS. The main headline "THINK BEYOND" is prominently displayed, followed by a paragraph about inspiration and progress, and a "MORE INFORMATION" button.

SIGGRAPH Computer Animation Festival Electronic Theater: Official Selections Announced [LEARN MORE](#)

SIGGRAPH THINK BEYOND
2020 [S2020.SIGGRAPH.ORG](https://s2020.siggraph.org)

VIRTUAL CONFERENCE

The SIGGRAPH 2020 Virtual Conference begins 17 August and registration is now open! Visit the conference page for the latest updates.

[REGISTER NOW](#)

SIGGRAPH 2020 UPDATES

ELECTRONIC THEATER

The SIGGRAPH 2020 Computer Animation Festival Electronic Theater official selections have been announced! See...

[VIEW ALL UPDATES](#)

SUBMISSIONS REGISTER VOLUNTEER SPONSOR
CONFERENCE EXHIBITION ATTEND PRESS

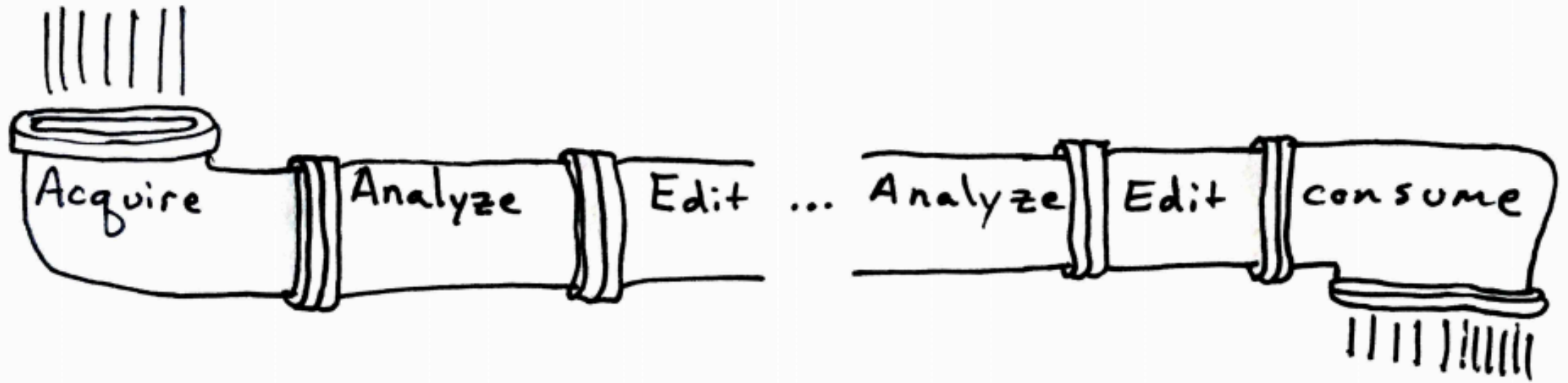
THINK BEYOND

Inspiration creates progress. Join researchers, artists, and technologists in computer graphics and interactive techniques for the SIGGRAPH 2020 virtual conference.

[MORE INFORMATION](#)

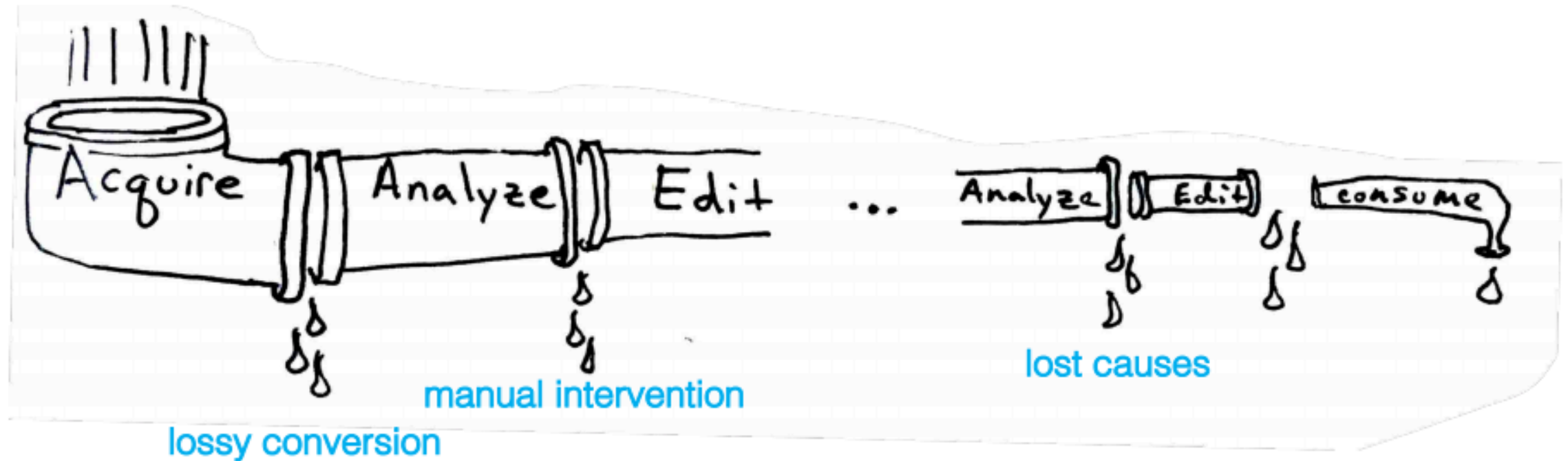
In practice

Traditionally we think of the geometry processing *pipeline*...



