

GEOMETRIC MODELING

Enrico Puppo - Claudio Mancinelli
Department of Computer and Information Sciences
University of Genova

Credits: course and slides

- Evolution from different sources
- Colleagues & friends
- Opportunities for internship, thesis, PhD



Daniele Panozzo, NYU



Olga Sorkine Hornung
ETH Zurich



Marco Tarini
University of Milan



Keenan Crane
Carnegie Mellon



Kai Hormann
University of Lugano

00 - Introduction and Overview

Who are we?

Enrico Puppo

- Professor of Computer Science @ DIBRIS
- Email: enrico.puppo@unige.it
- URL: <https://person.dibris.unige.it/puppo-enrico/>

Claudio Mancinelli

- Assistant Professor of Computer Science @ DIBRIS
- Email: claudio.mancinelli@unige.it
- URL: <https://cmancinelli.com/>

Room: 306 (both)

Web site of the course

<https://2024.aulaweb.unige.it/course/view.php?id=2431>

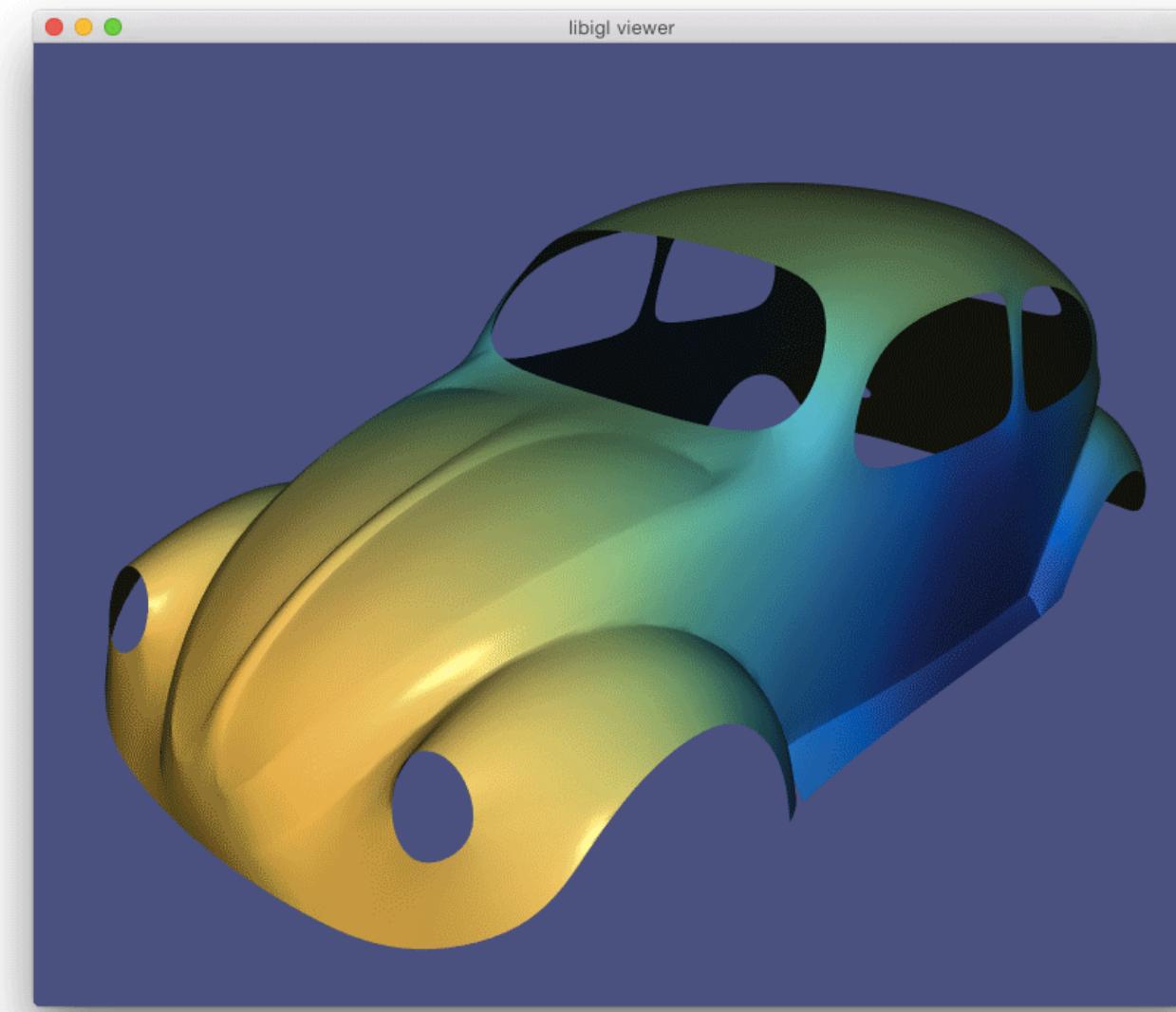
- Logbook
- Slides
- Links to on-line material
- Forum
- Exam rules

