

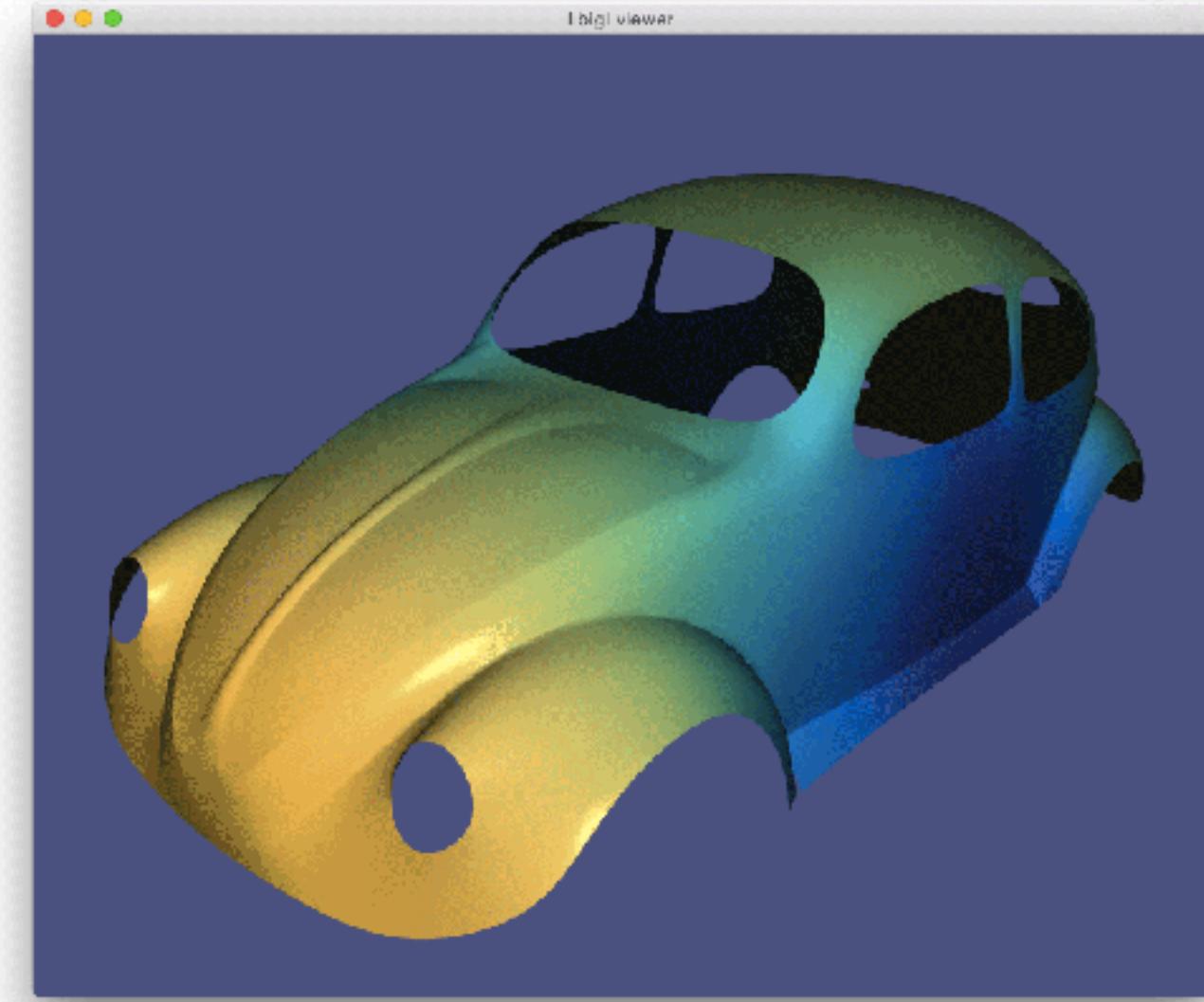
Introduction To Geometric Modelling

Course Goals

- Learn how to design, program and analyze algorithms for **interactive 3D shape modeling** and **digital geometry processing**
- Theory and applications of 3D mesh processing
- Hands-on experience with shape modeling and geometry processing algorithms

Geometric Modeling and Processing

- The shape of an object is an important characteristic (not the only one...)
- Geometry processing:
computerized modeling of 2D/
3D geometry

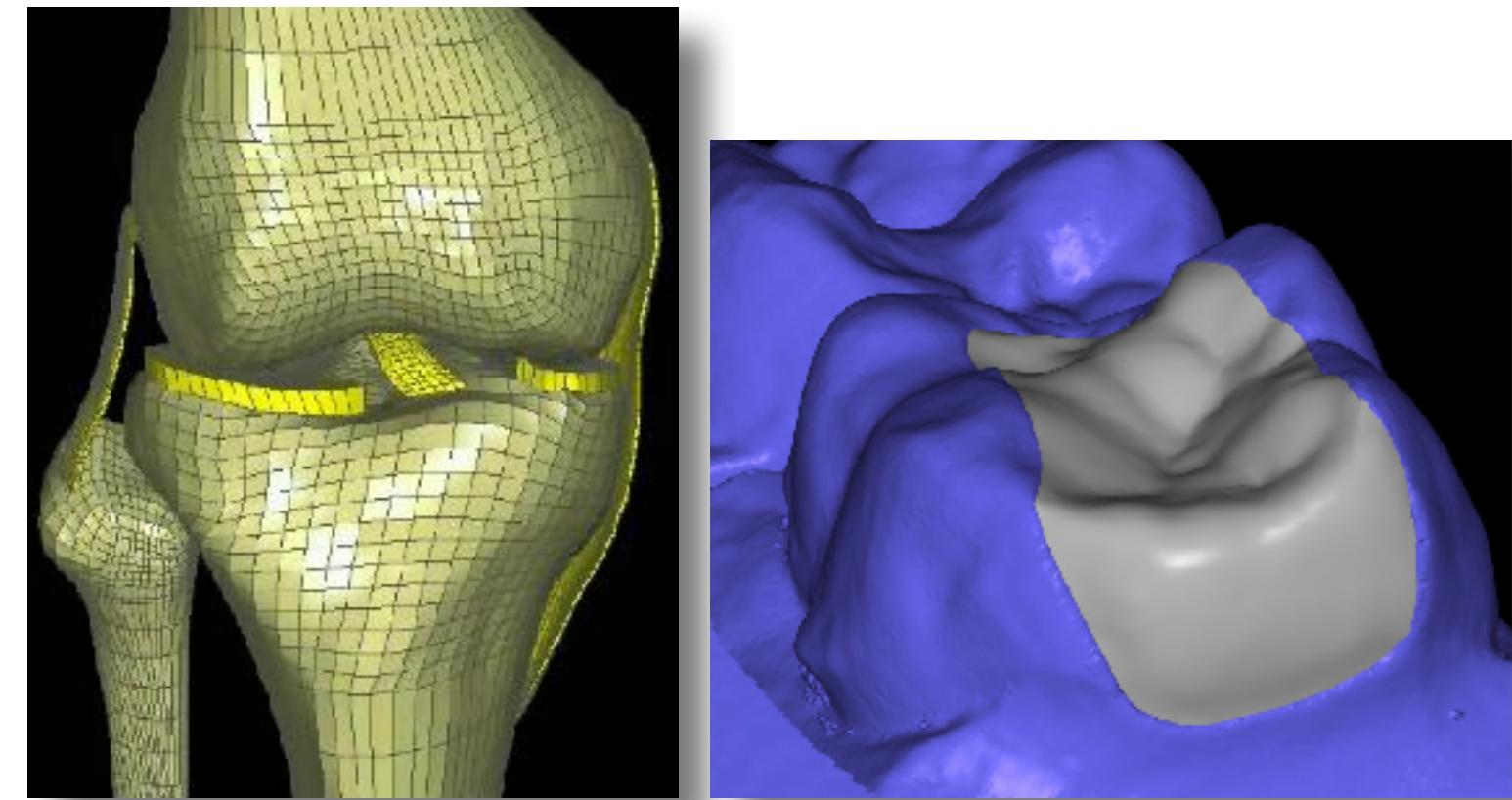


Copyright: Blender

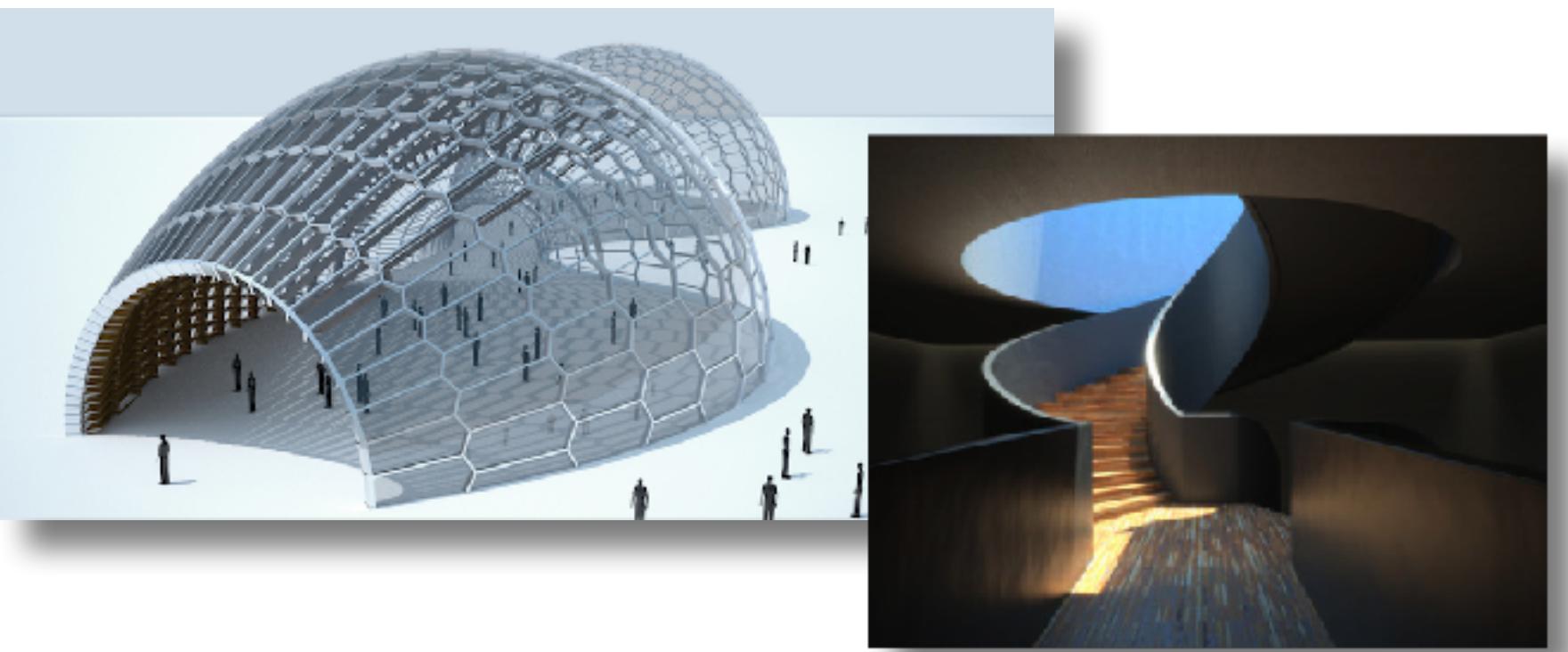
Applications



Product design and prototyping



Medicine, prosthetics

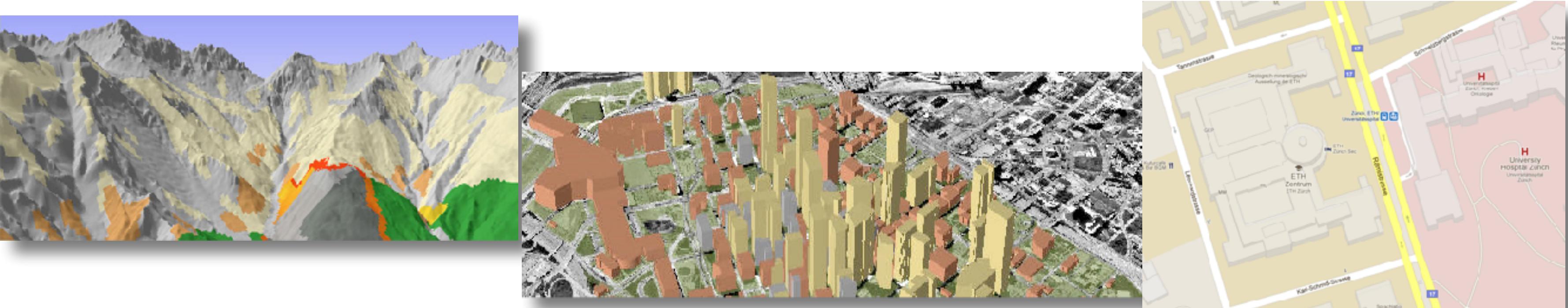


Architecture



Cultural heritage

Applications



Geographical systems

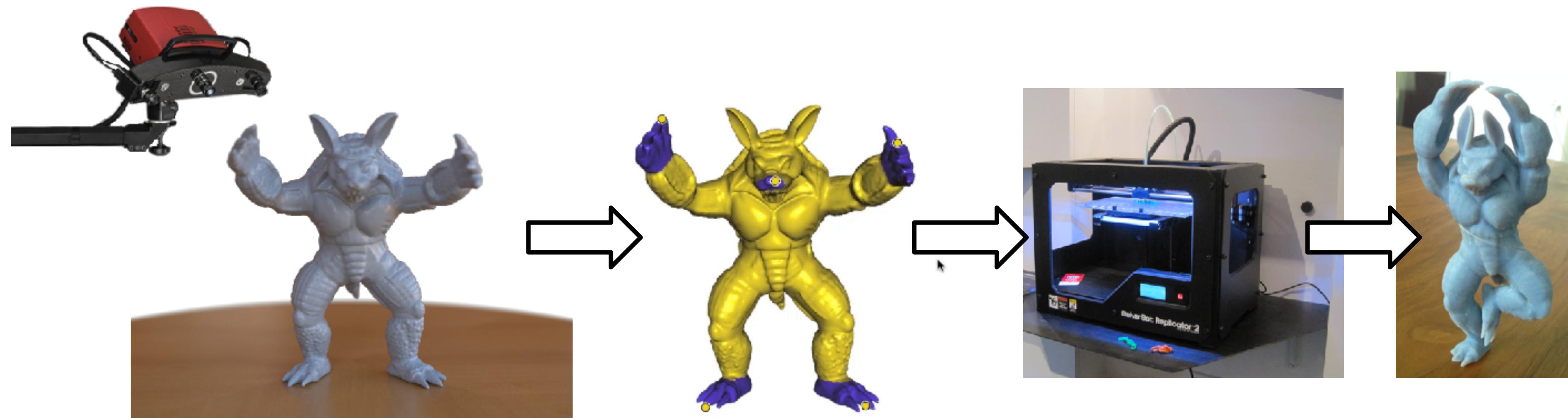


[Bickel et al., ACM SIGGRAPH 2010]

Manufacturing, 3D Printing

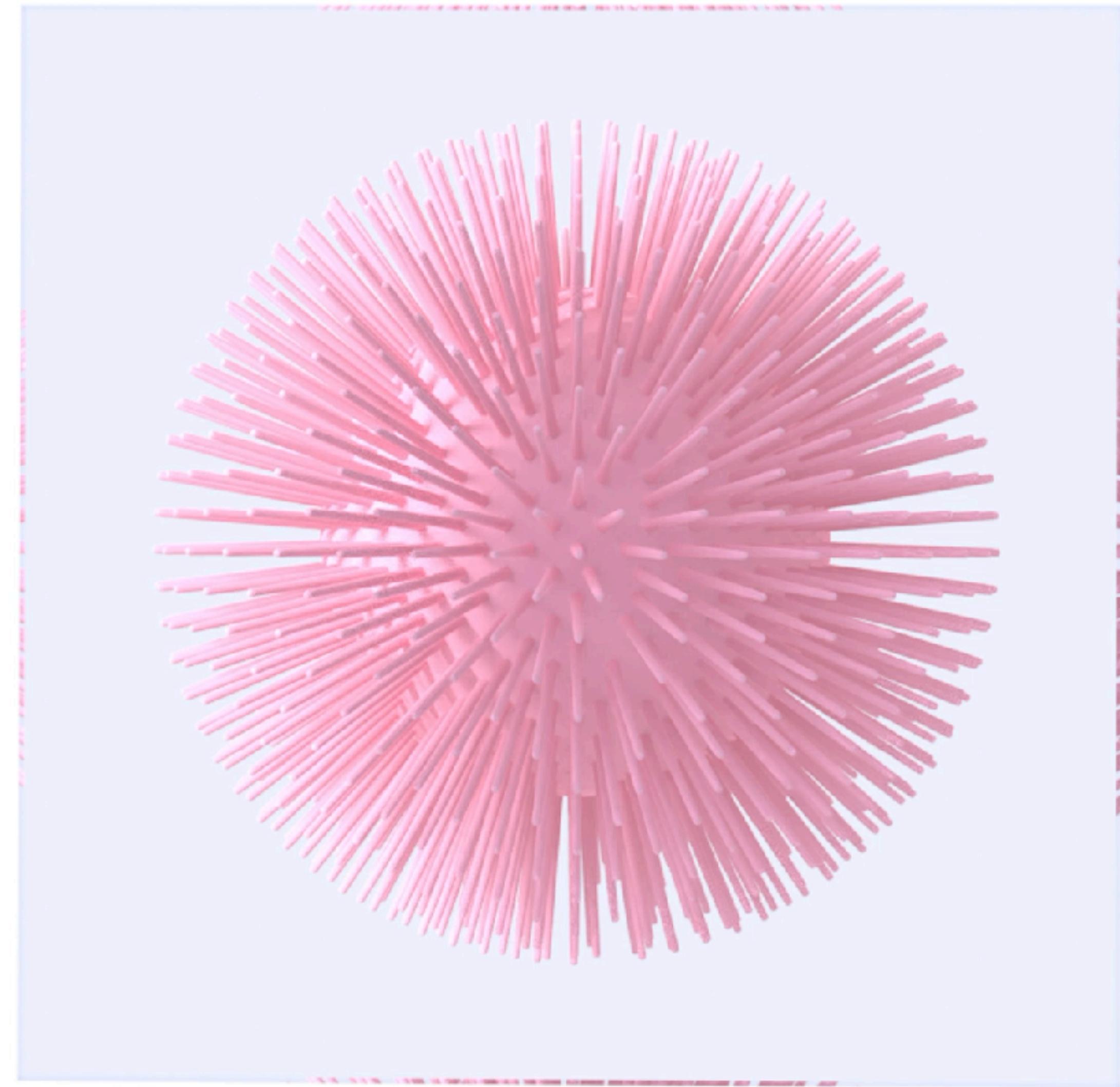
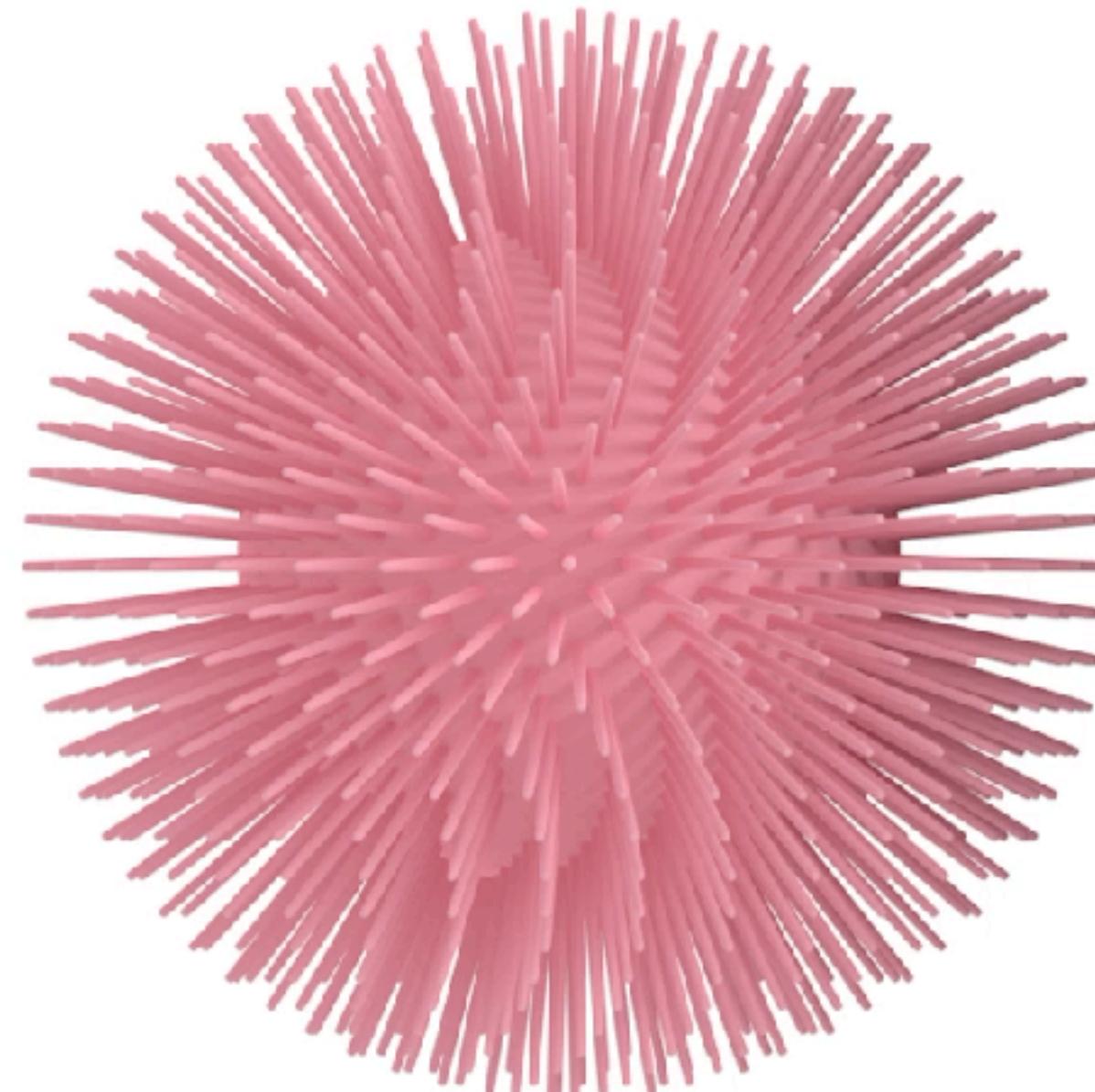
Fabrication