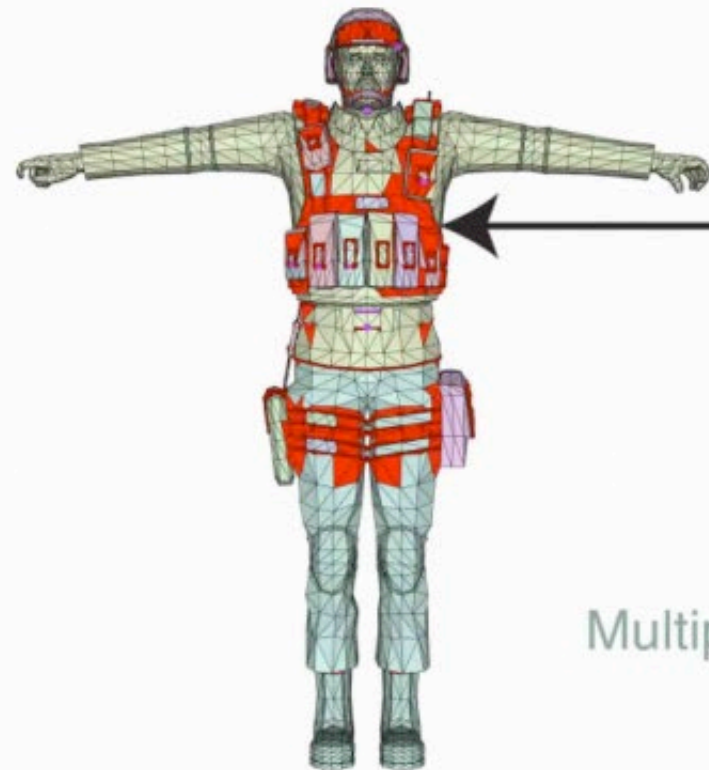
In practice

... in the *wild* this pipeline is leaky



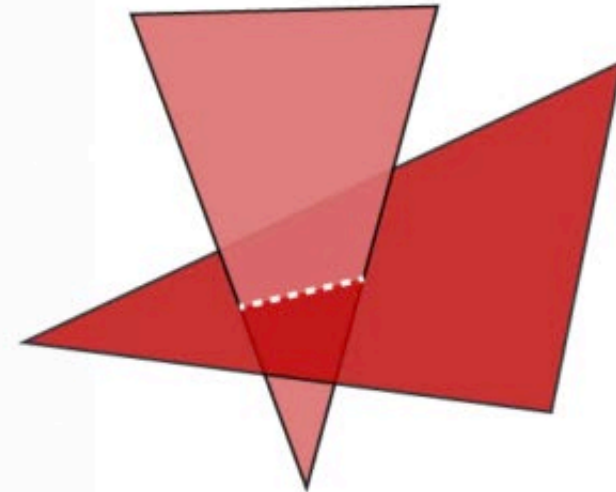
In practice, we want algorithms that work on any mesh, even yucky ones