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
- No, I will not teach you how to use modeling systems like Blender, Lightwave, 3DS Max, Maya, Modo, ZBrush, etc.
- No, there is no AI or learning at all in this course

Geometric Modeling and Processing

- The shape of an object is an important characteristic (not the only one...)
- Non-geometric characteristics:
 - Pictorial appearance (color, texture, shininess, transparency, ...)
 - Physical properties (weight, elasticity, ...)



Copyright: Blender

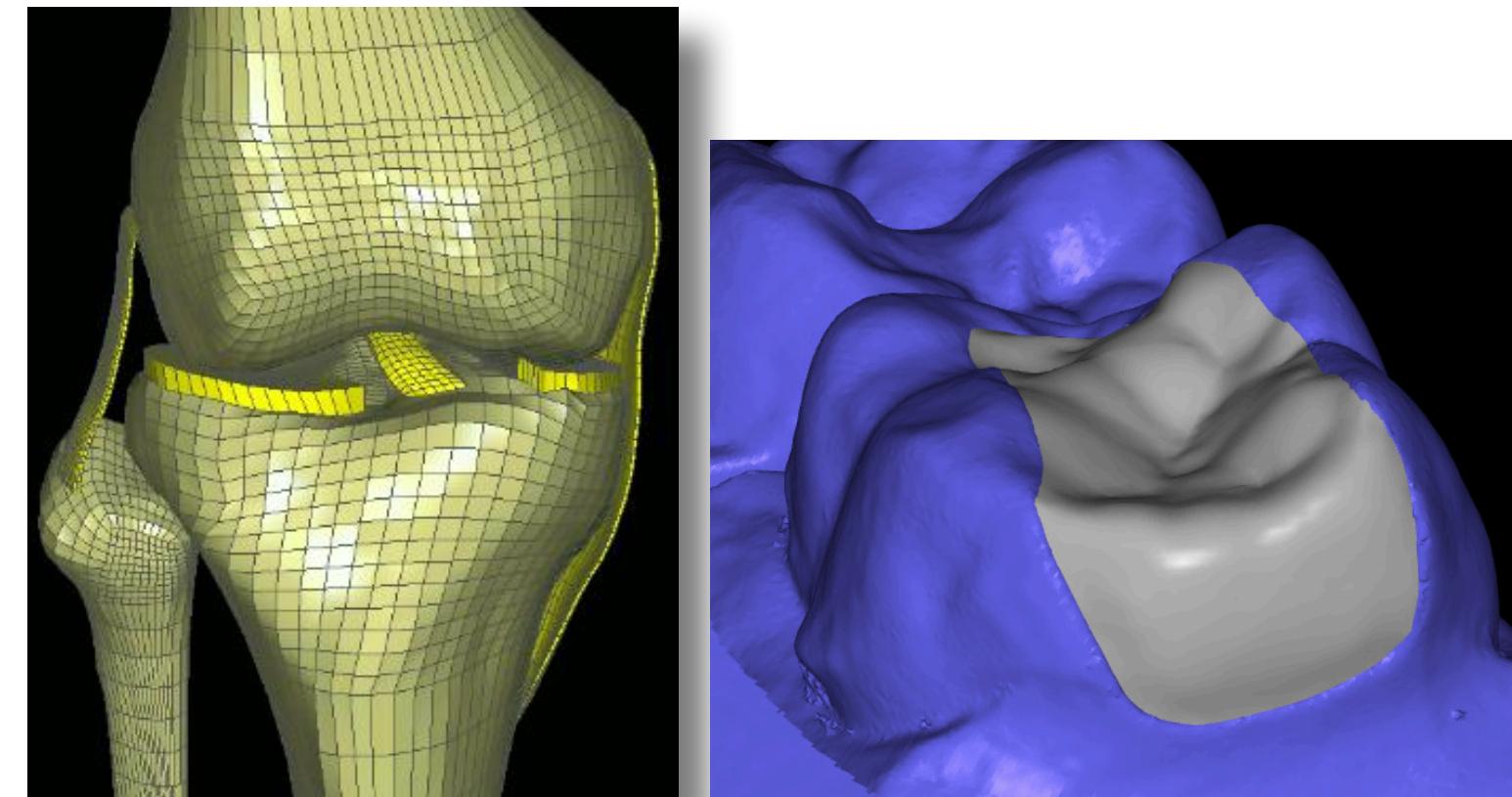
Geometric Modeling and Processing

- Modeling: representing shapes in a computer
 - Querying
 - Rendering
 - Interaction
- Processing: algorithms acting on digital shapes
 - Build: Generate, acquire & reconstruct
 - Modify: Smooth, repair, re-encode, refine, simplify
 - Manipulate: Parametrize, deform, animate