- Modern scanning and 3D printing technologies allow replication and much more



Simulation

IPC



tetrahedra: 2314K

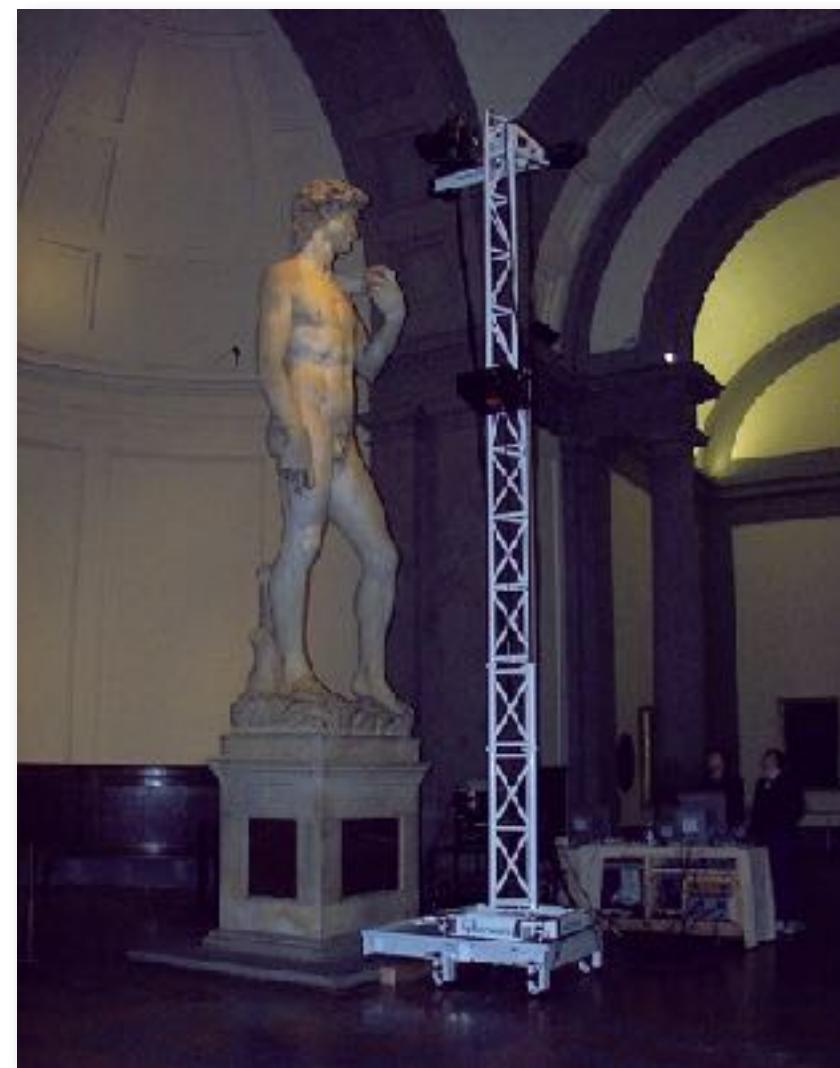
contacts per step (max): 5.6K

dt: 0.001

μ : 0

Digital Geometry Processing (DGP)

- Processing of discrete surfaces/volumes
- Why discrete?
 - Representable by a computer
 - Efficiently rendered by graphics hardware
 - Input to most simulation/analysis tools
 - Easy to acquire(CT, MRI, LIDAR, Kinect...)



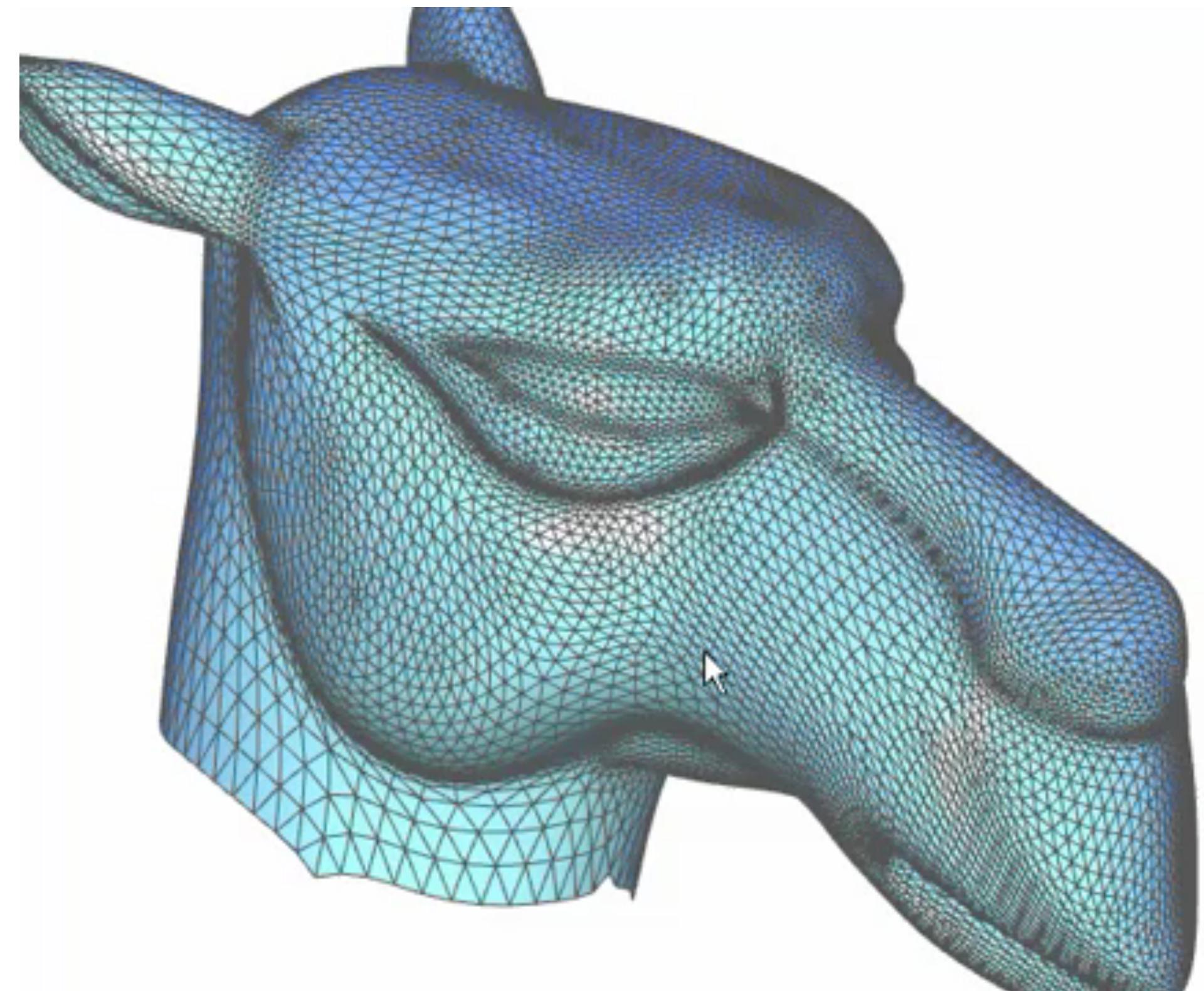
Copyright: The Digital Michelangelo Project



Computer Science

Interactive Shape Modeling

- Tools for design, editing and animation of digital shapes
 - Interactive means fast algorithms
 - Intuitive – convenient interface and predictable outcome



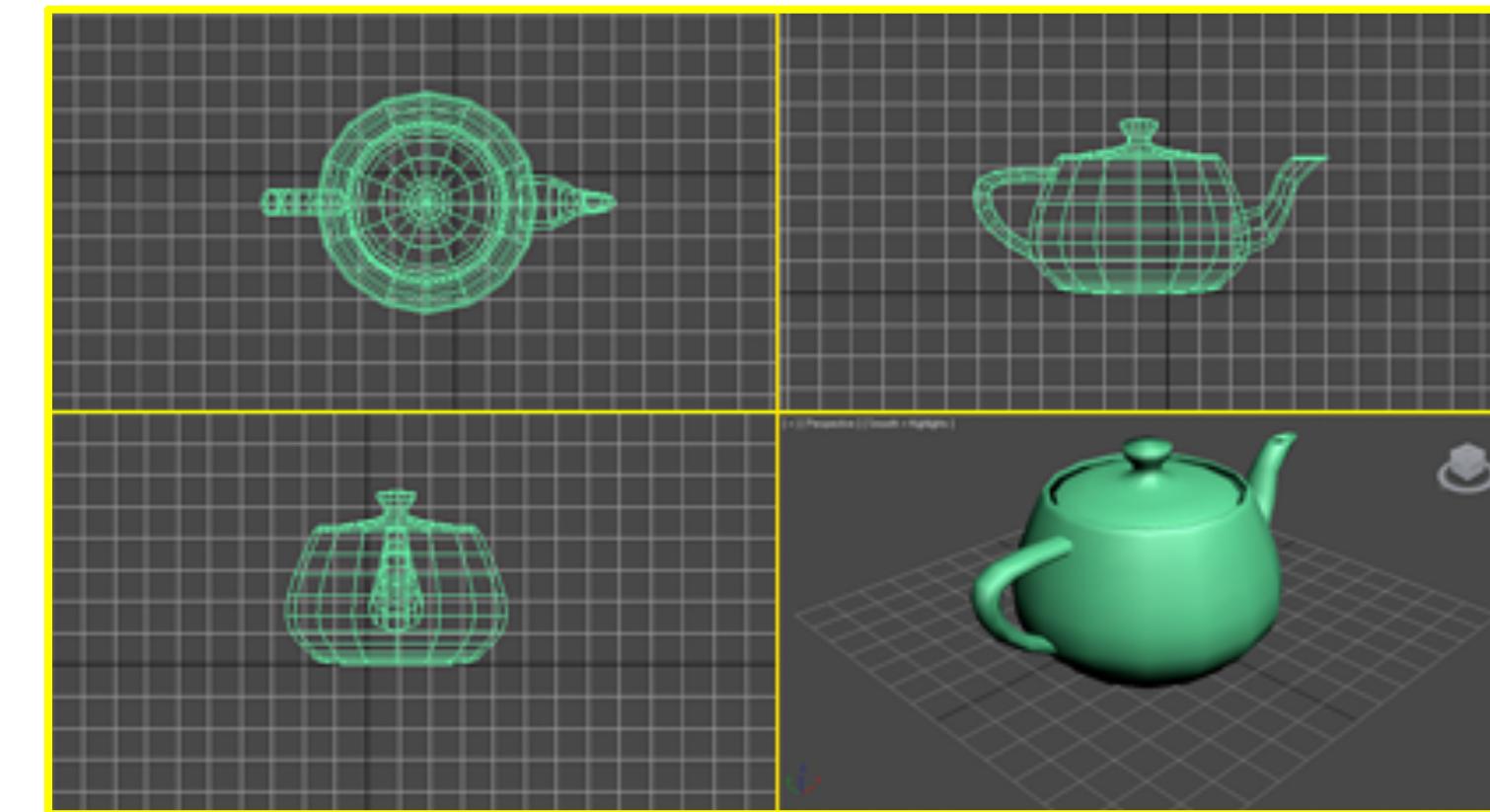
<http://youtu.be/EMx6yNe23ug>

Digital Shape Modeling

- How do shapes find their way into computers?
 - Geometric modeling is difficult



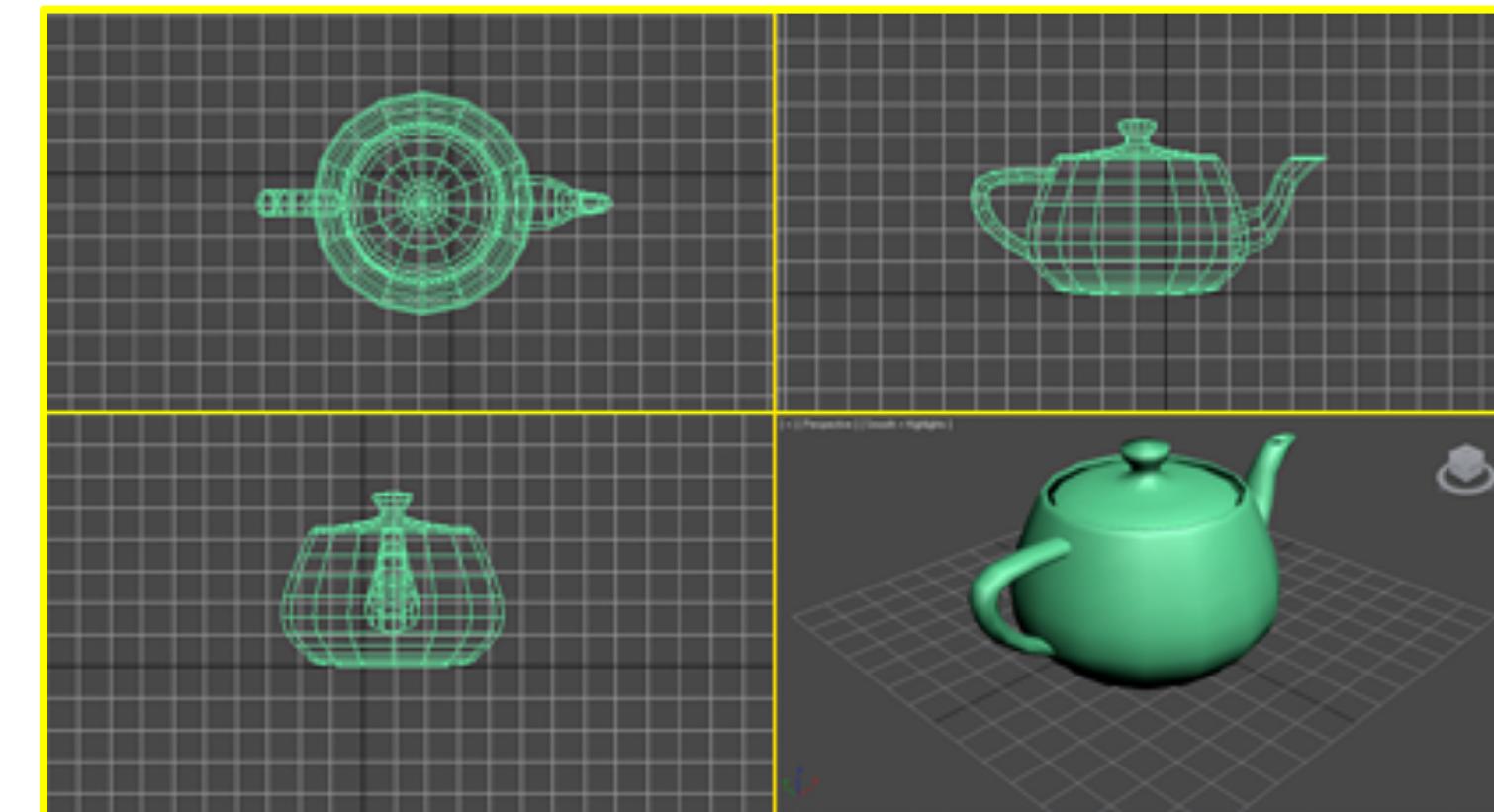
Humans have no
direct “video out”



“Translation” from 2D
to 3D is hard

Digital Shape Modeling

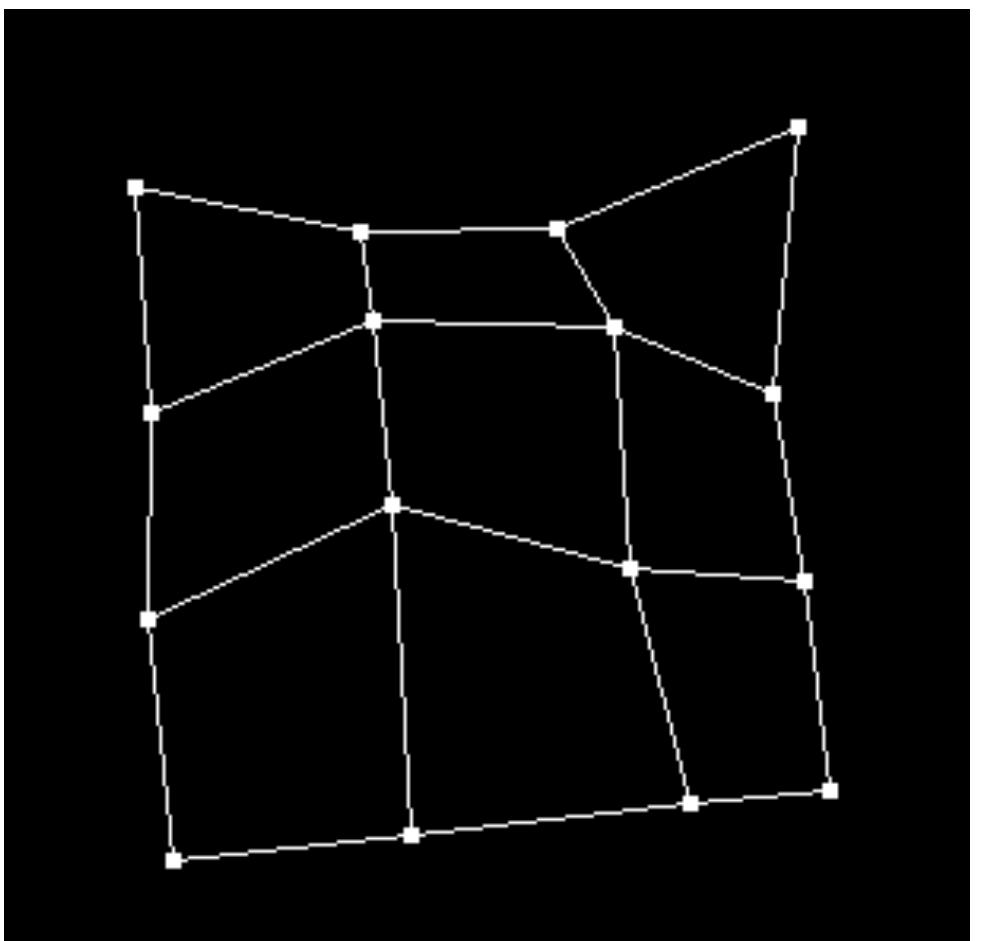
- How do shapes find their way into computers?
 - Geometric modeling is difficult



Use computation to compensate for lack of direct ability to convey visual information