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

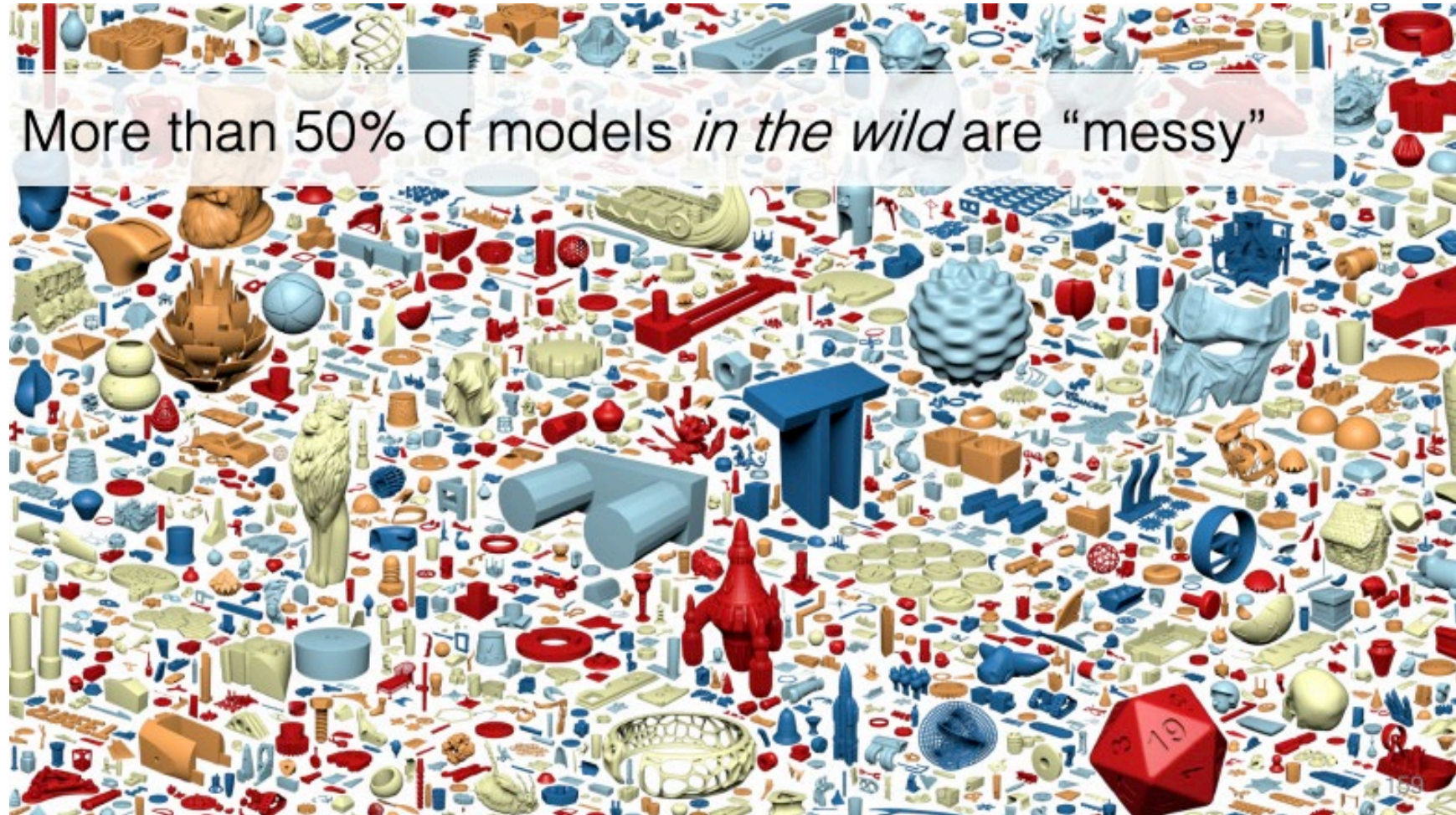


Self-intersections

Multiple connected components

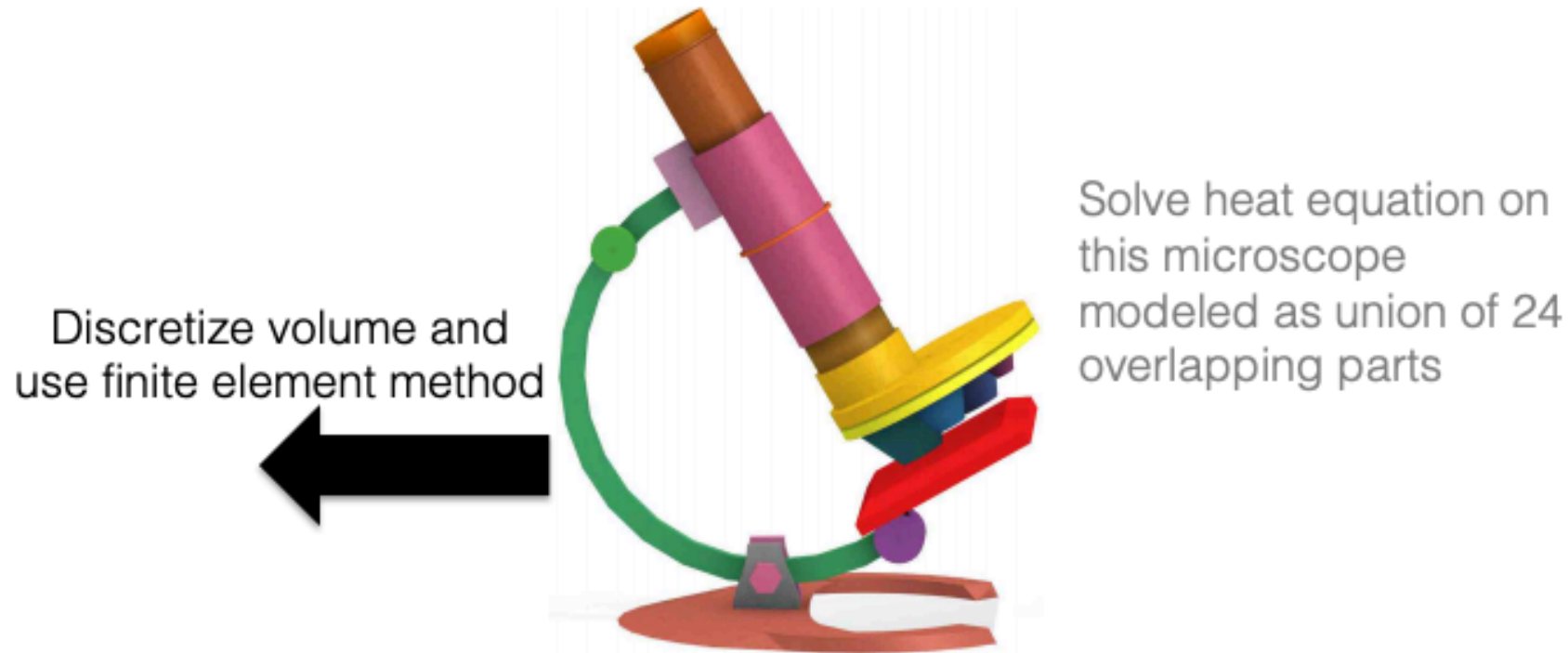


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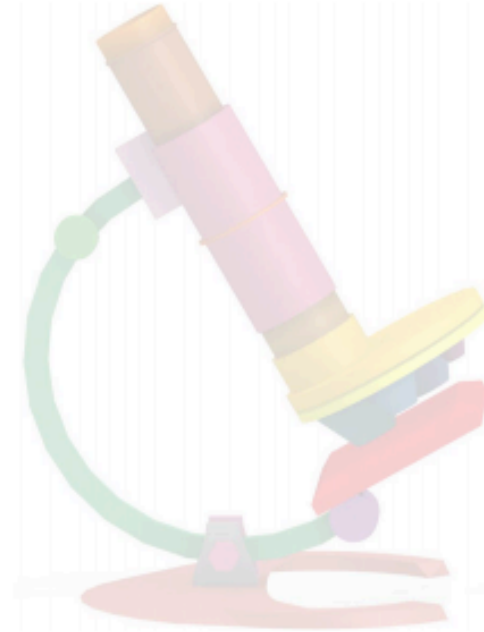
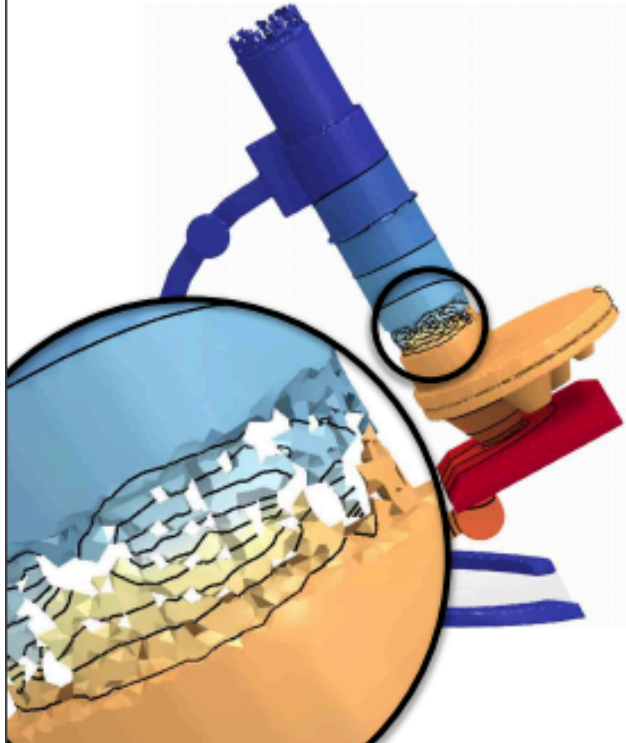
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Isolating subproblems from full pipeline
can make robustness harder



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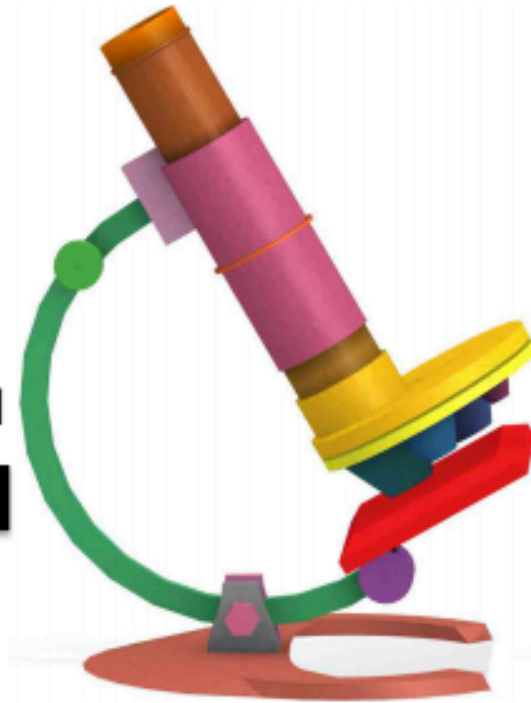