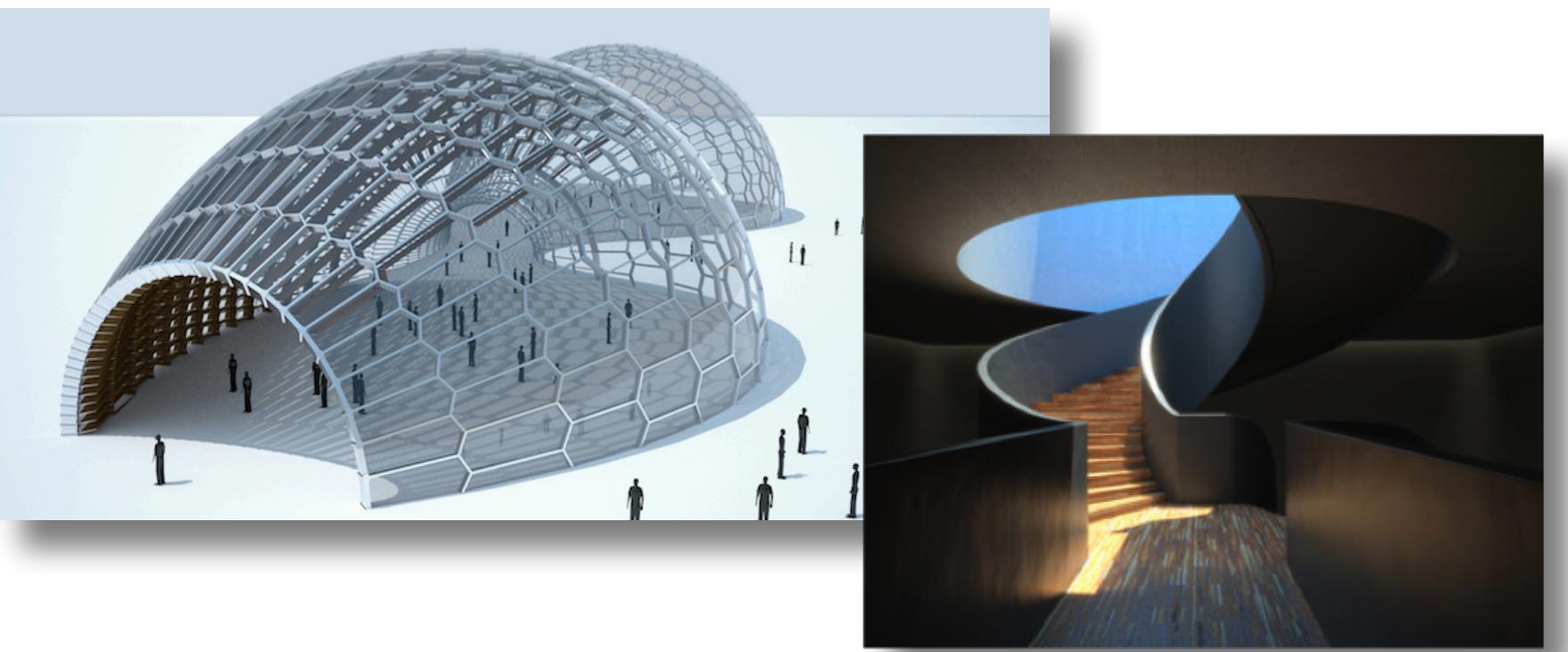
Applications



Product design and prototyping



Medicine, prosthetics

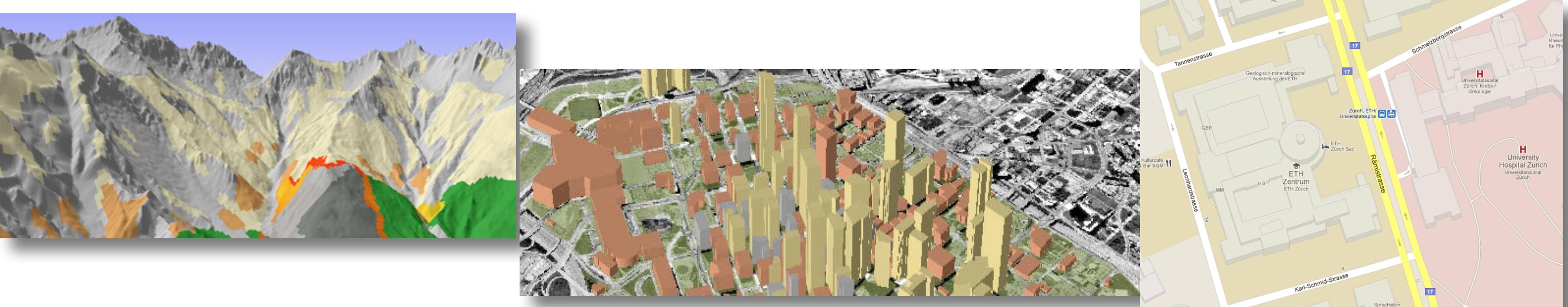


Architecture