Computer-Aided Geometric Design

- Traditional pipeline for modeling shapes from scratch

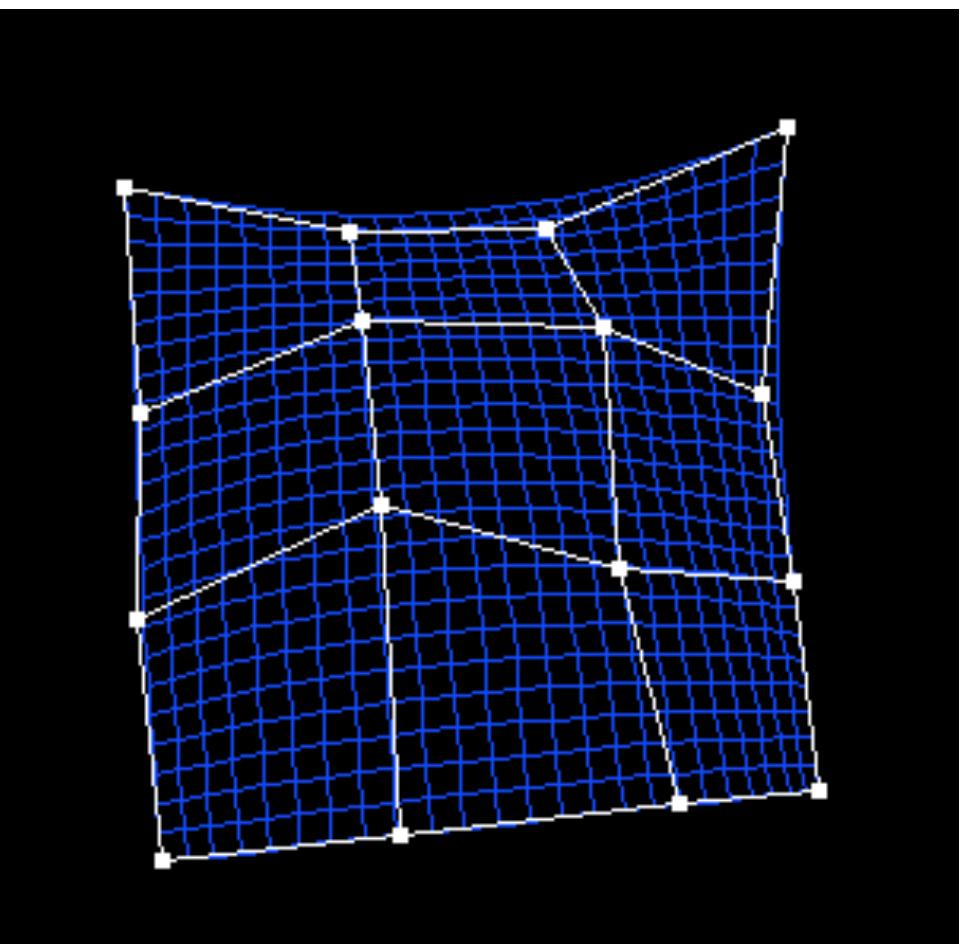


User defines a layout
of surface patches and
control points



Computer-Aided Geometric Design

- Traditional pipeline for modeling shapes from scratch



User defines a layout
of surface patches and
control points

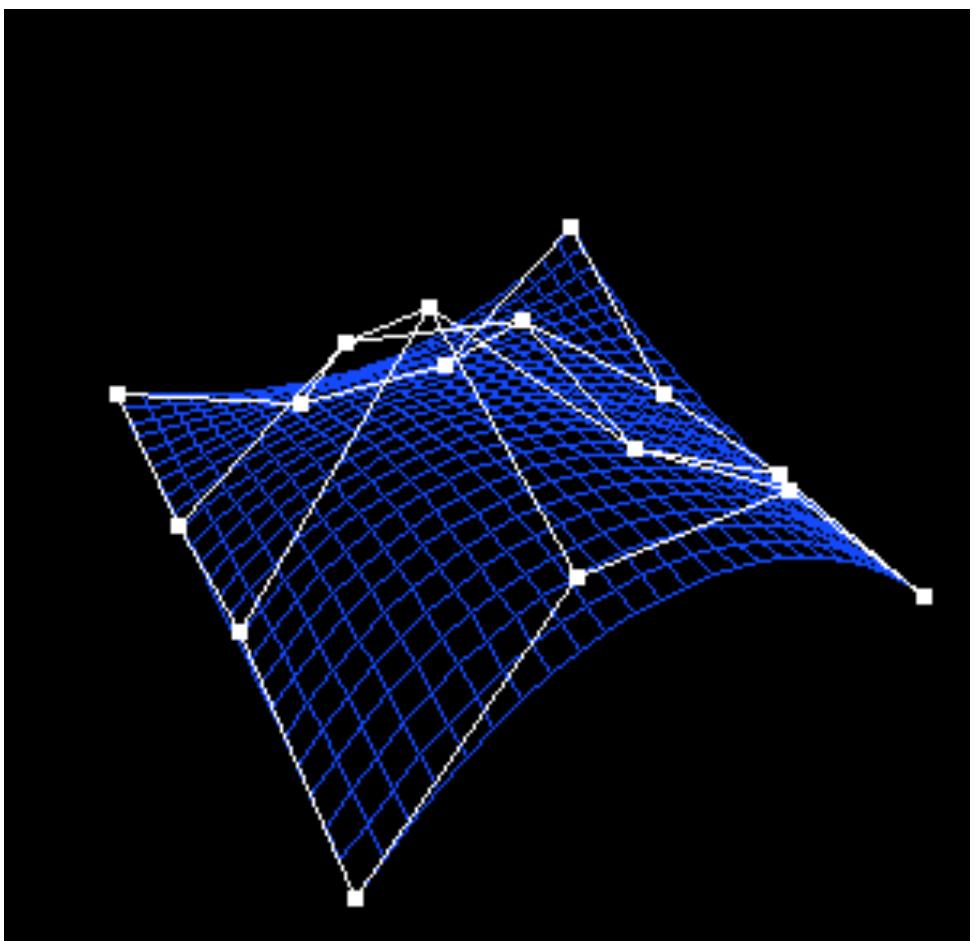


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Computer-Aided Geometric Design

- Traditional pipeline for modeling shapes from scratch

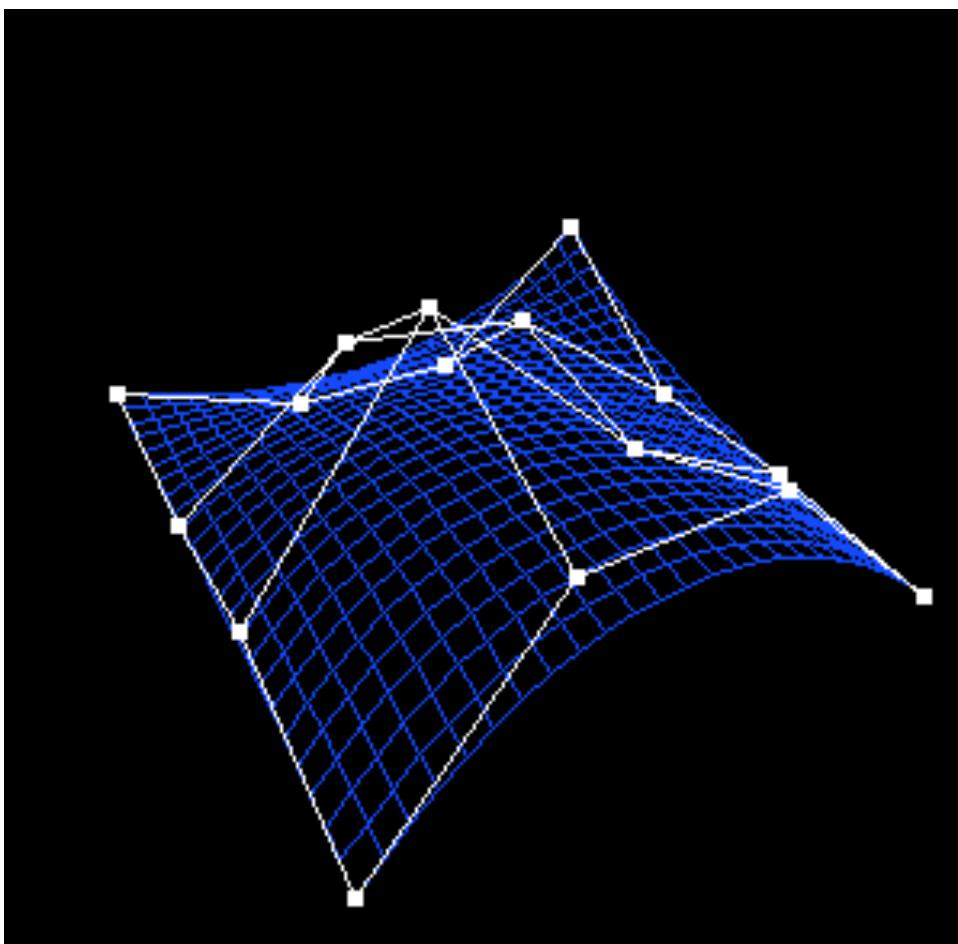


User defines a layout
of surface patches and
control points

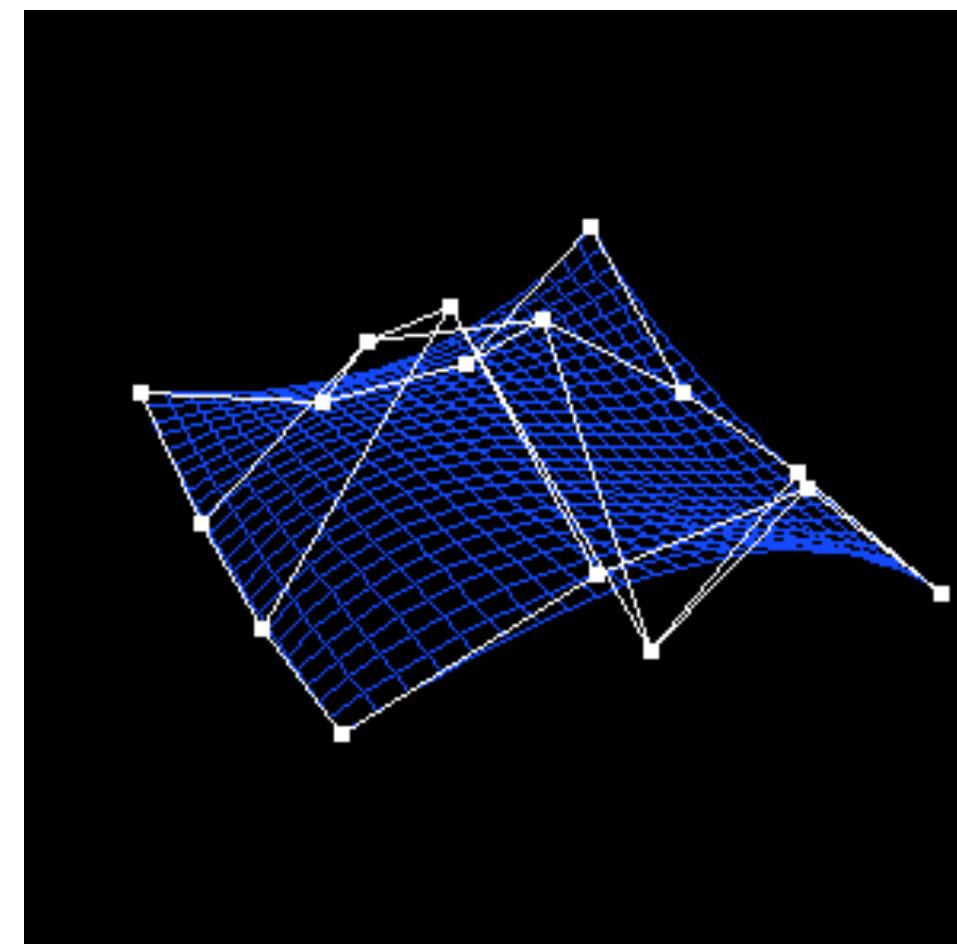
Editing is performed
by moving control
points and/or
prescribing tangents

Computer-Aided Geometric Design

- Traditional pipeline for modeling shapes from scratch



User defines a layout
of surface patches and
control points



Editing is performed
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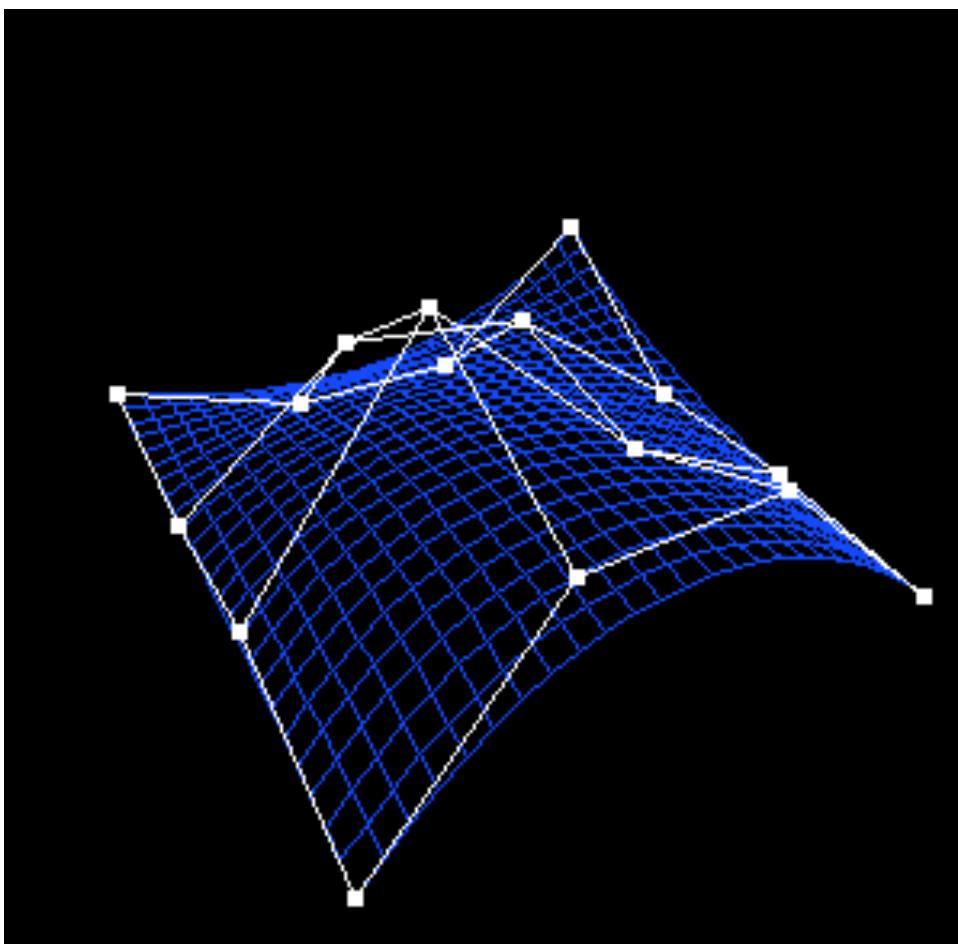


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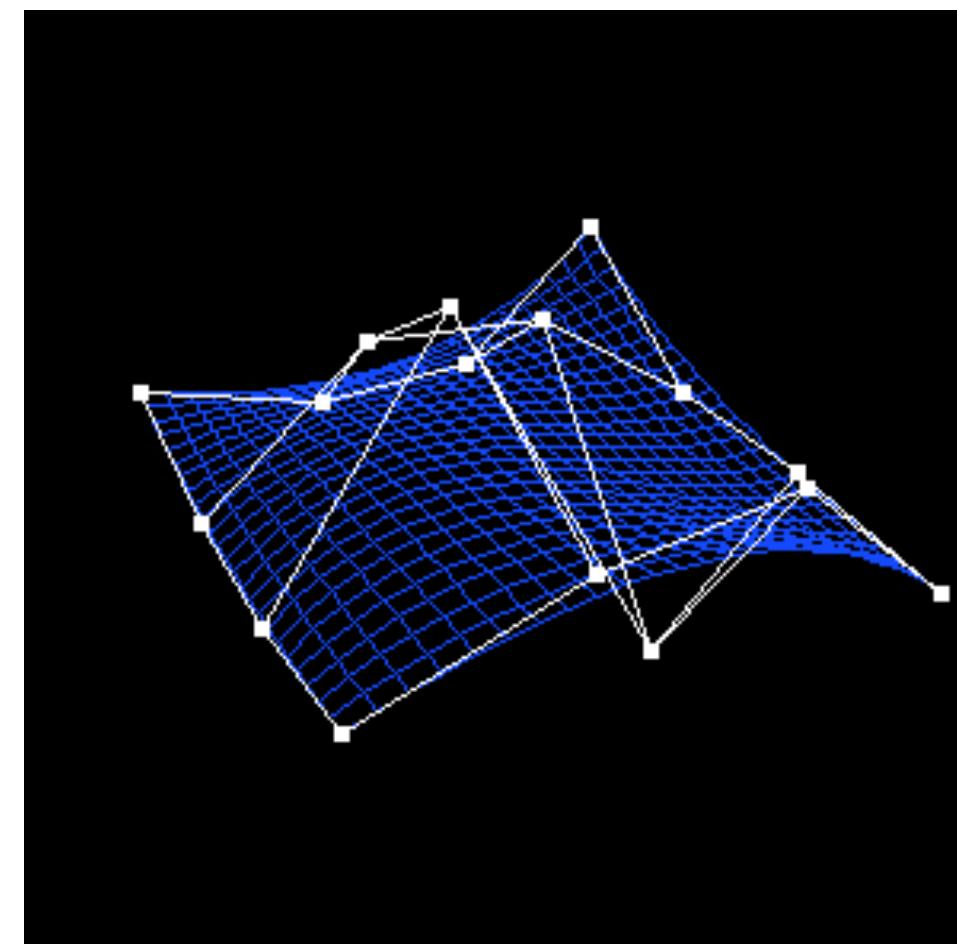
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Computer-Aided Geometric Design

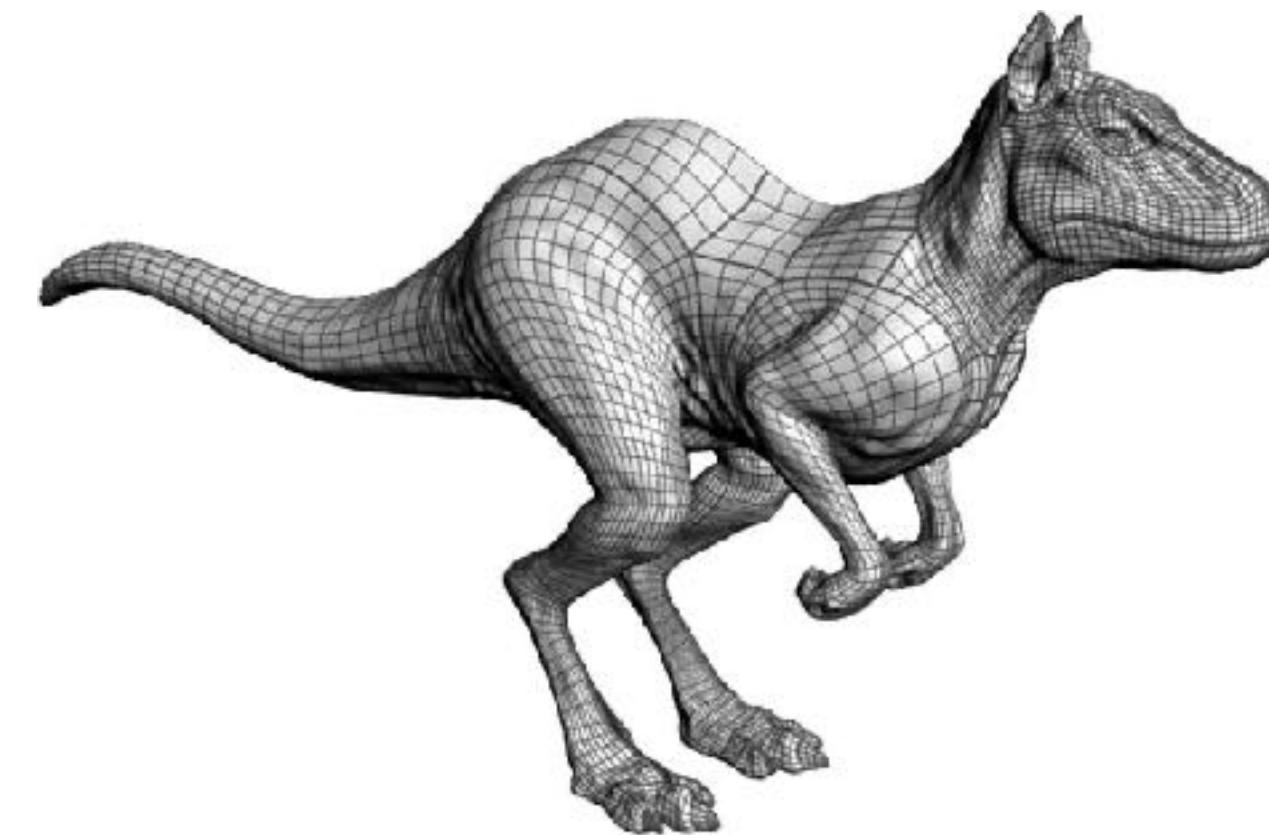
- Traditional pipeline for modeling shapes from scratch