Solve heat equation on
this microscope
modeled as union of 24
overlapping parts

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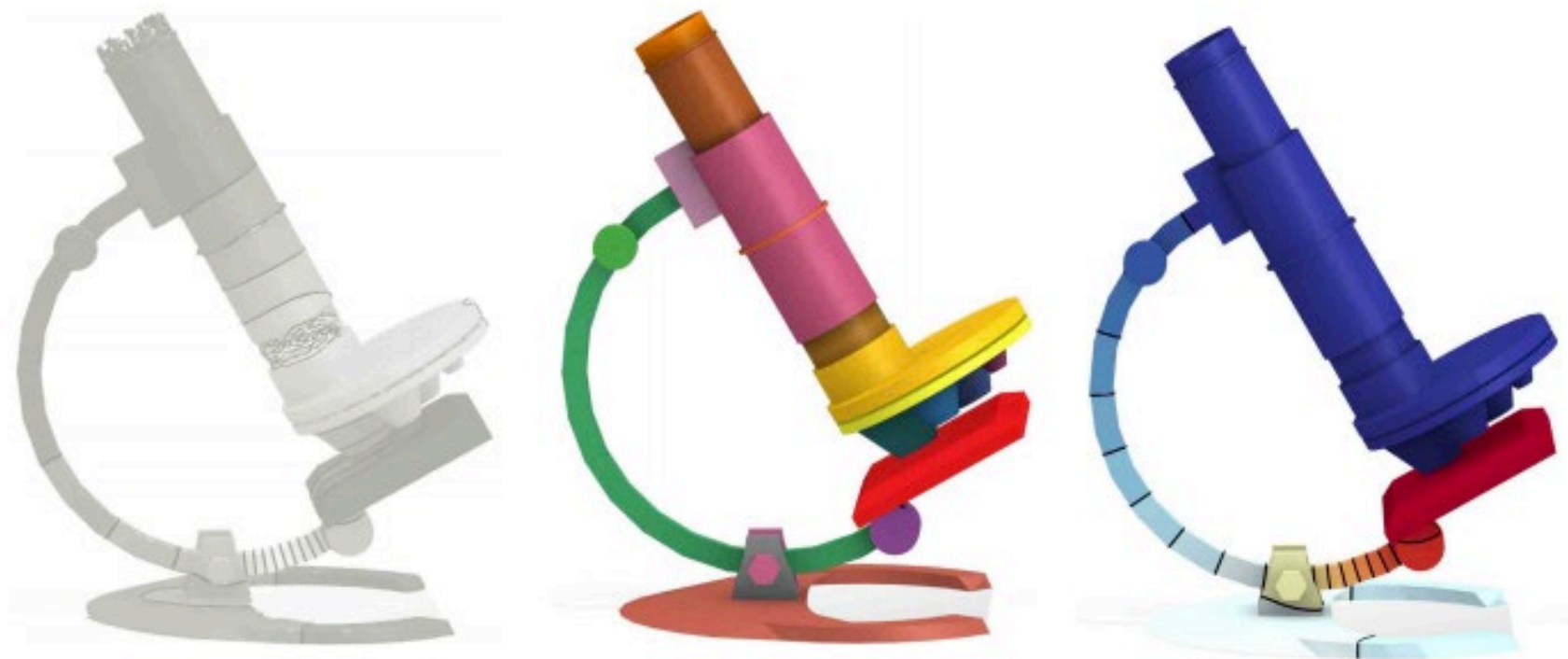
Discretize volume and
use finite element method



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this microscope
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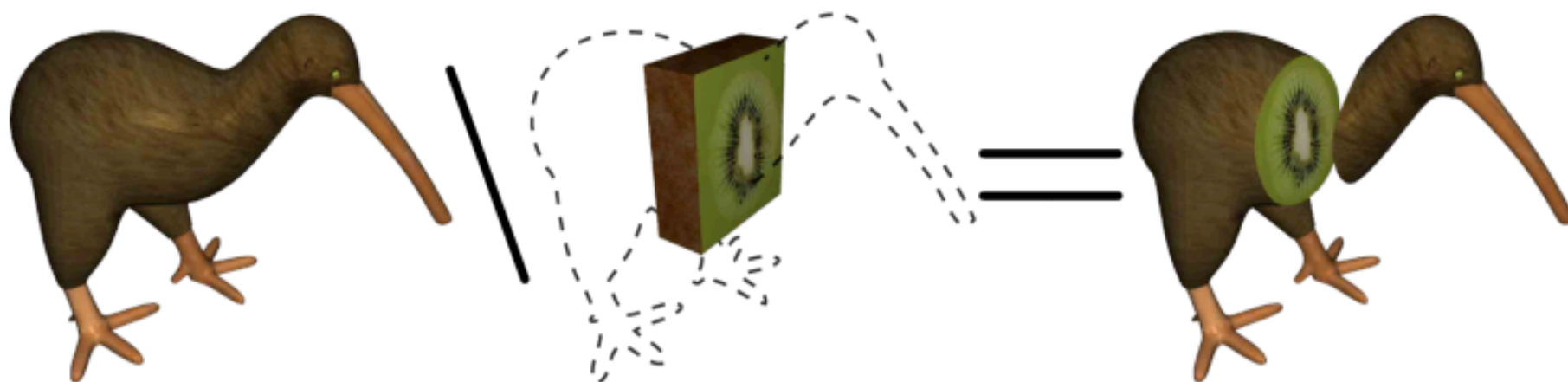
Isolating subproblems from full pipeline
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"Solid Geometry Processing on Deconstructed Domains"
[Sellán, Cheng, Ma, Dembowski, & J. 2019]

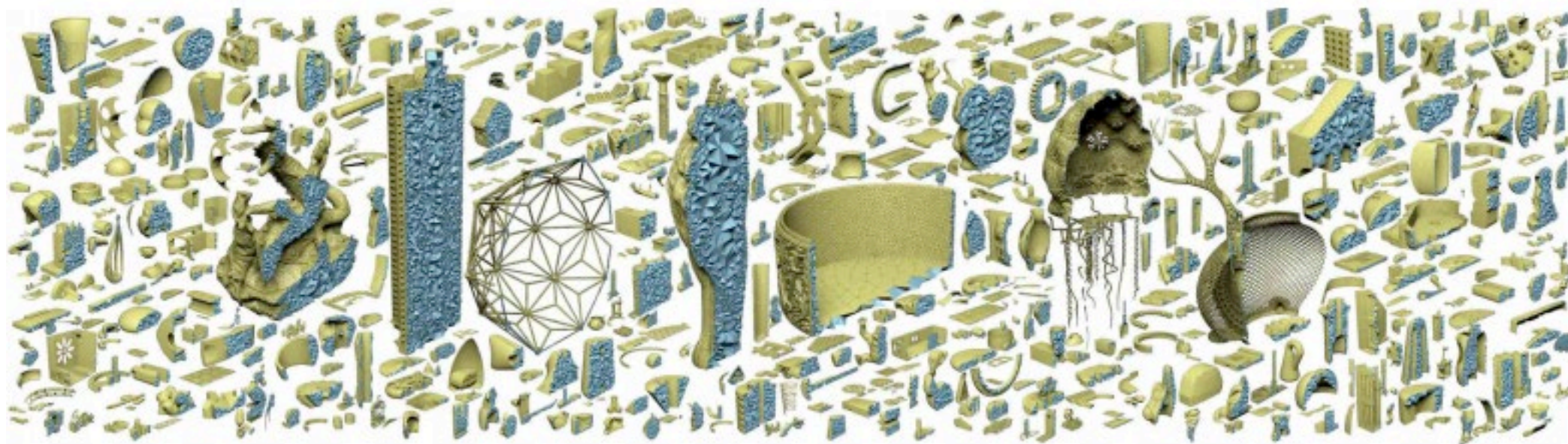
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Novel Boolean algorithm accepts
all piecewise-constant winding number meshes