User defines a layout of surface patches and control points

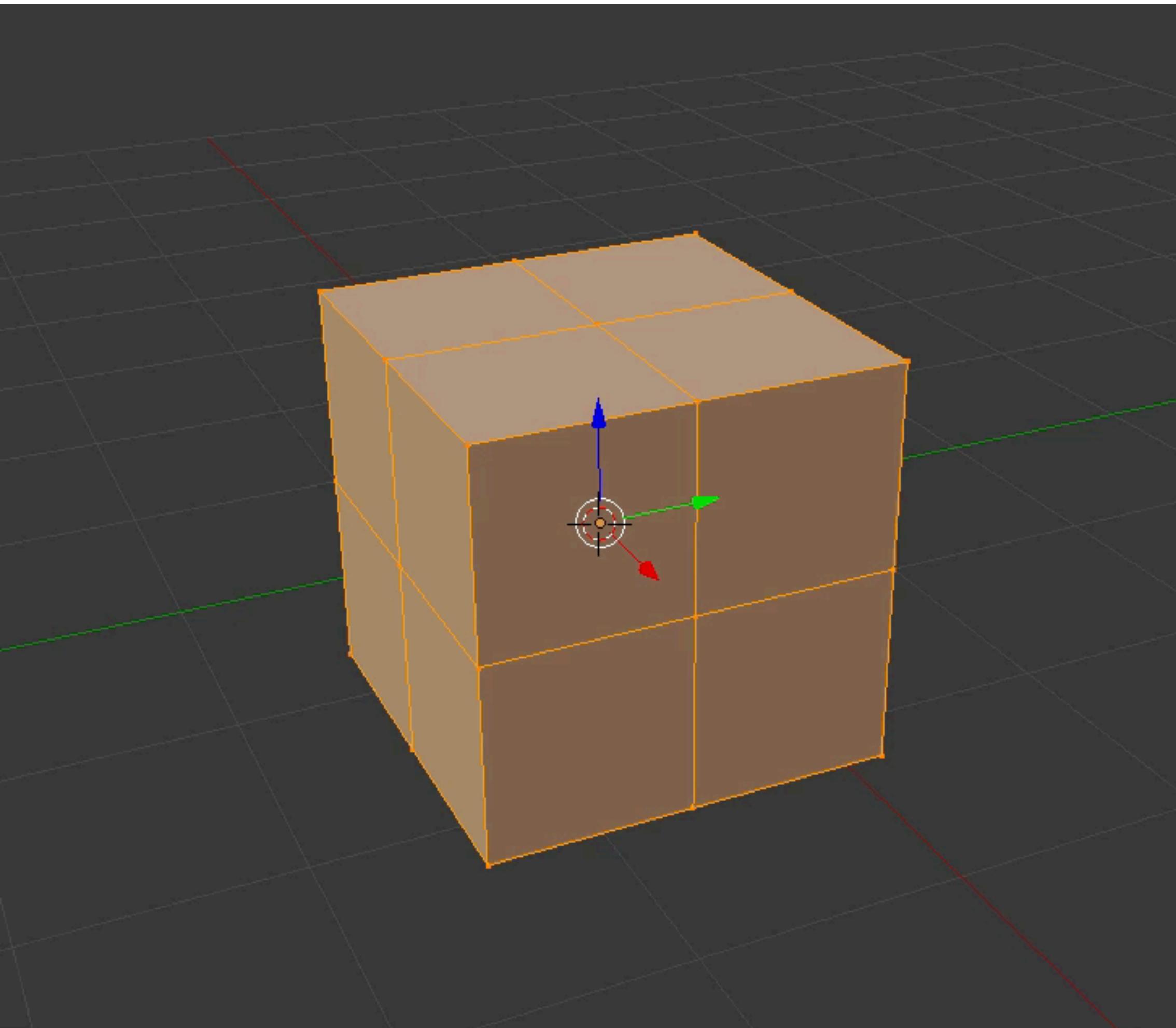


Editing is performed by moving control points and/or prescribing tangents



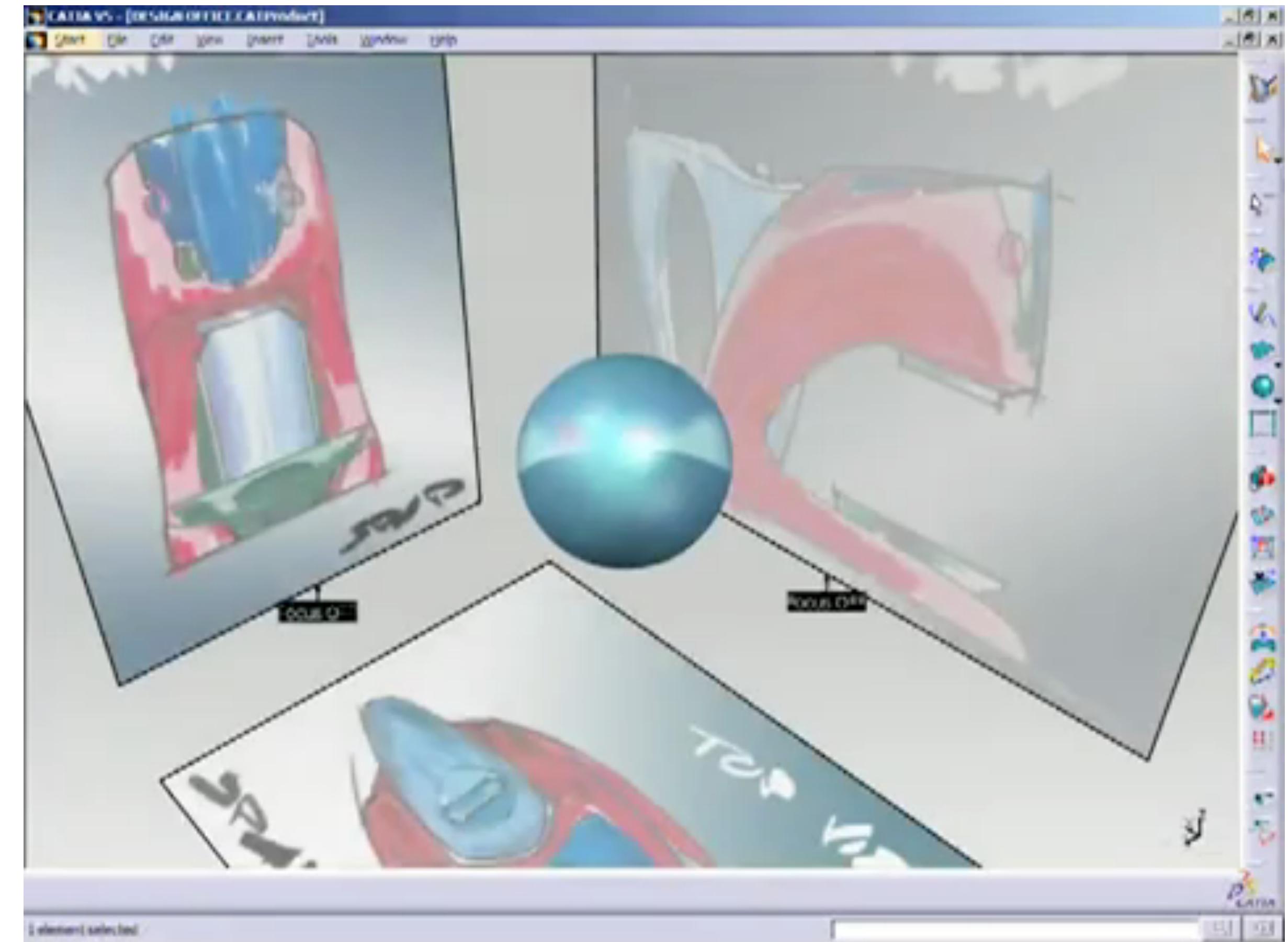
Patch-based construction of a surface

Blender Demo



Computer-Aided Geometric Design

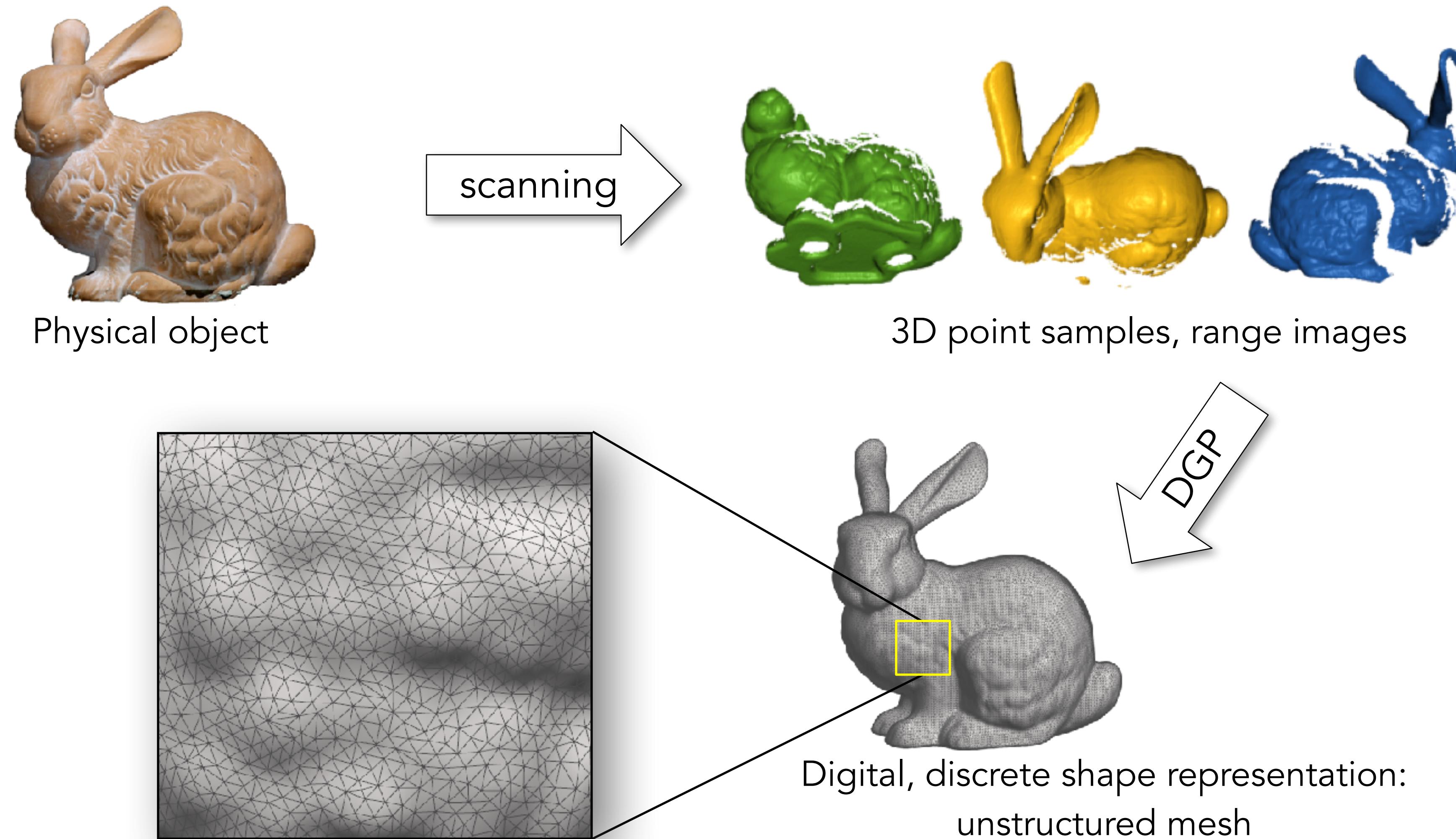
- High-quality surfaces
- Constrained modeling
- Requires a specific idea of the object first
 - Not easy to experiment and explore alternatives
- Requires extensive training



CATIA, Dassault Systems

<http://youtu.be/gTC5zMktMr0>

Modern Geometry Acquisition Pipeline



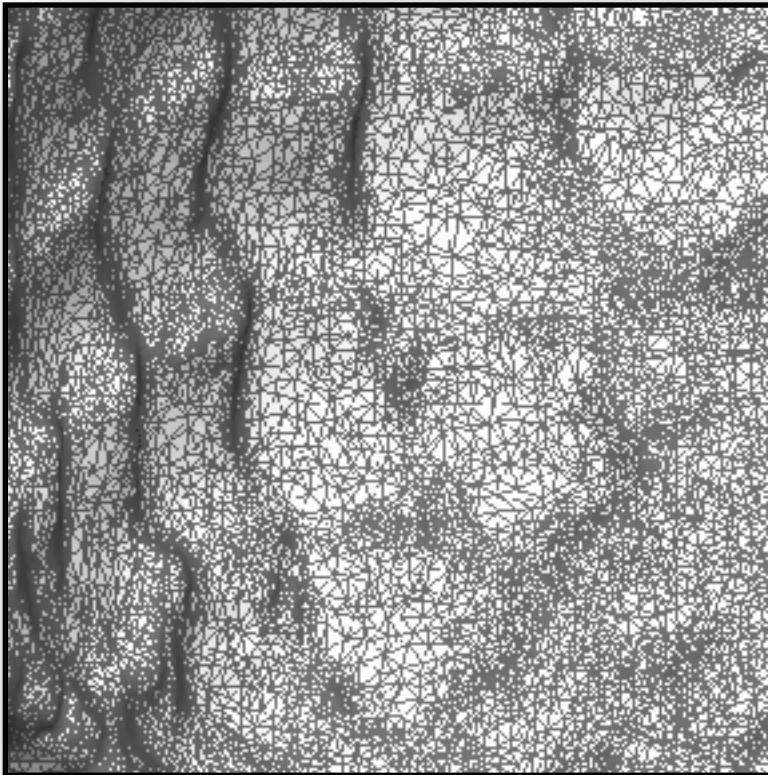
The Stanford Bunny, Stanford 3D Scanning Repository



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Unstructured Digital Shapes

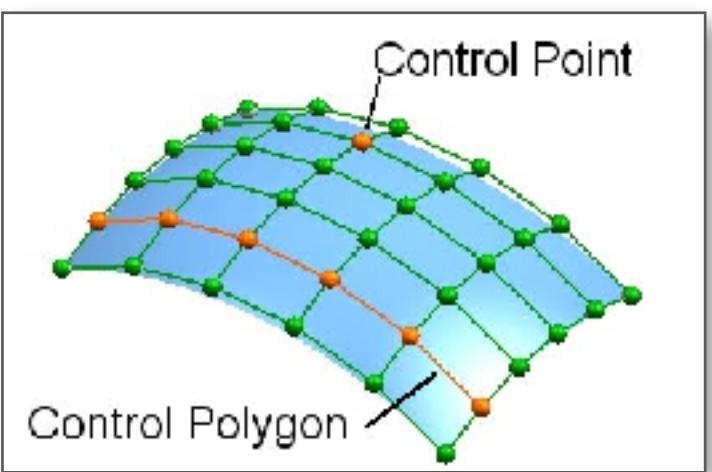
- How to **edit** and **animate**?
- How to convert to a **structured representation**?
- Computational challenge:
very large amounts
of data, yet modeling has to
remain interactive



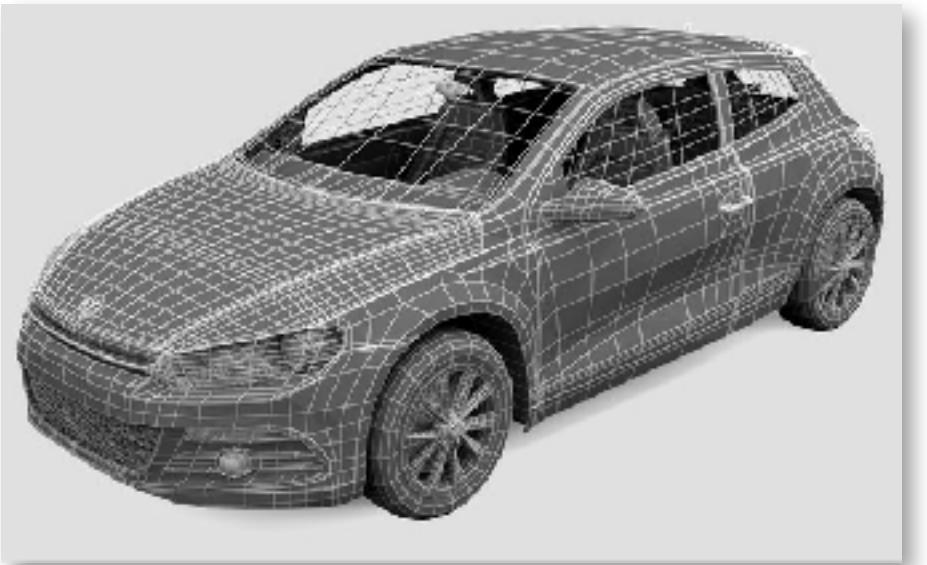
Thai statue, 10M triangles, Stanford 3D Scanning Repository

Traditional CAD vs Modern Mesh Modeling

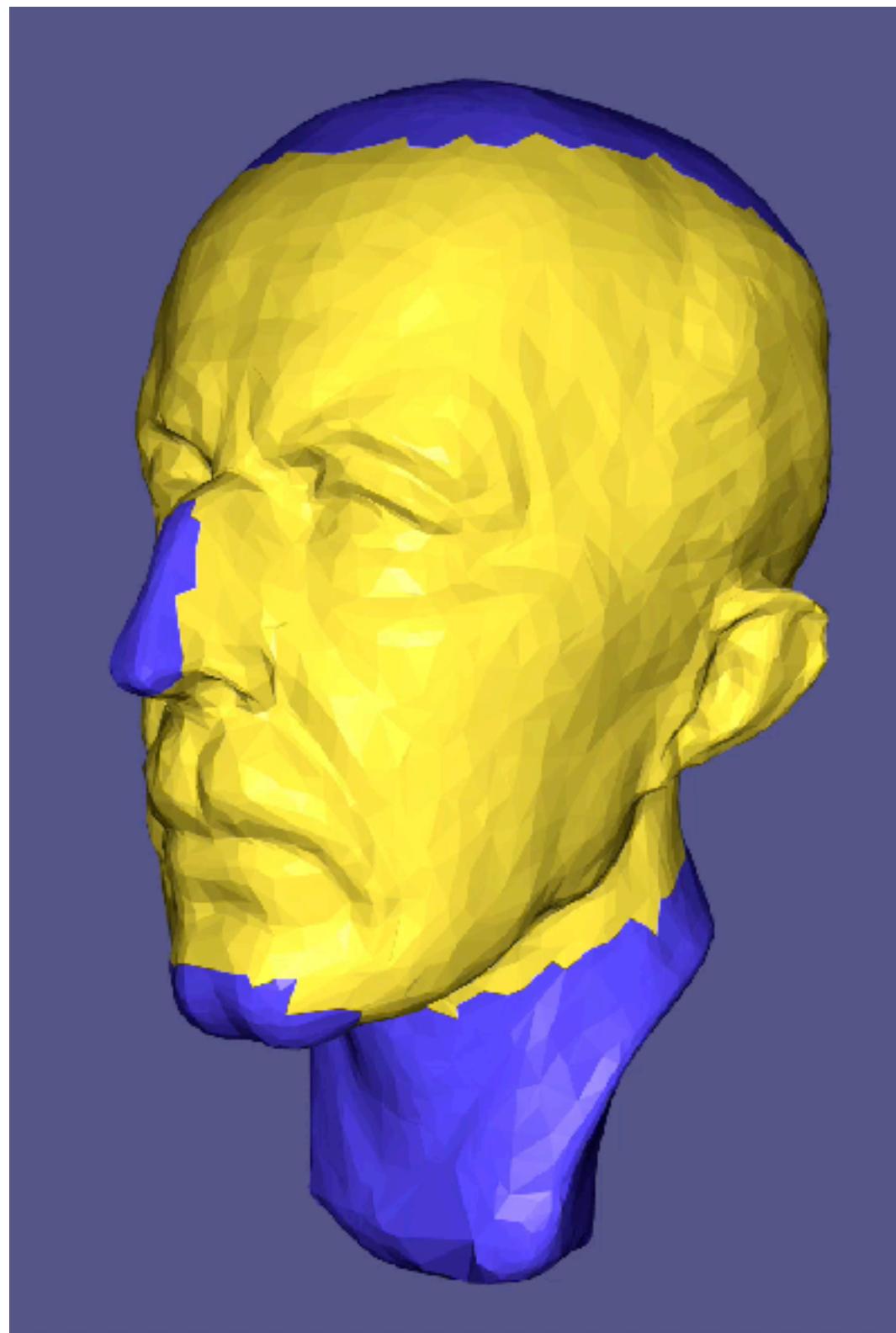
Traditional CAD



$$\mathbf{x}(u, v) = \sum_{i,j} \mathbf{p}_{i,j} B_i(u) B_j(v)$$



Modern mesh modeling

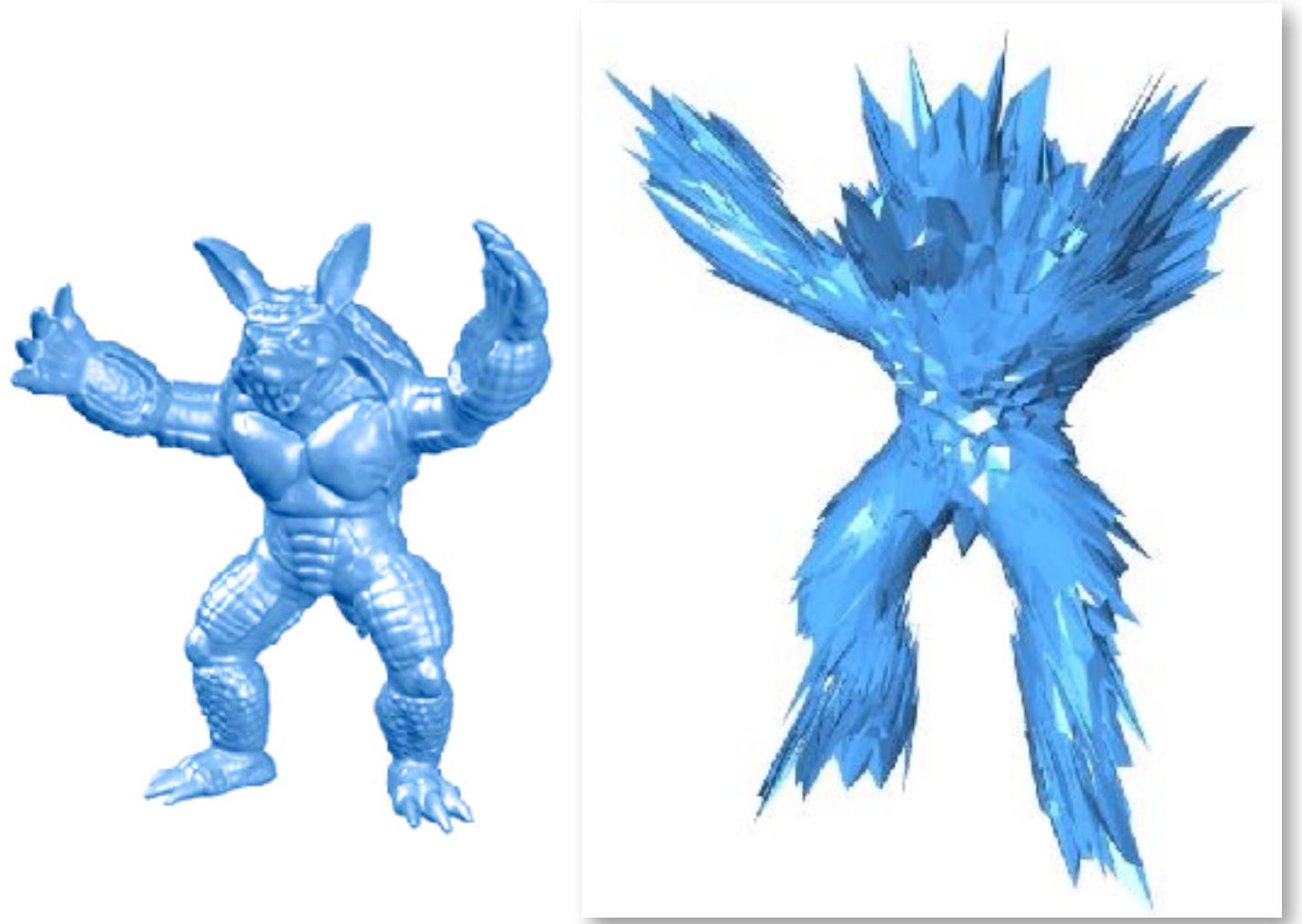


$$\min_{\mathbf{x}} \int_S E(\mathbf{x}) \quad s.t. \quad \mathbf{x}|_C = \mathbf{x}_{\text{fixed}}$$

User has more freedom!
Select and manipulate
arbitrary regions.

Tools?

- Use techniques from both CS & Math
 - PDEs
 - Discrete differential geometry
 - Numerical linear algebra
 - Graph theory
 - ...
- ...combined with intuition and creativity ...
- work on real data = write/use code



Prerequisites

- Linear Algebra
 - We **will not** cover the concepts that you need. If you are not familiar with basis, points, vectors, matrices, and linear systems, the course will be hard to follow.
- Python
 - We **will not** review the basic concepts of Python and Jupyter notebooks. There will be plenty of examples given, it should be easy to catch up if you never used it before.
 - Alternatively, you can use C++ for the assignments. However, no starting code will be provided.

Organization

- Course Website
- Weekly Lecture
- Office Hours
- MS Teams

Organization

- Weekly live lectures
 - TWF 9:30am - 10:20am ECS 108
- Office hours:
 - Wednesdays 1:00pm- 2:00pm ECS 612
 - By appointment
- Use MS Teams

Lectures

- I will upload the slides on the website, so that you can directly annotate them
- For every class, I will always add references in the end to the textbook and/or external resources
- You are encourage to take a look at the material **before** I present it in class

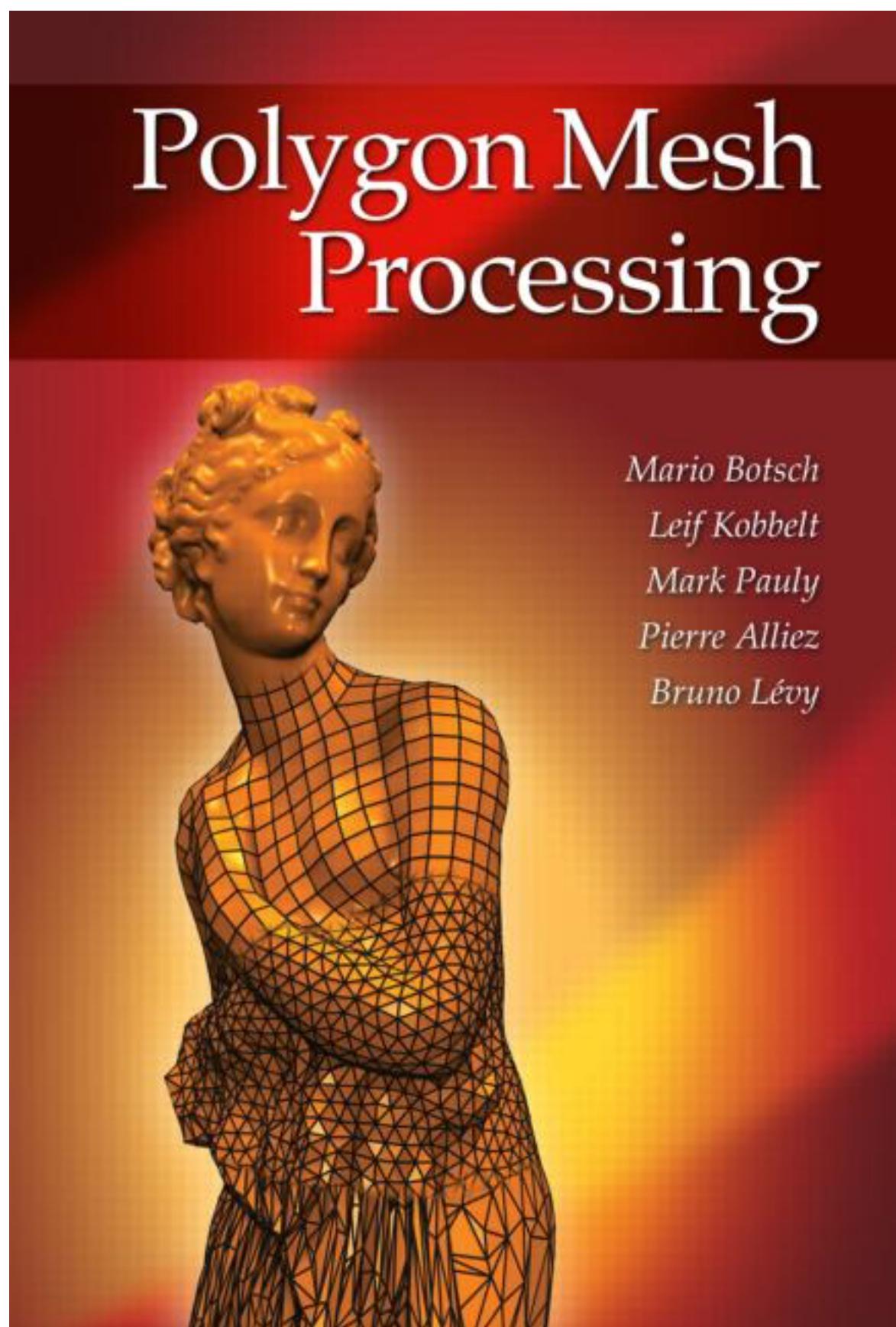
Lectures

- Please interrupt me at any time to ask questions

Final Coding Project (optional)

- Individual project, we will publish the rules later but you are essentially free to do whatever you want, as long as it requires geometry processing

Material



Polygon Mesh Processing



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



<https://www.wikipedia.org>

Grading

- **Assignments 65% (70% Grad)**
 - Late assignments count 70%
- **Project or Exam: 35% (30% Grad)**
- There will be optional tasks, that will allow you to recover points lost in the assignments



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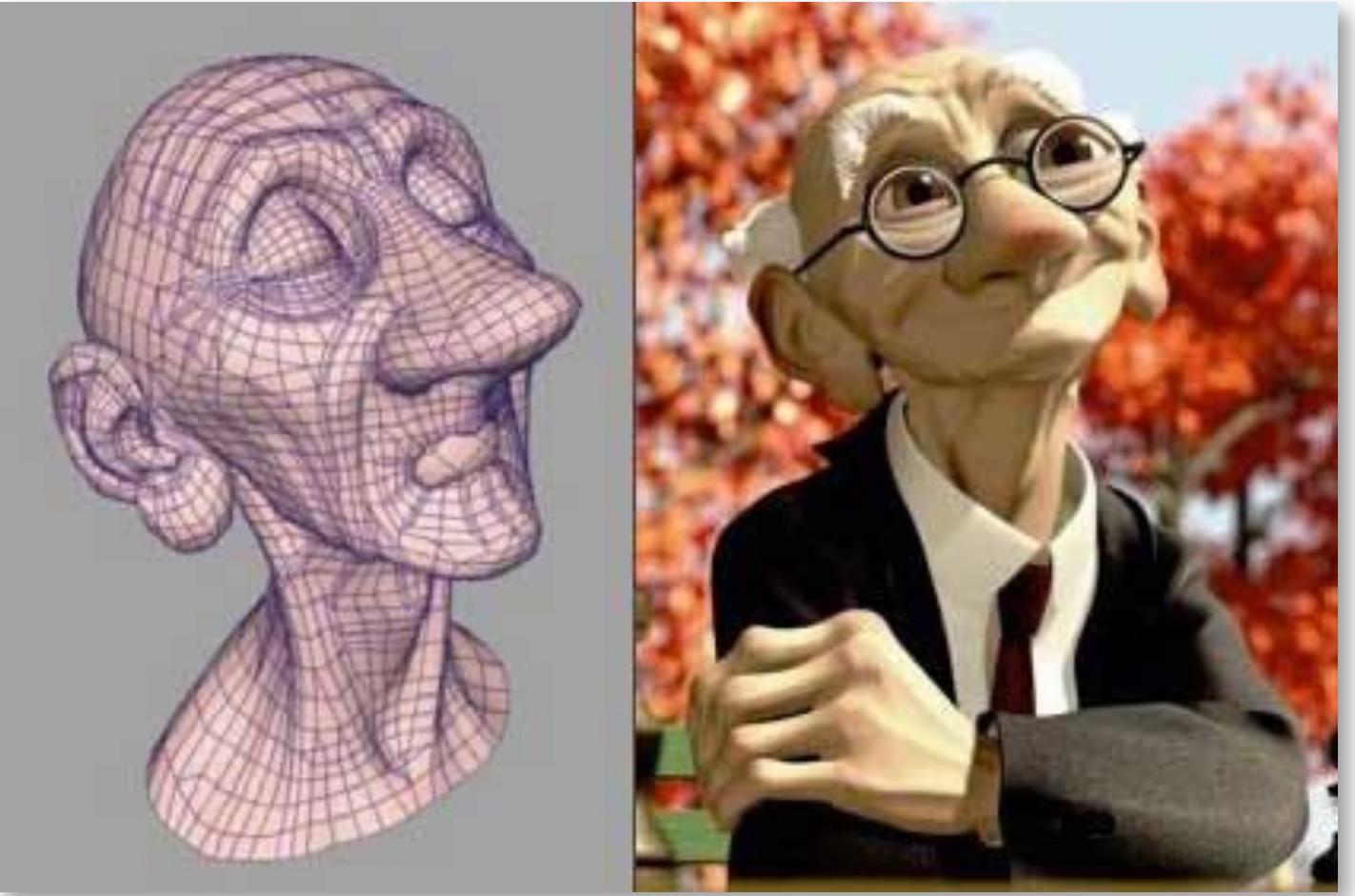
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Policy

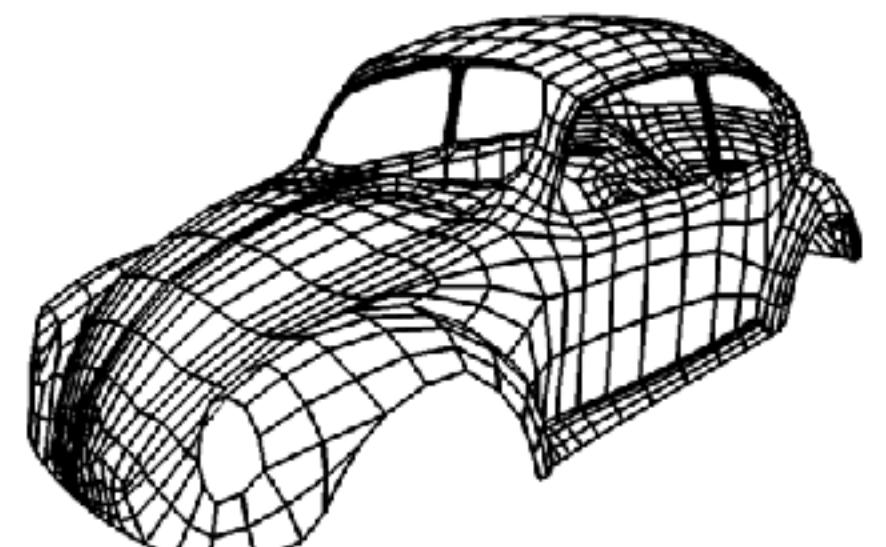
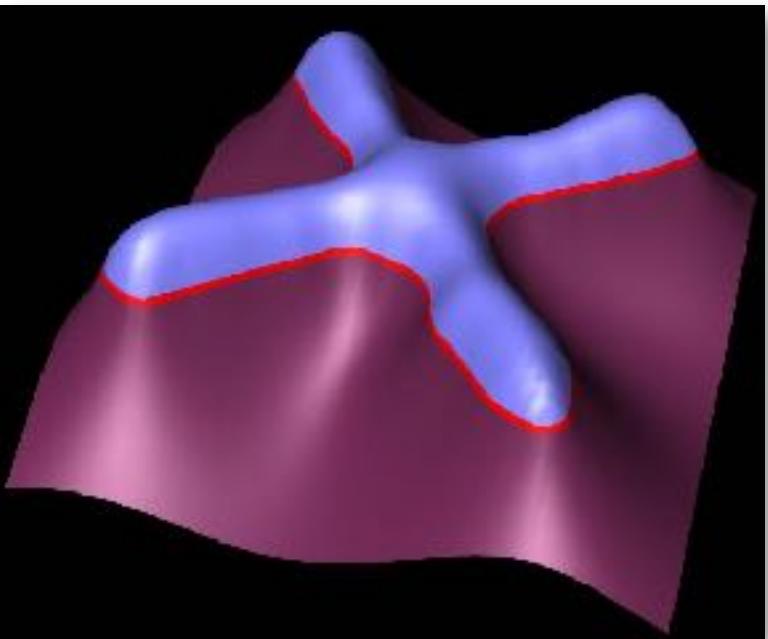
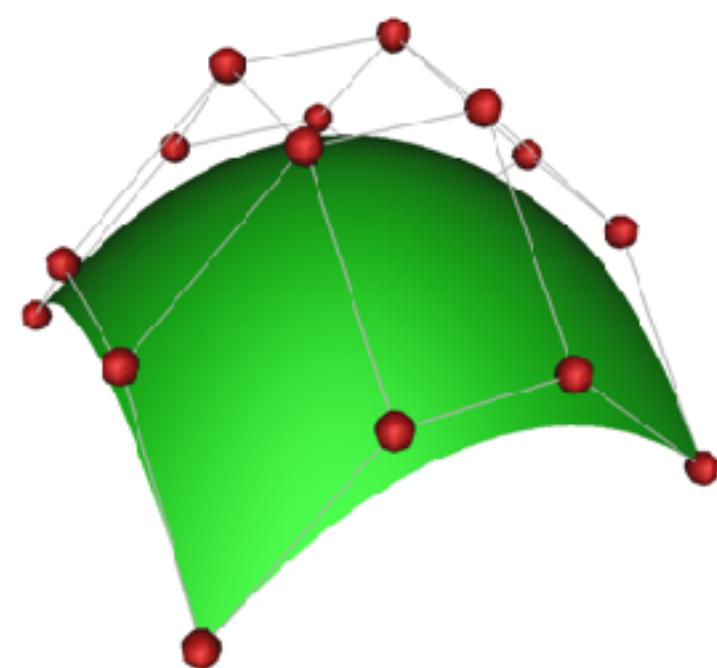
- You are encouraged to consult with your classmates/friends but collaboration in the assignments is **NOT** allowed.
- You are **NOT** allowed to copy code online or use external libraries (except those provided in the class) for the first 3 assignments.
- We will use plagiarism tools to validate all homework. Plagiarism will be punished with a zero-tolerance policy: **the minimal penalty will be a score of 0 points on the assignment, the reduction of 1 letter grade in the final score, and a permanent ban on university-related jobs.**

Course Topics

- Overview of shape representations
 - Parametric curves/surfaces
 - Implicit
 - Polygonal meshes