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

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

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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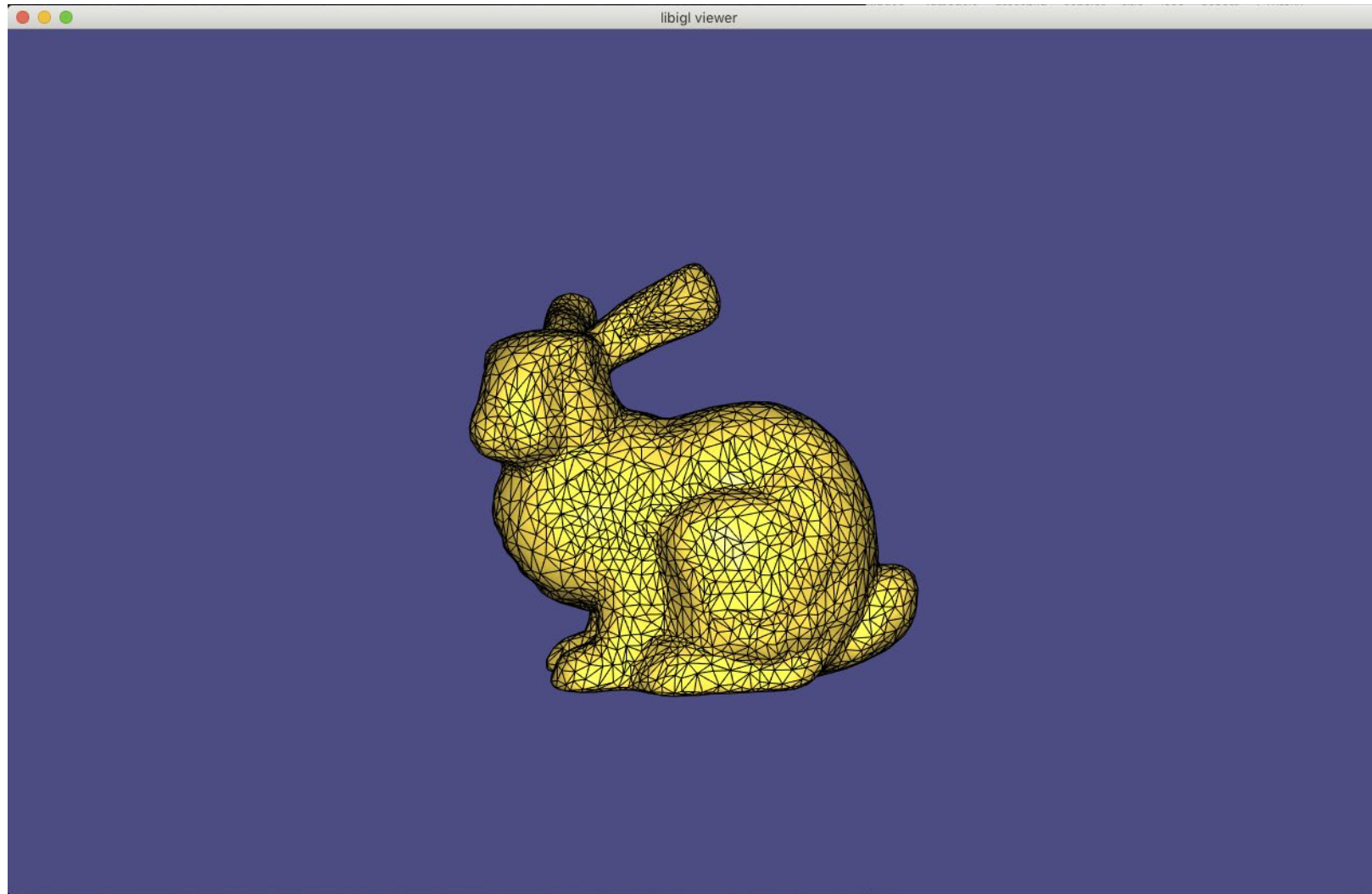
7 assignments