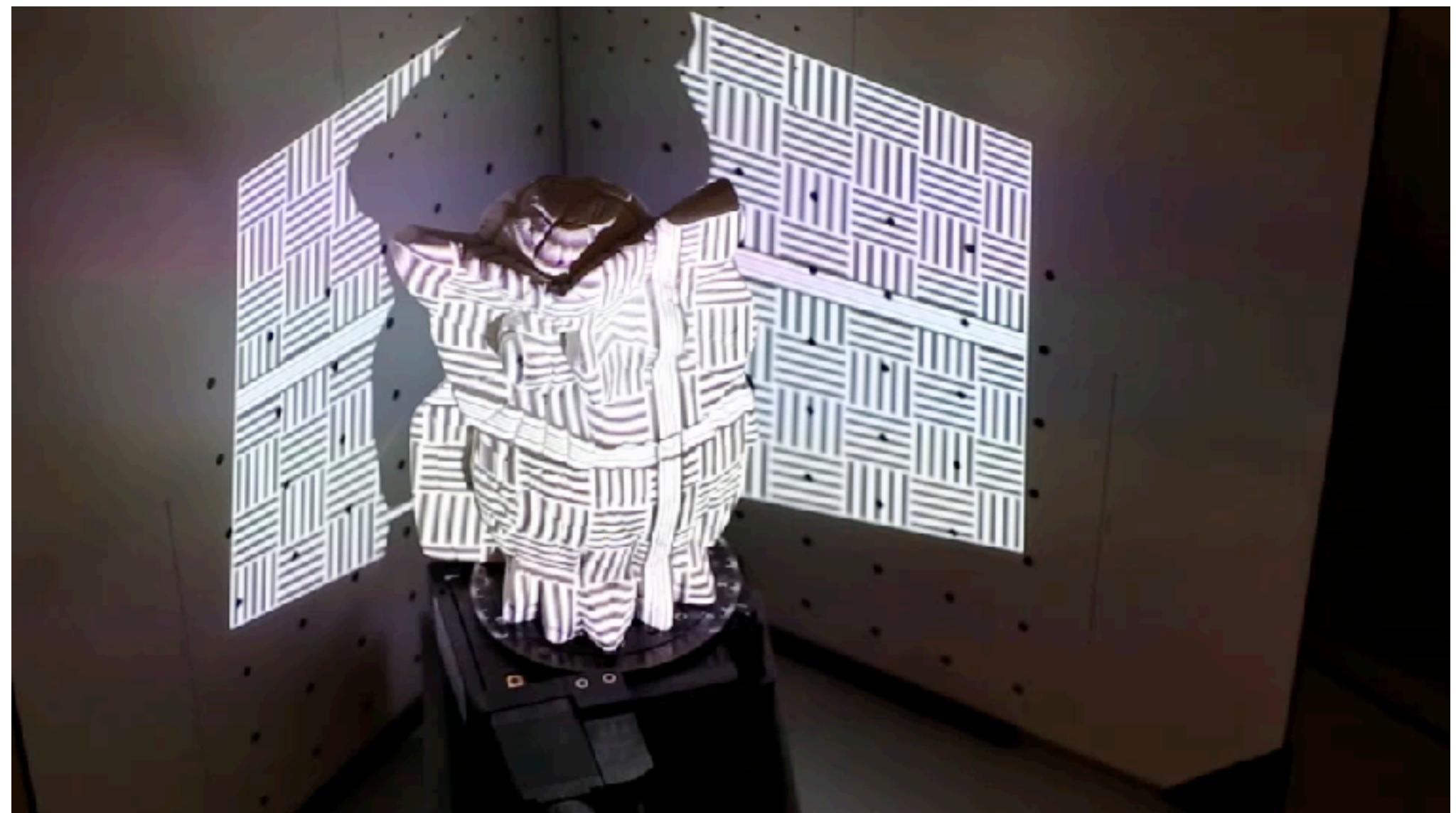
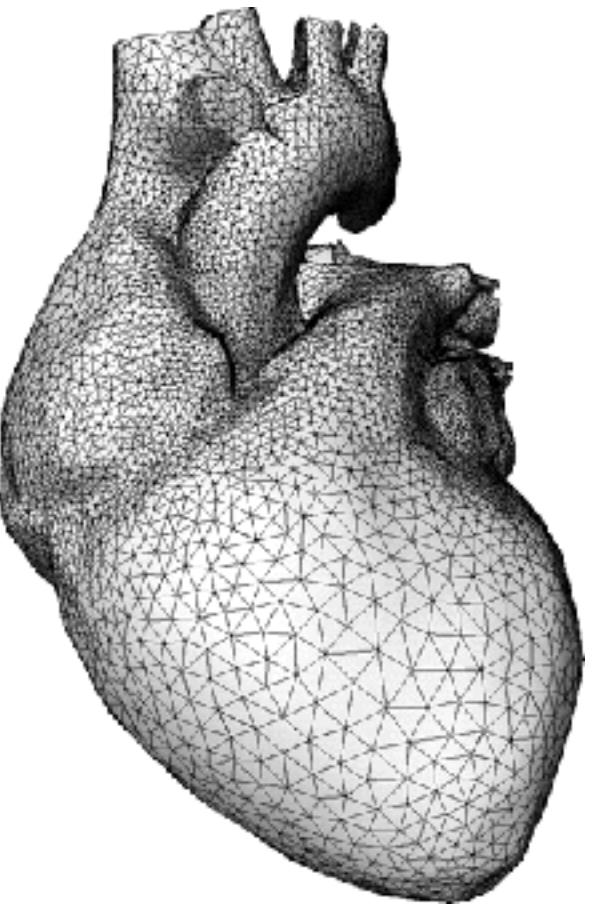
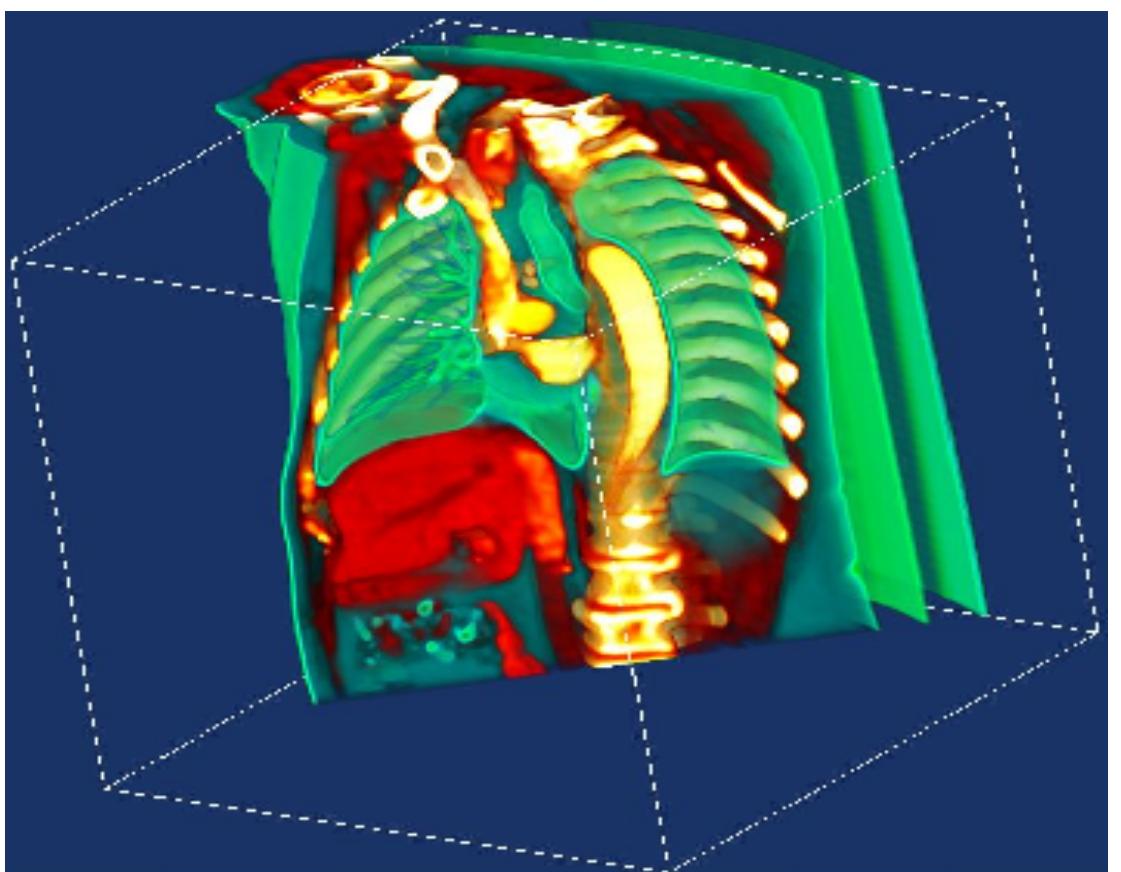
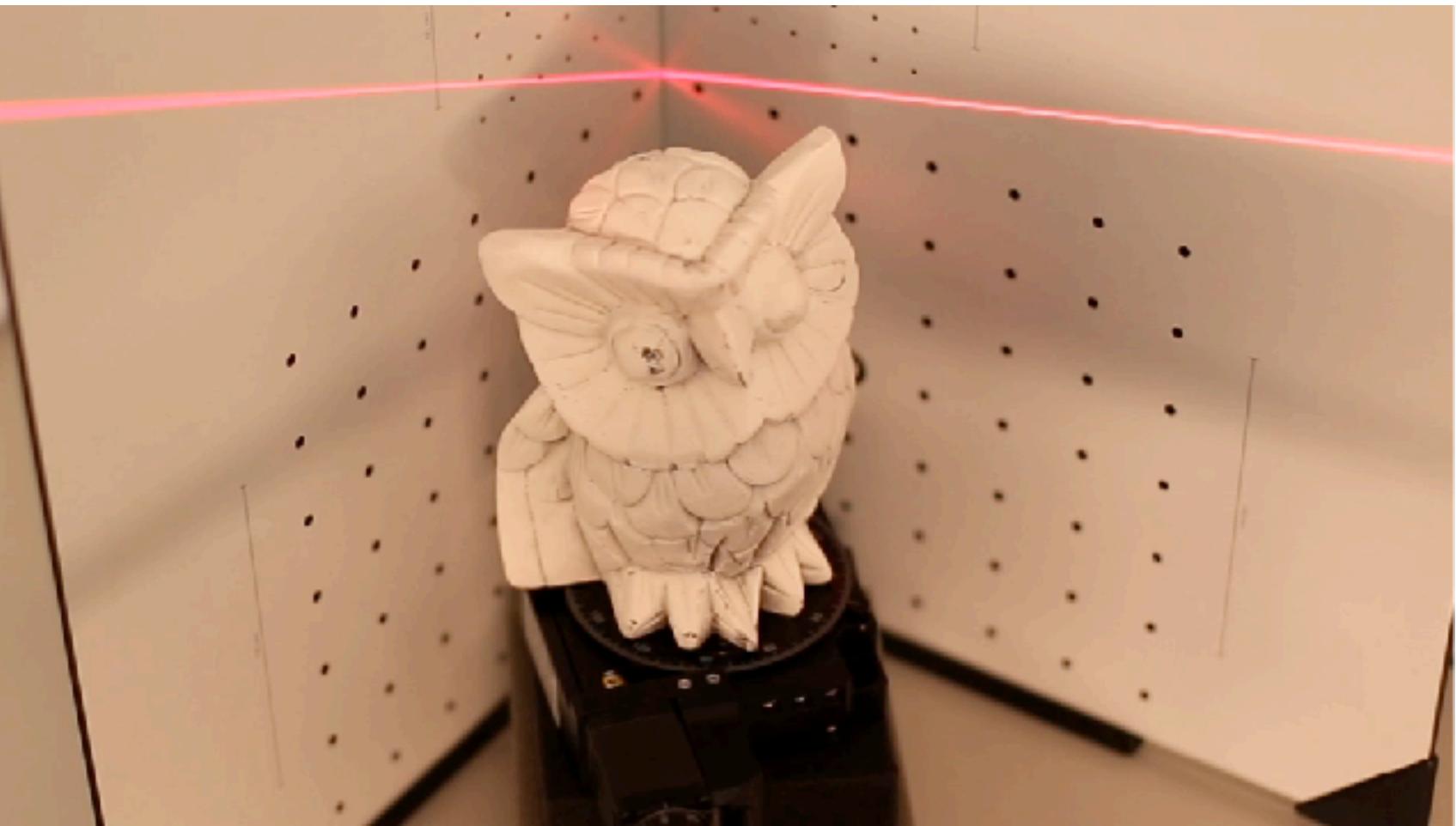


Pixar



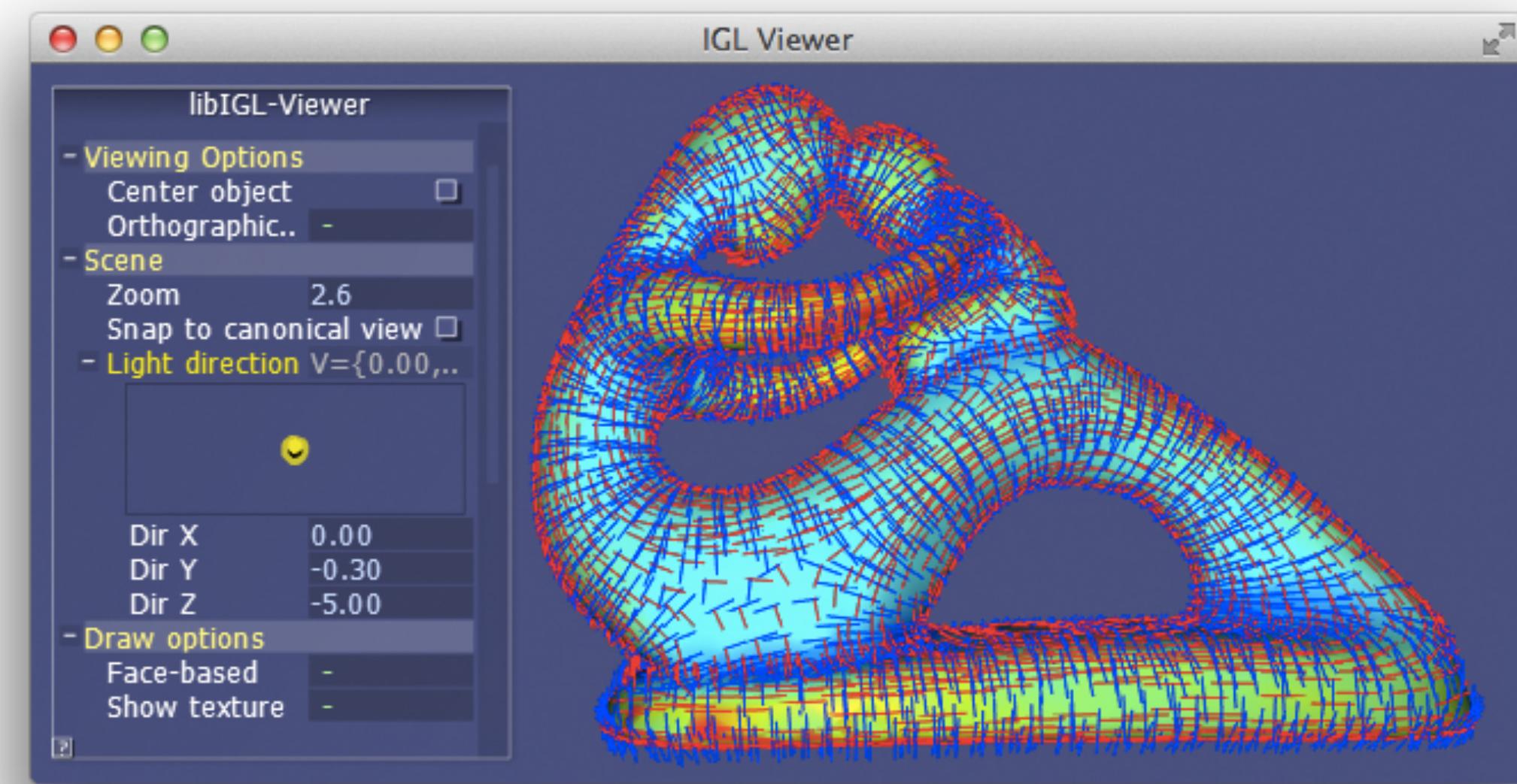
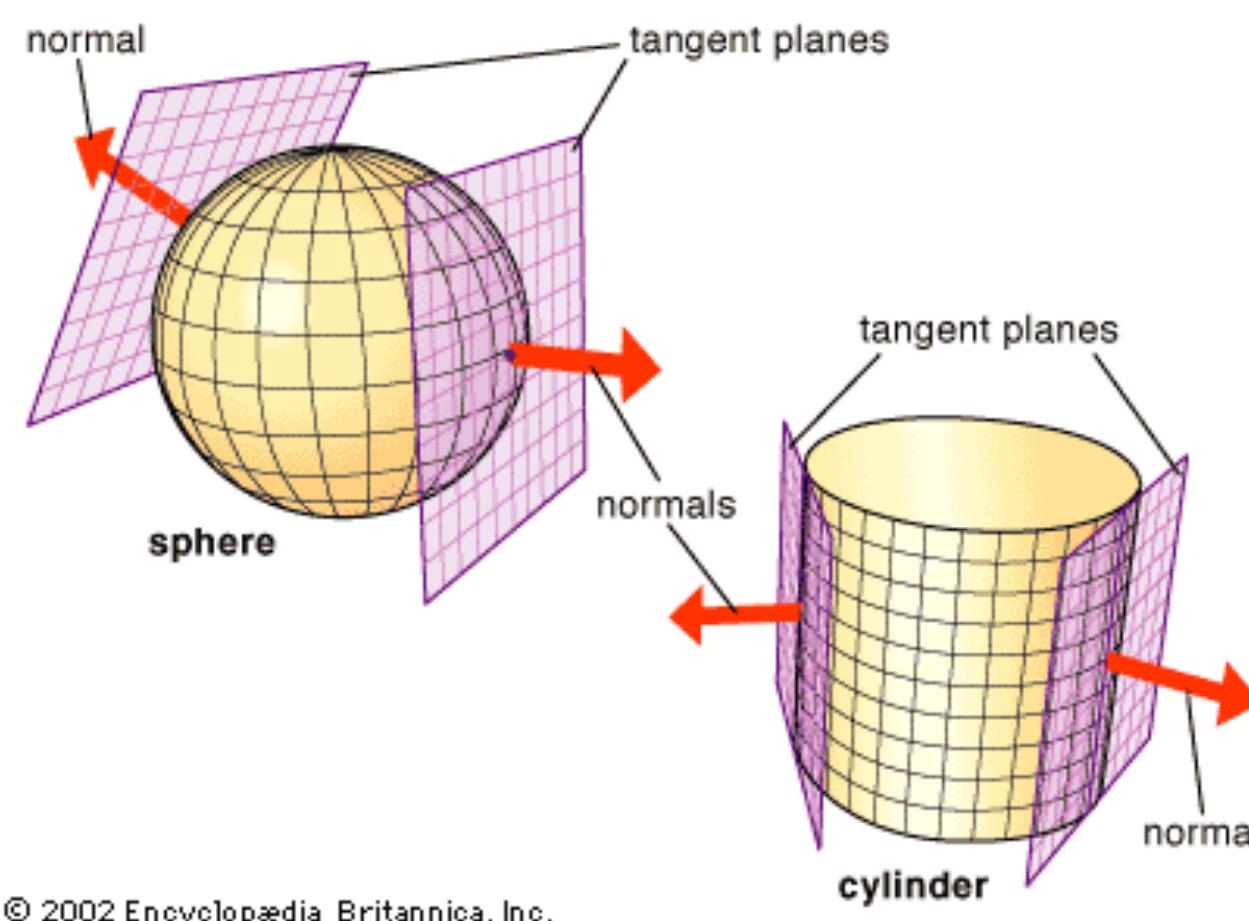
Course Topics

- Shape acquisition
 - Scanning/imaging
 - Reconstruction



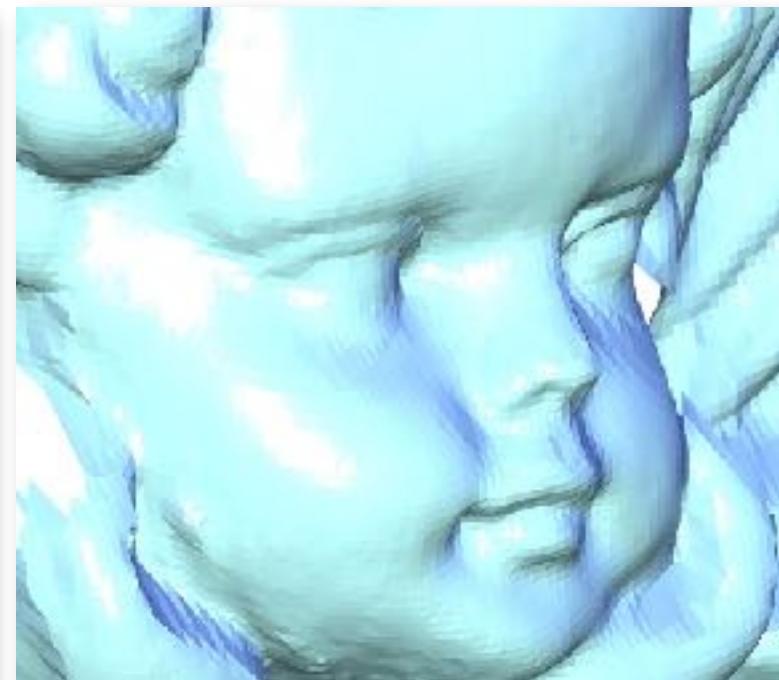
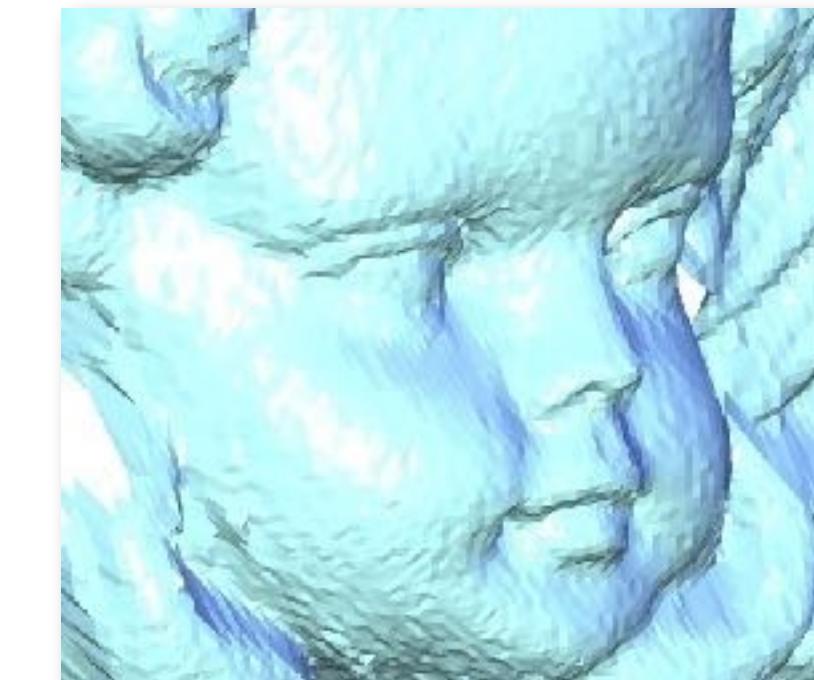
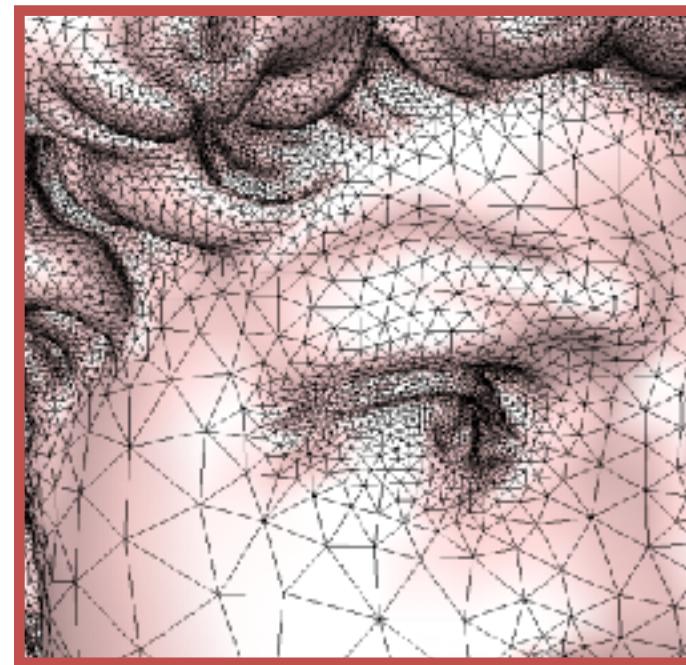
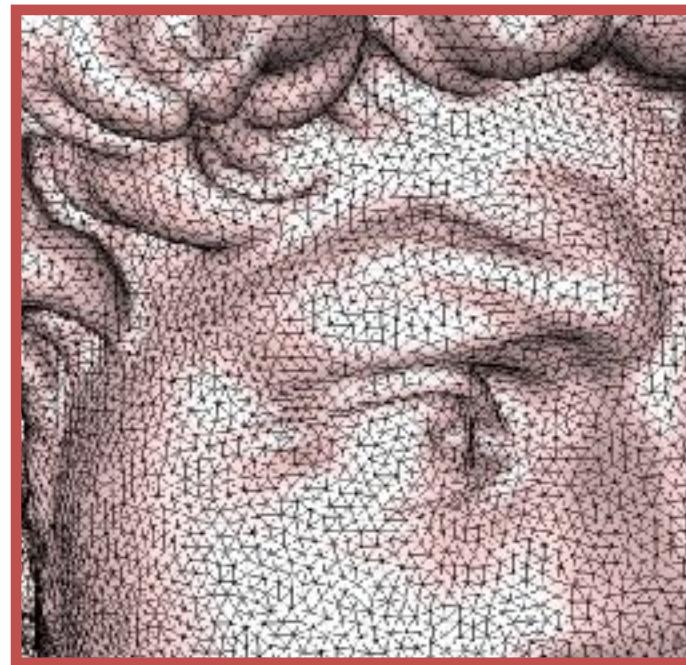
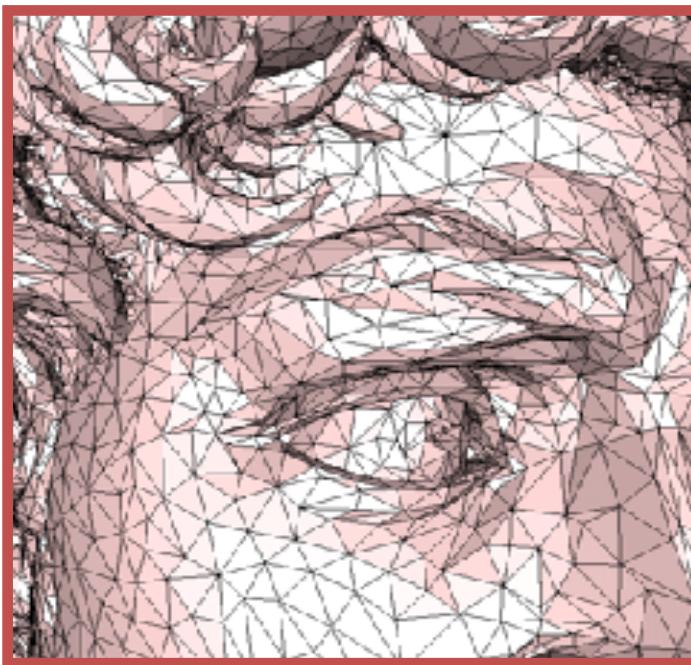
Course Topics

- Differential geometry
 - Continuous and (mostly) discrete
 - Powerful tool to analyze and model shapes



Course Topics

- Digital geometry processing
 - Denoising, smoothing, simplification, remeshing, parameterization, compression



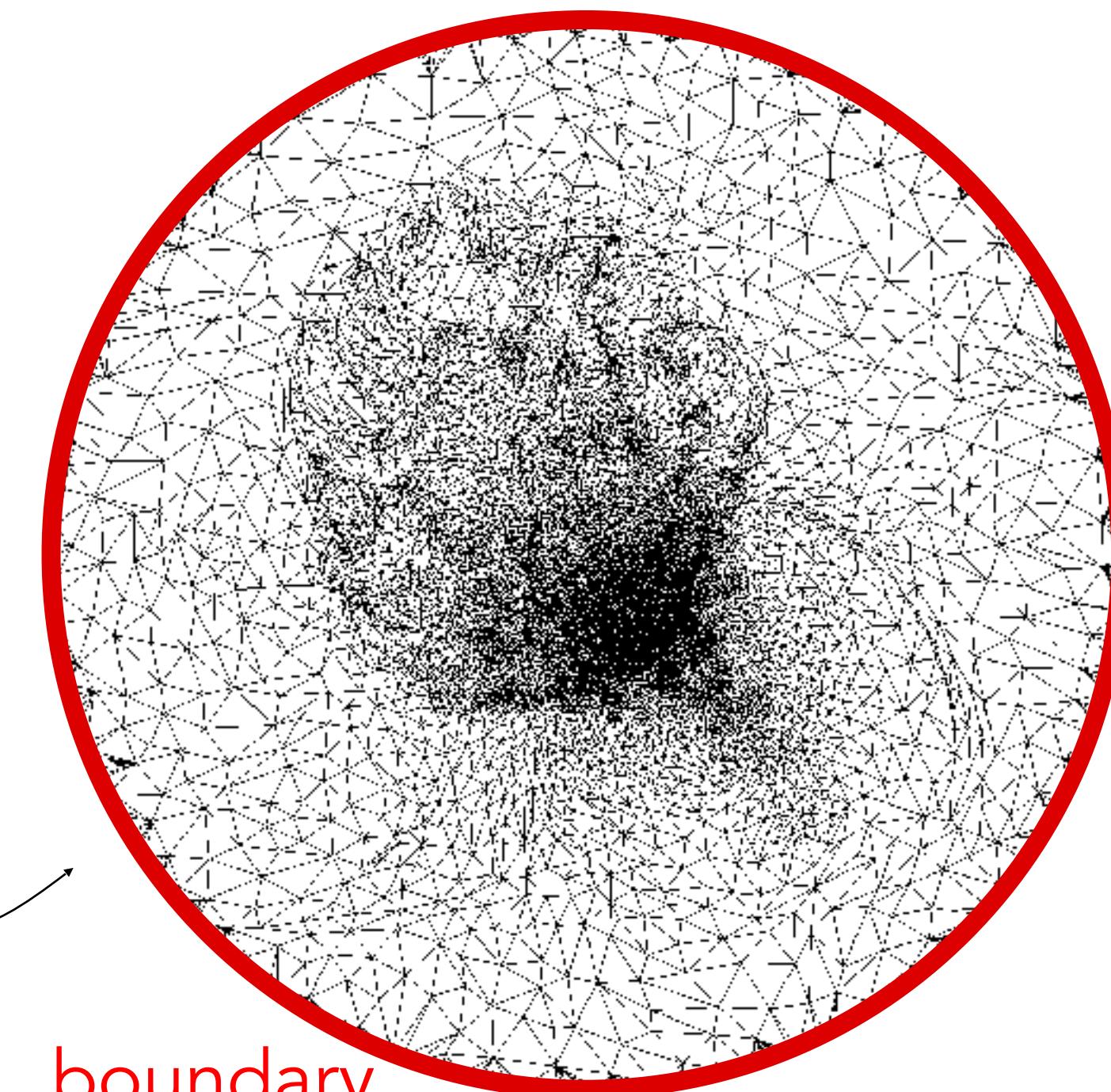
Course Topics

- Parameterization

3D space (x,y,z)



2D parameter domain (u,v)