Course project

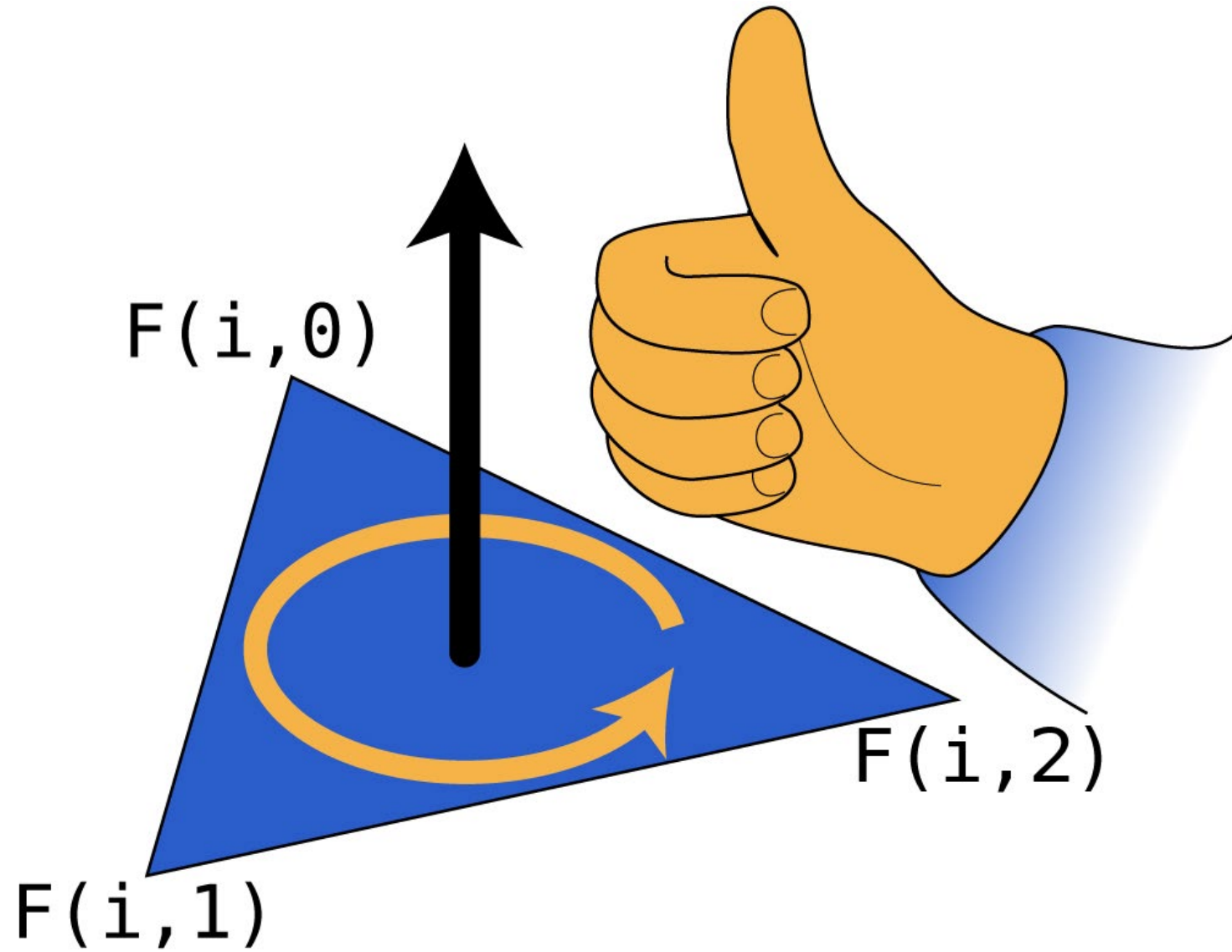
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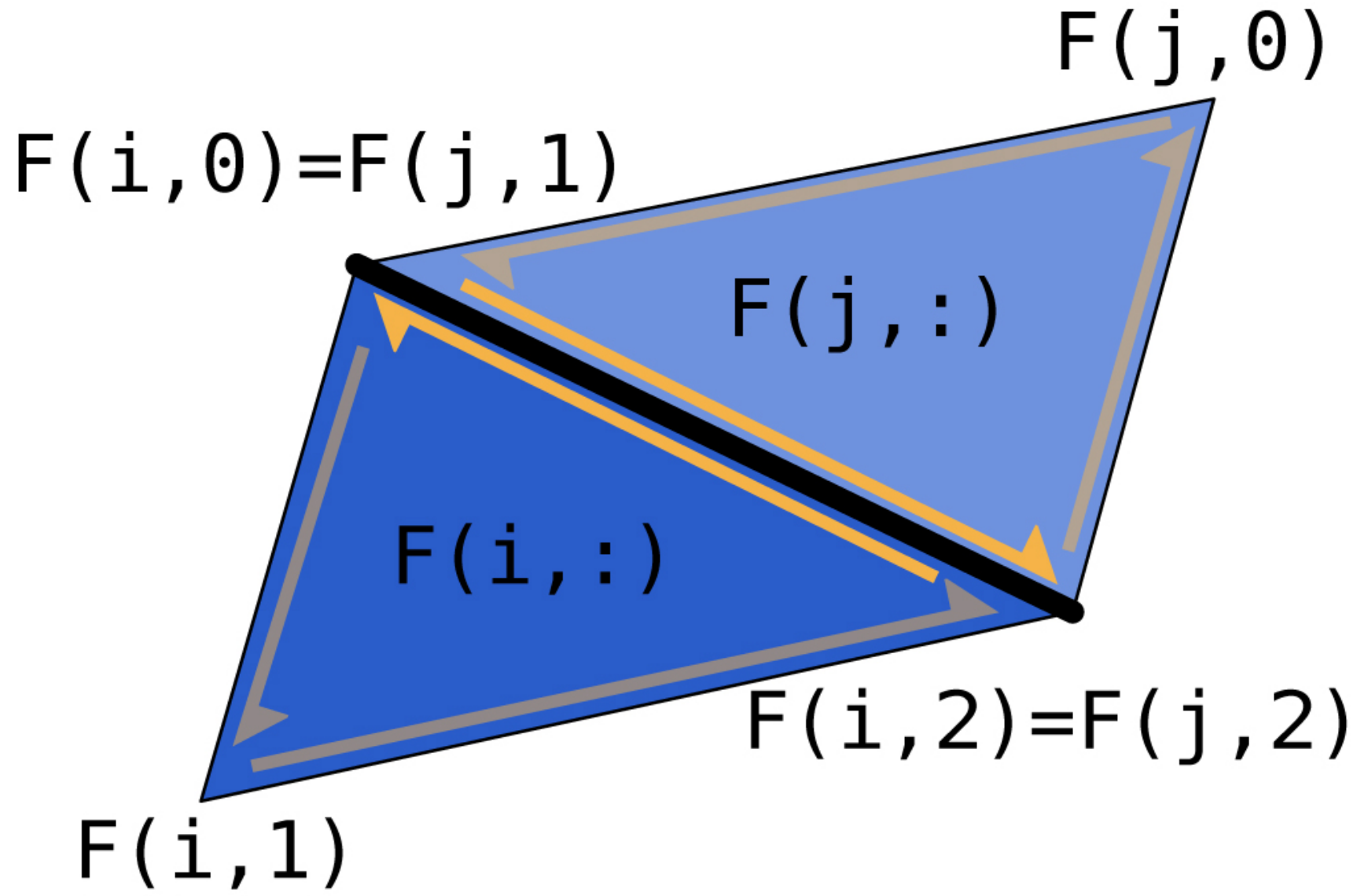
Fundamentals



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

Regis

Y

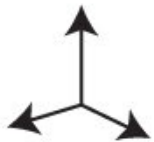
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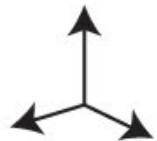
X