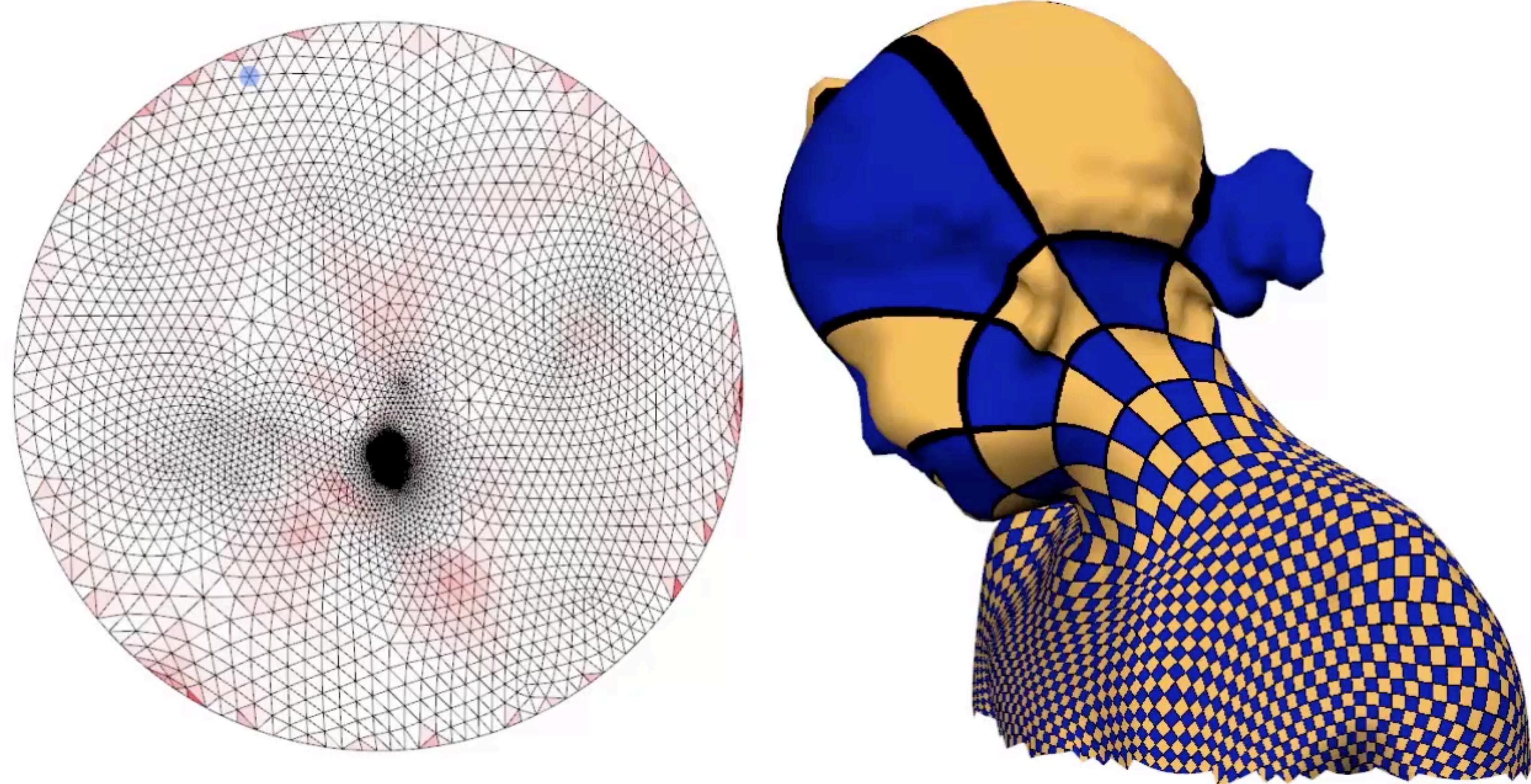


boundary

boundary

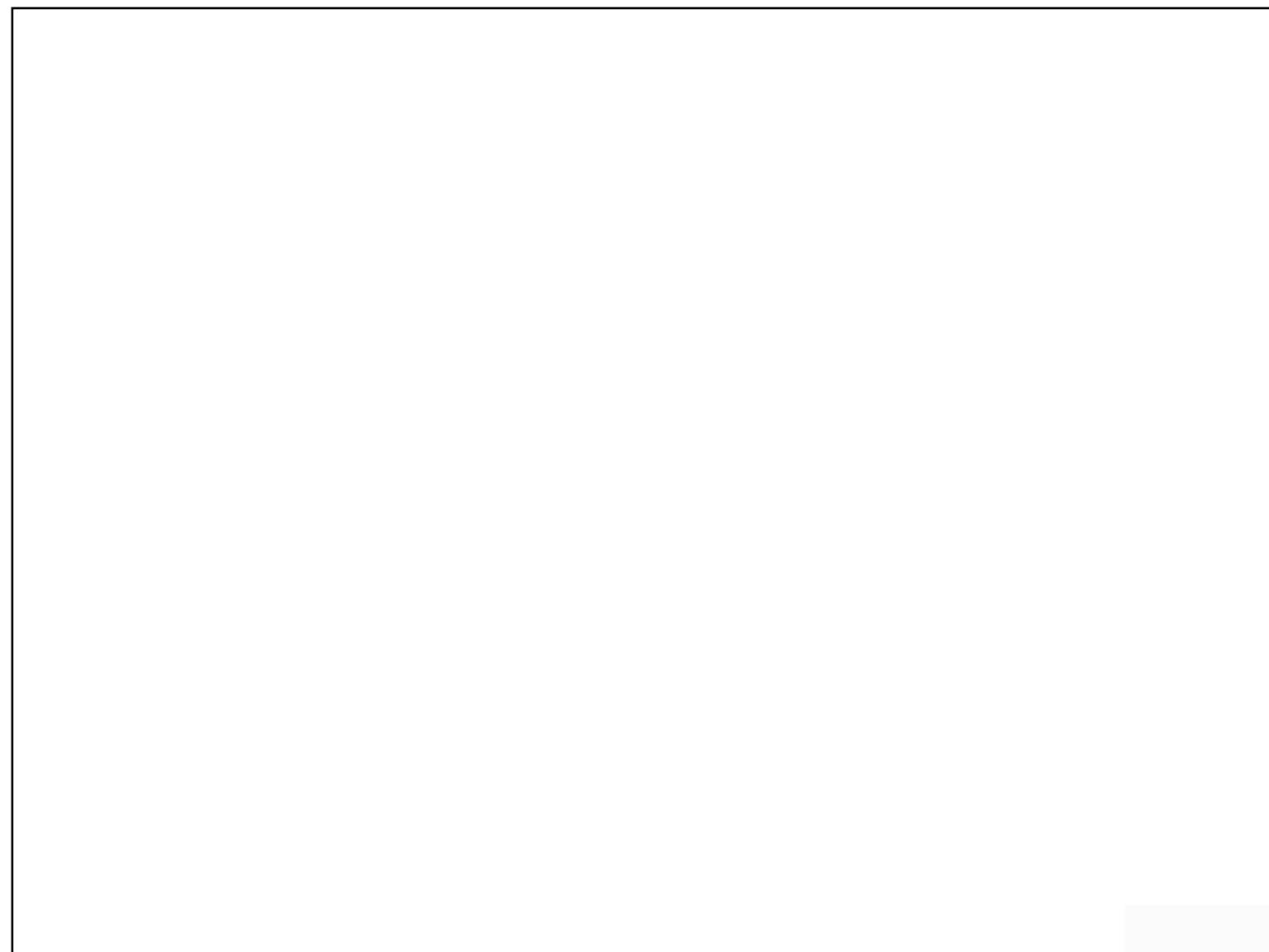
Course Topics

- Parameterization
-

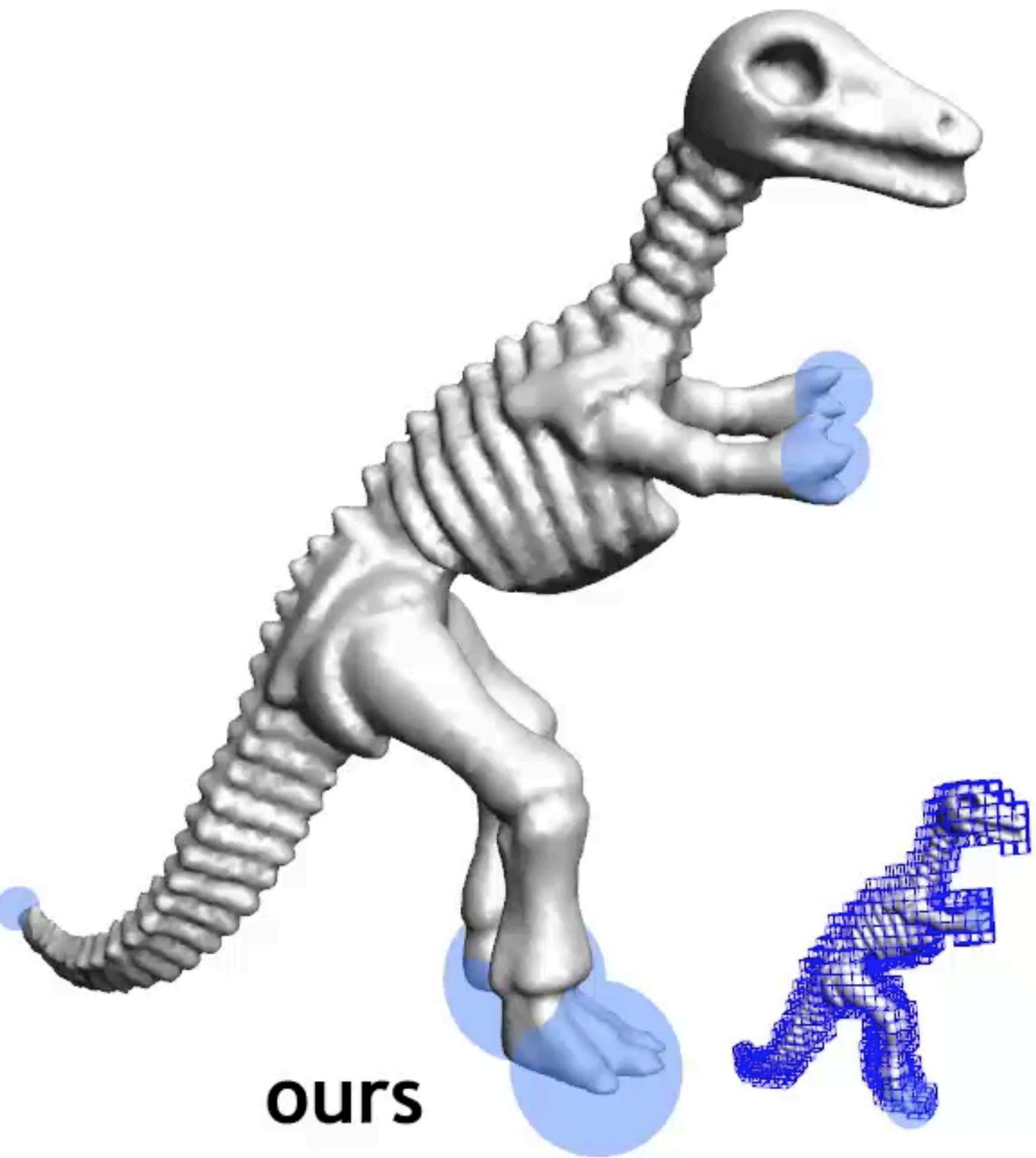


Course Topics

- Shape creation and editing

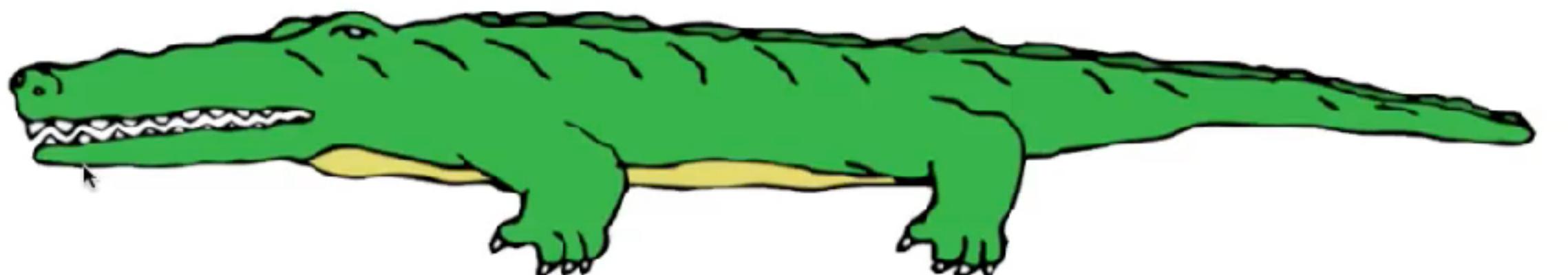


<http://youtu.be/W0XGkS7zebo>

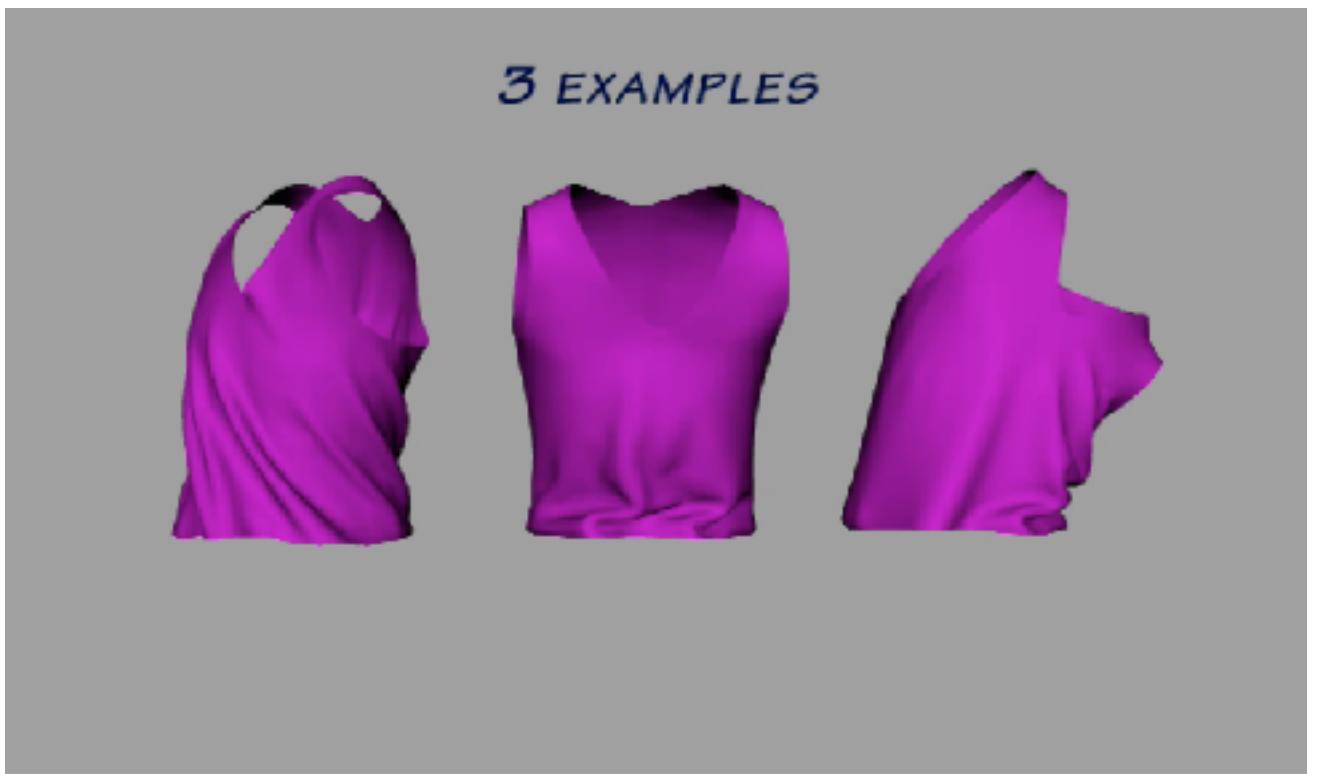


Course Topics

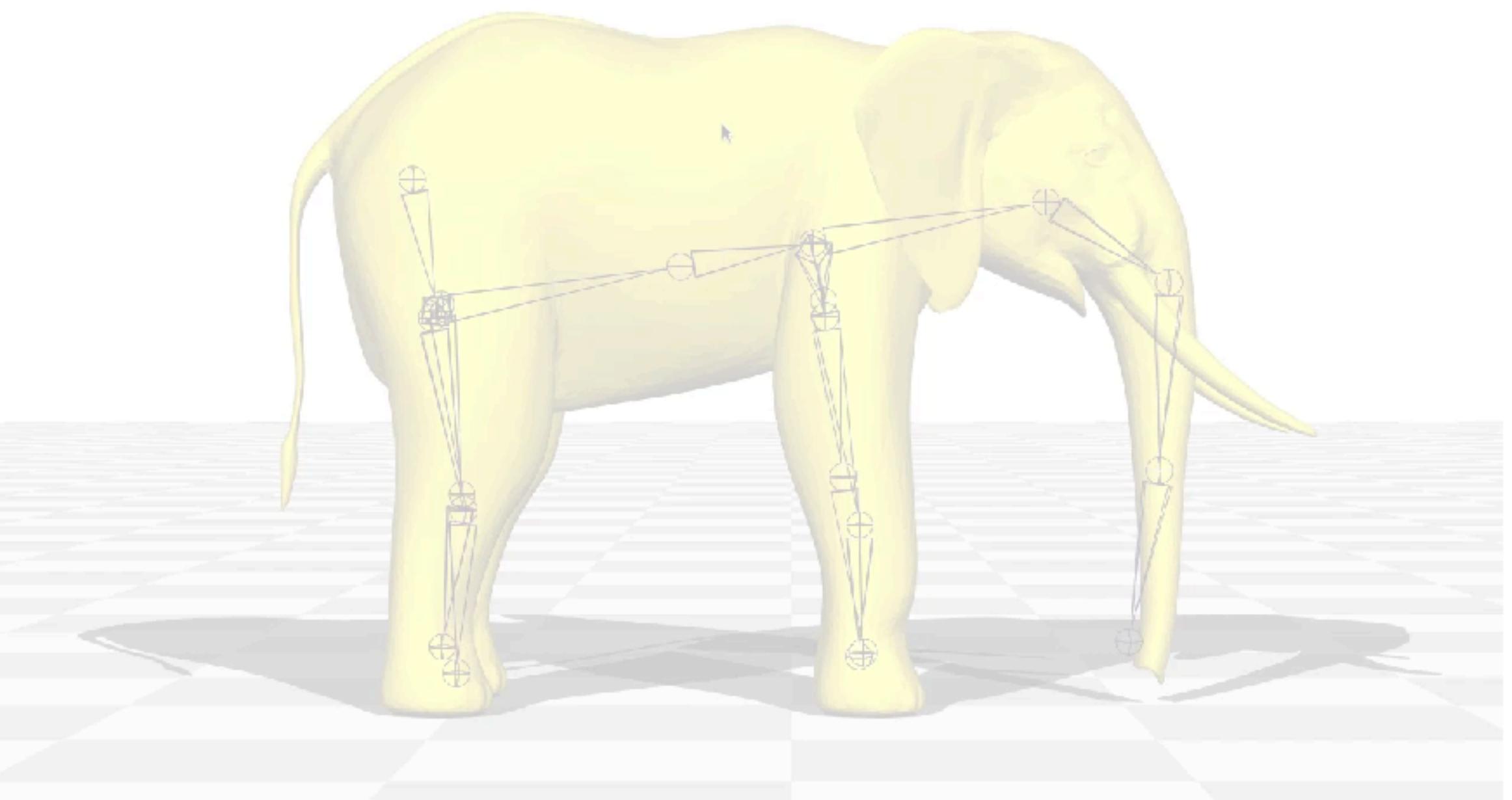
- Skinning, animation



<http://youtu.be/P9fqm8vgdB8>

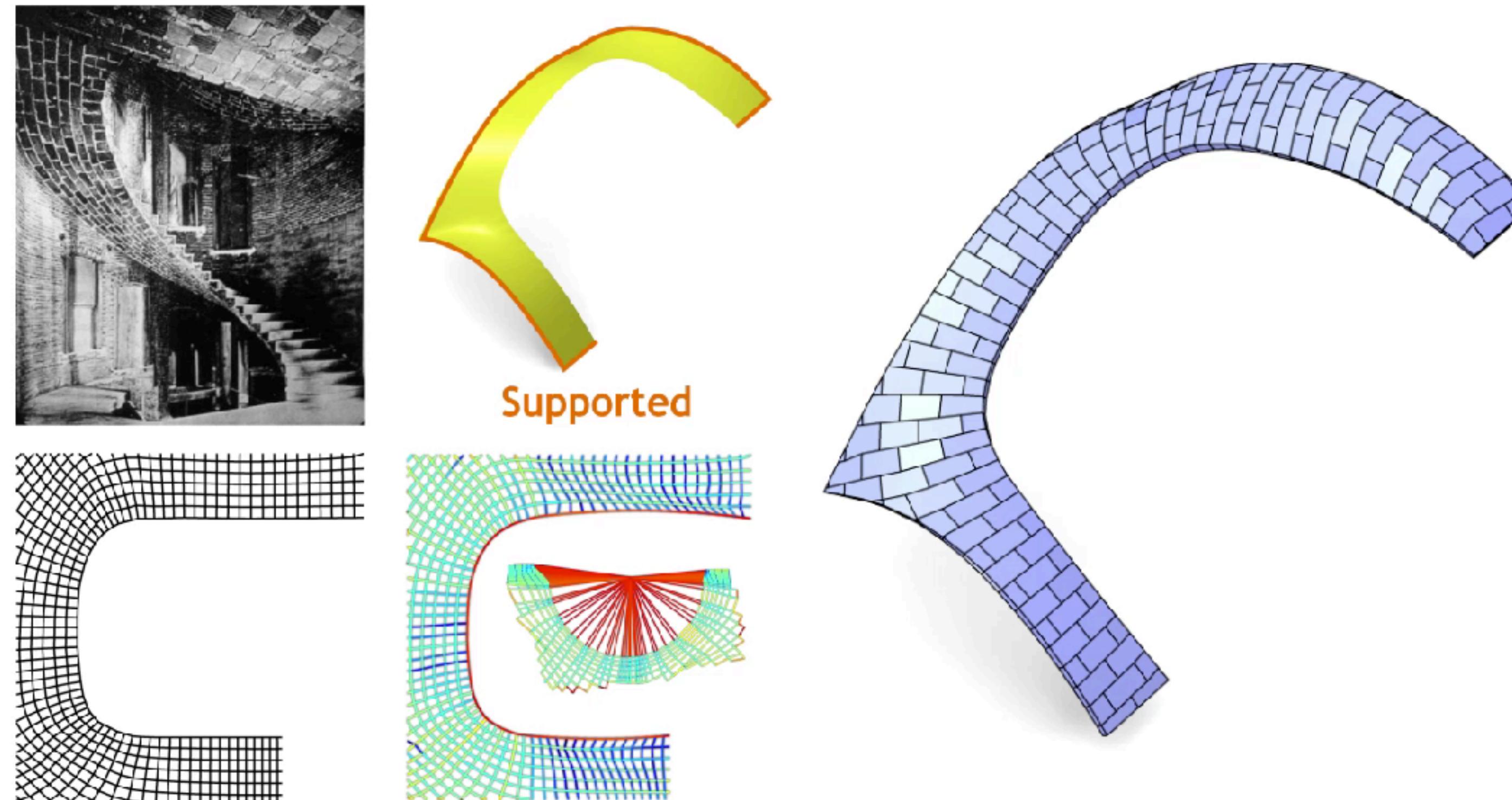


<http://youtu.be/Pjg33pH9RKO>



Course Topics

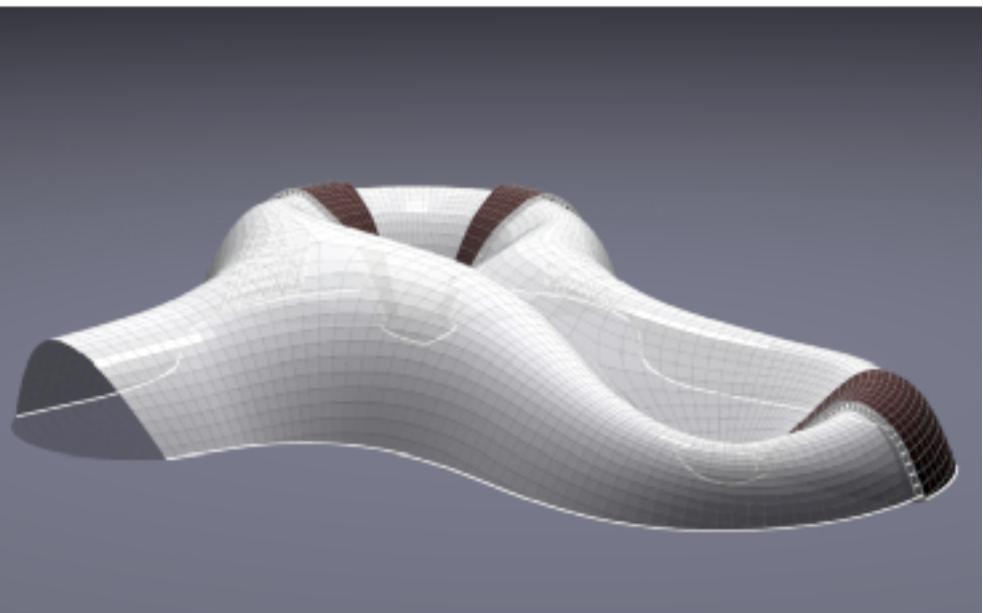
- Architectural geometry and structure-aware modeling



[Panizzo et al. SIGGRAPH 2013](#)

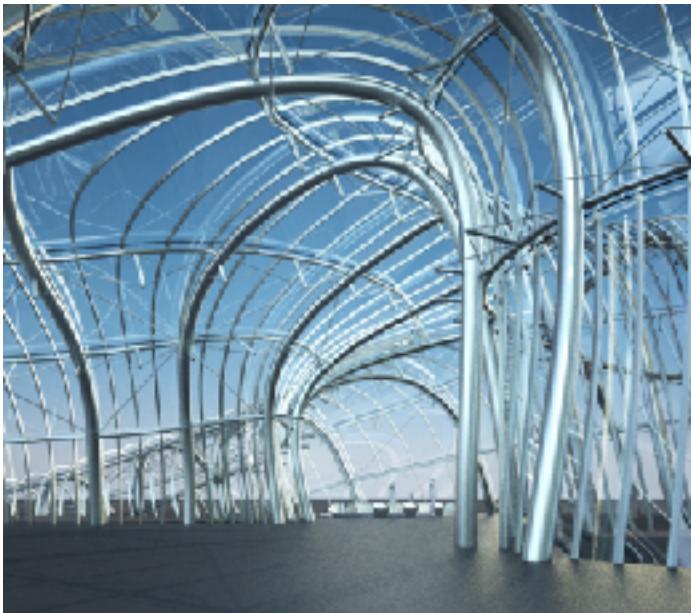
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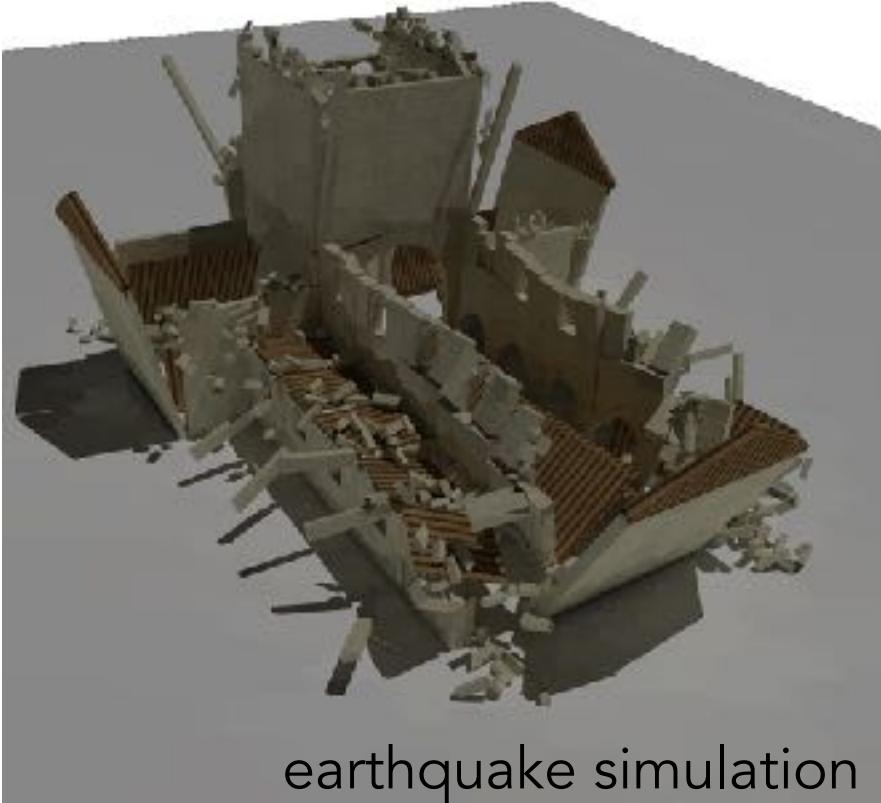
[Pottmann 08]

<http://www.dmg.tuwien.ac.at/pottmann/2008/panels08/panels.html>

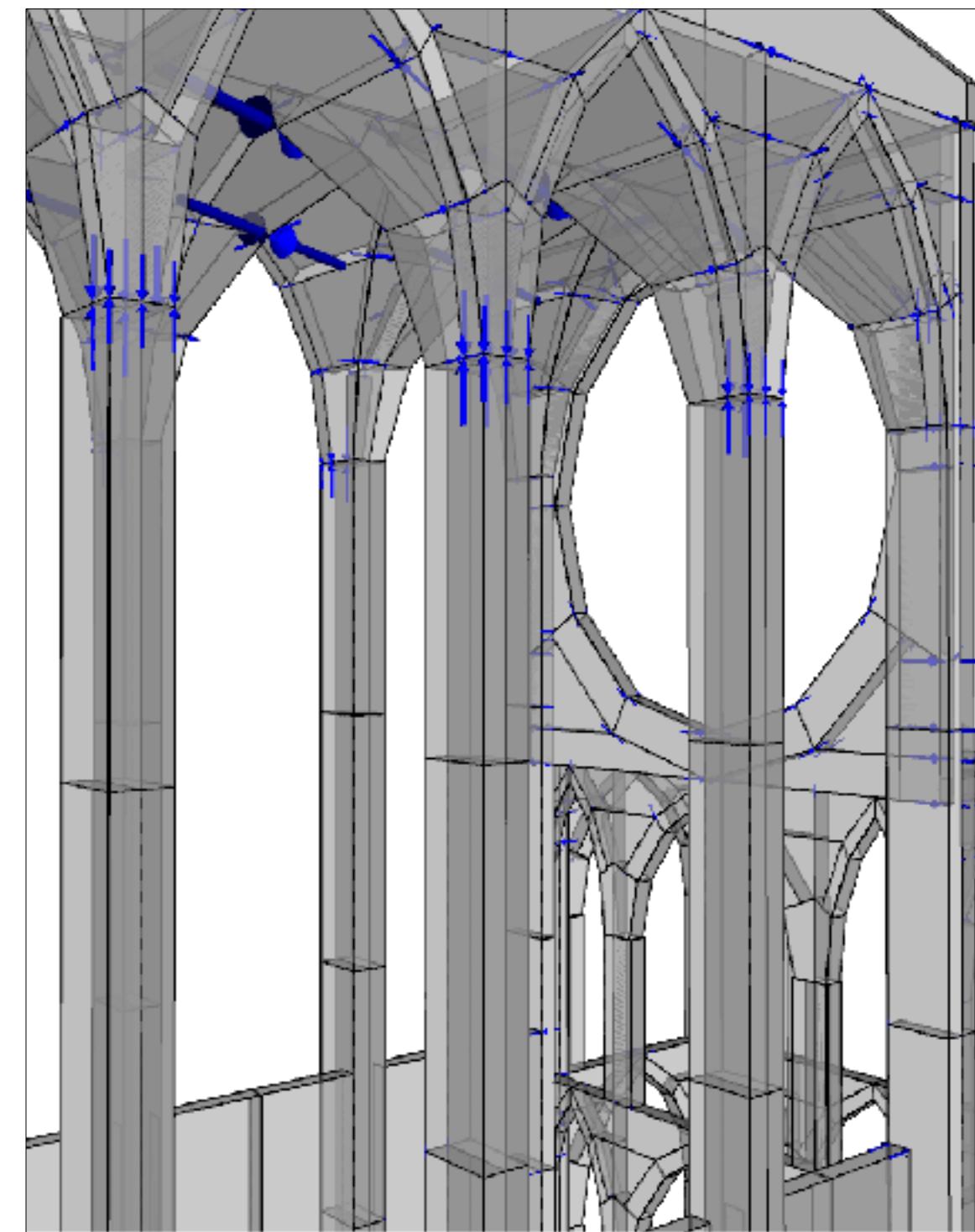


[Whiting 09]

<http://www.inf.ethz.ch/personal/whitinge/projects/siggraph09.html>



earthquake simulation

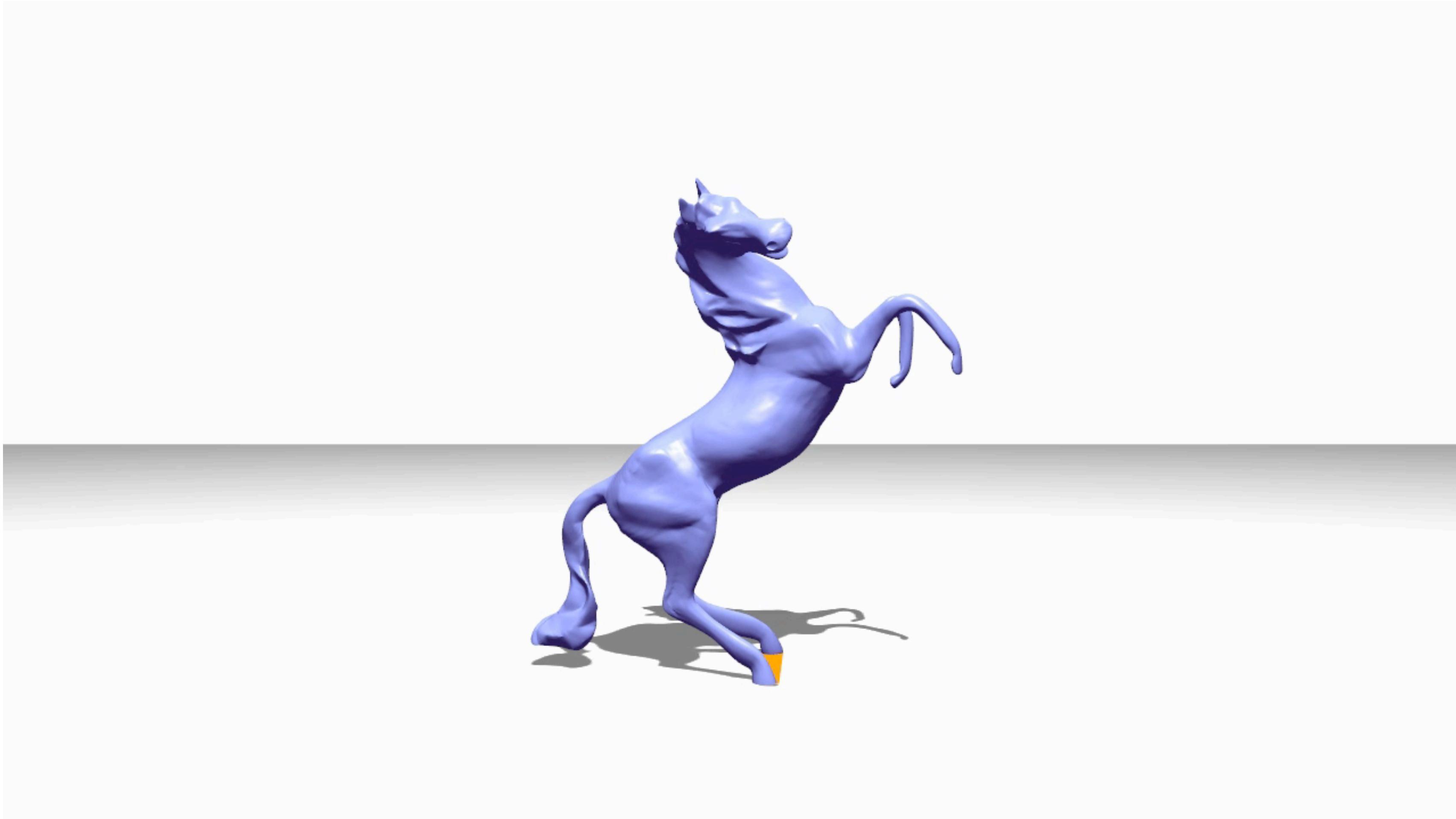


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Course Topics

- 3D fabrication-aware shape modeling



Course Topics

- 3D fabrication-aware shape modeling



Vacuum Forming

Thank you