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<https://>

```
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

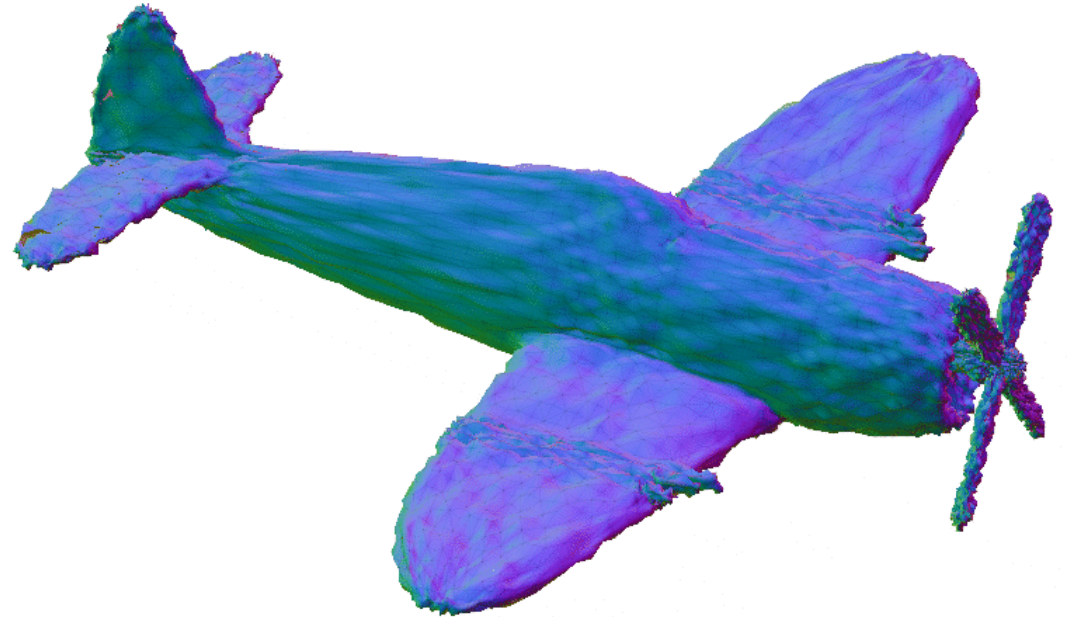
Denoise

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

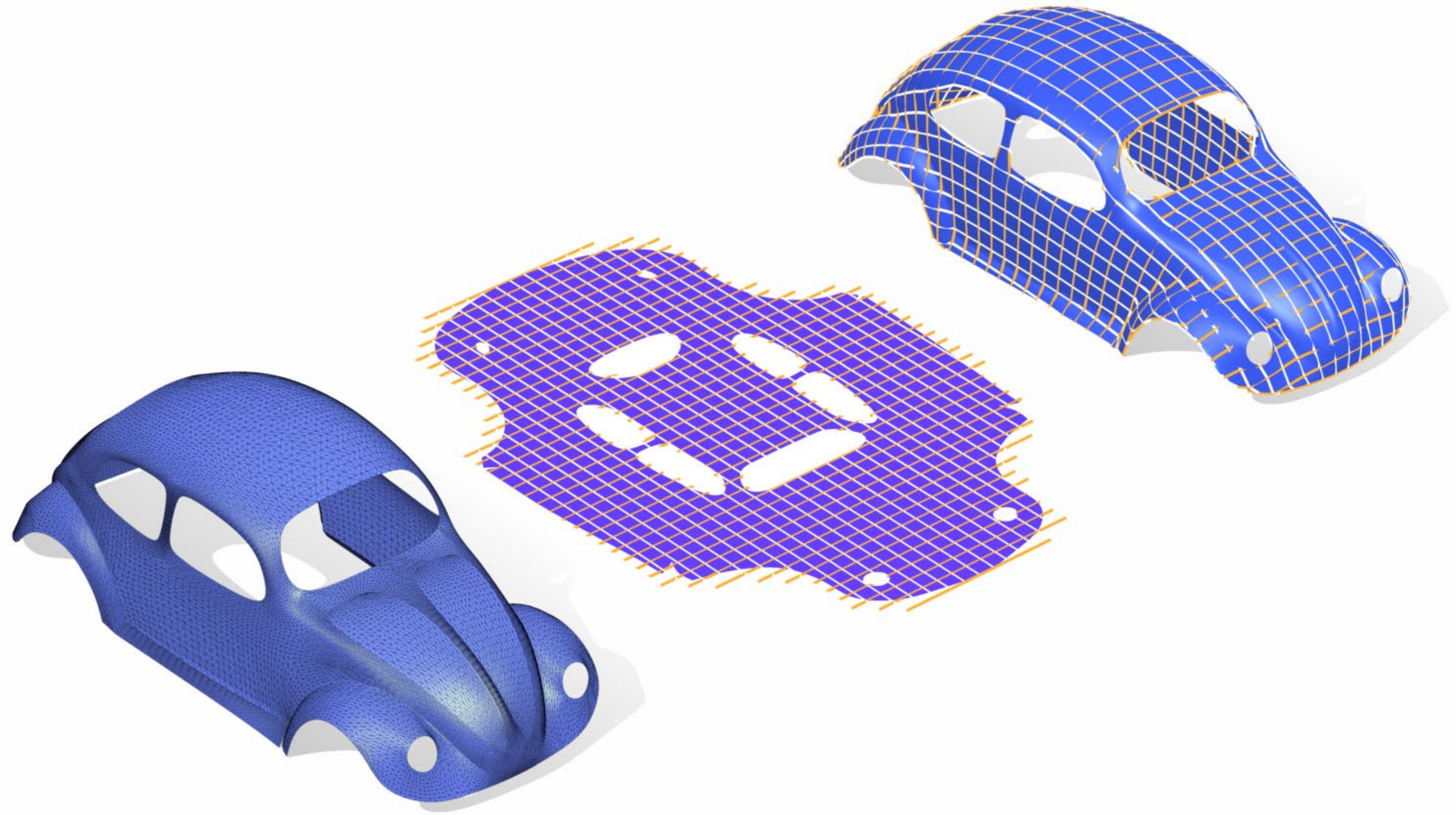
Parameterization

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

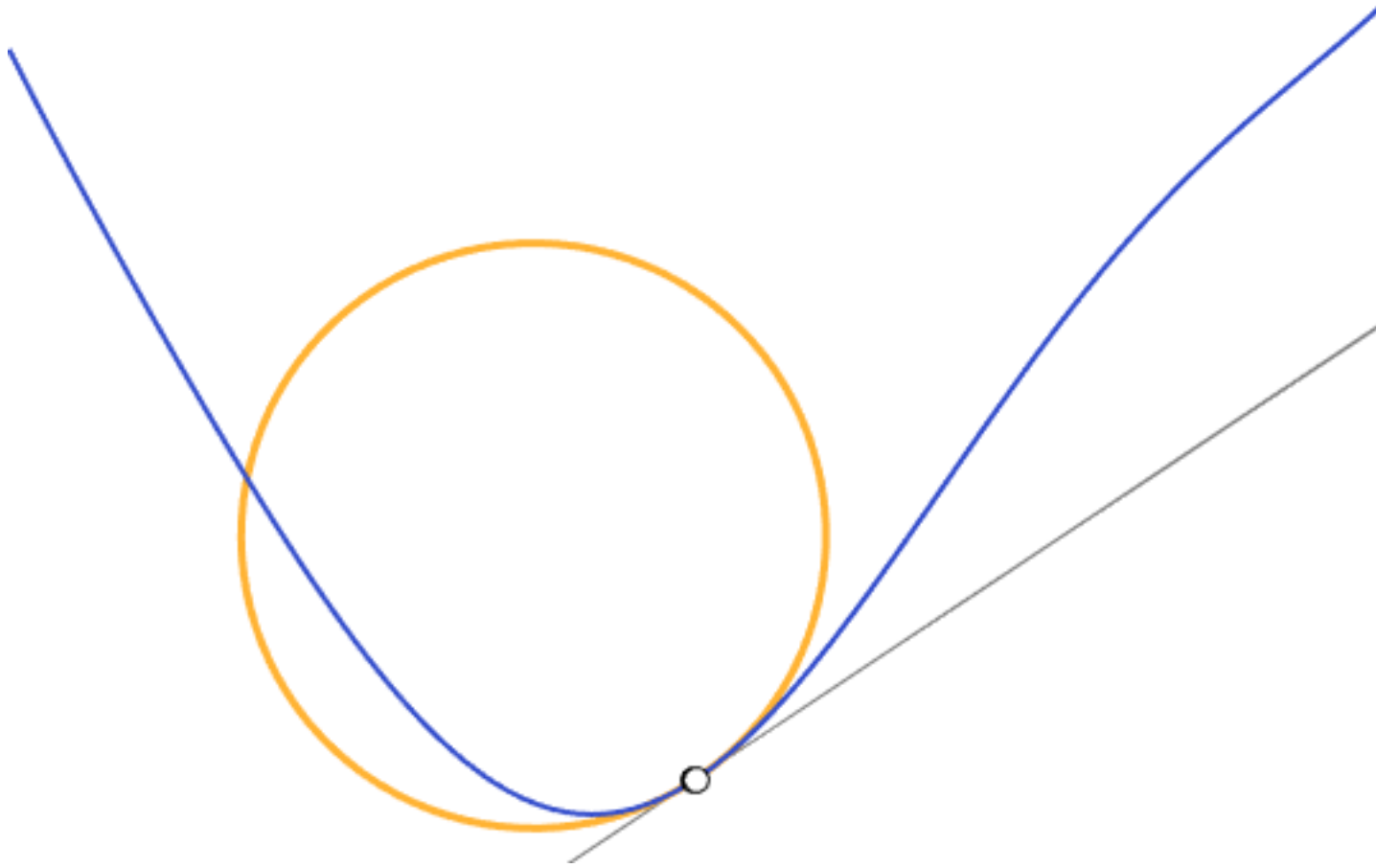
- define energies

- salient points

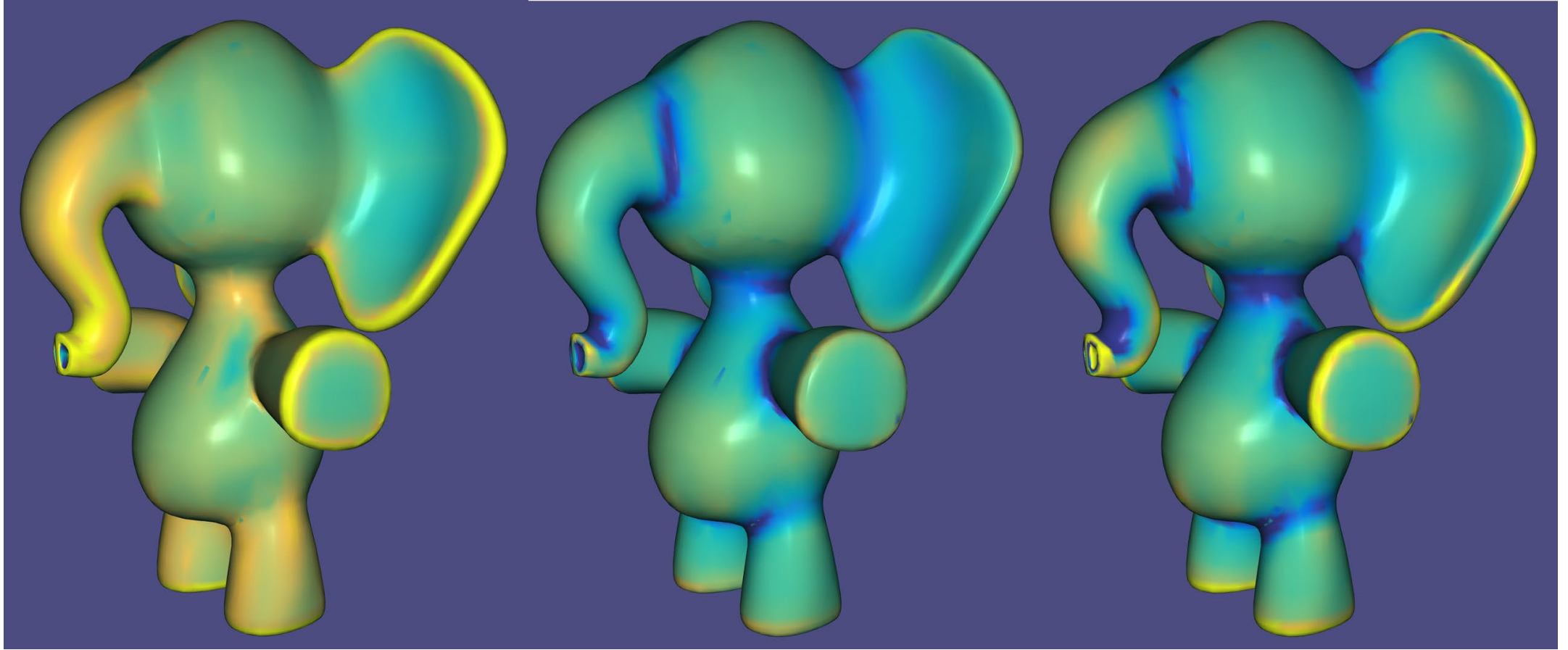
- provide constraints for remeshing

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

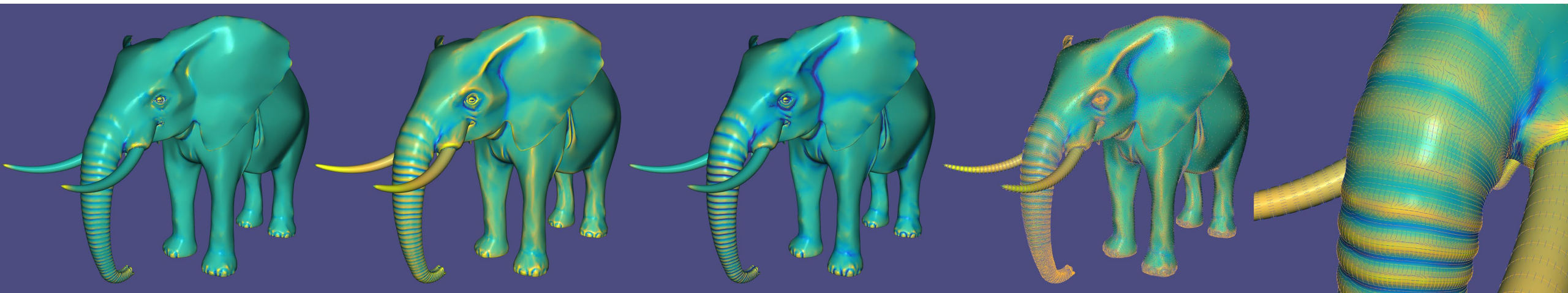
Curvature



Curvature



Curvature



Done for Today