Cultural heritage

Applications



Geographical and urban systems

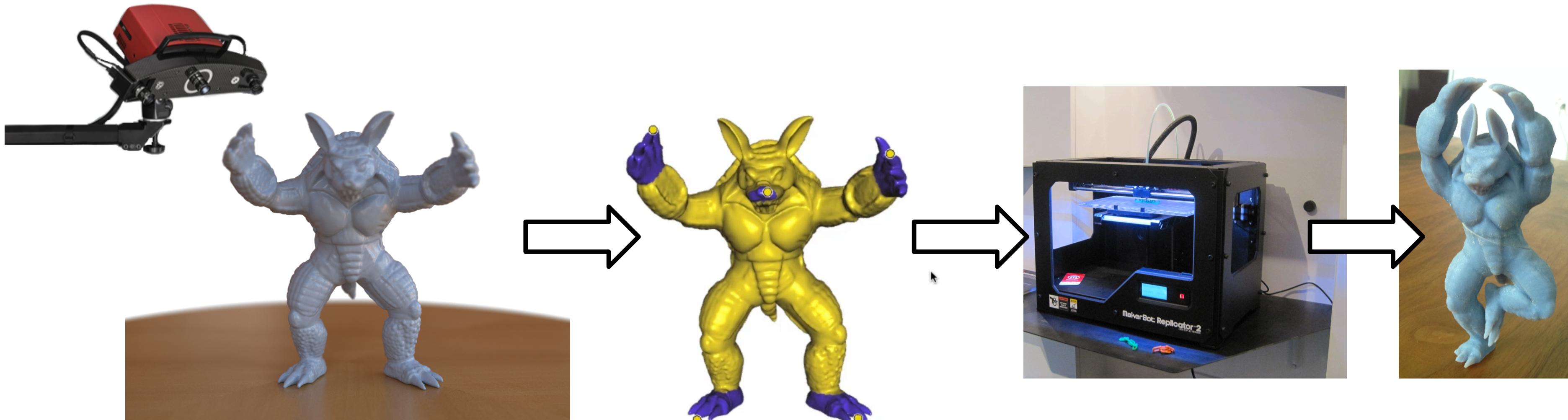


[Bickel et al., ACM SIGGRAPH 2010]

Manufacturing, 3D Printing

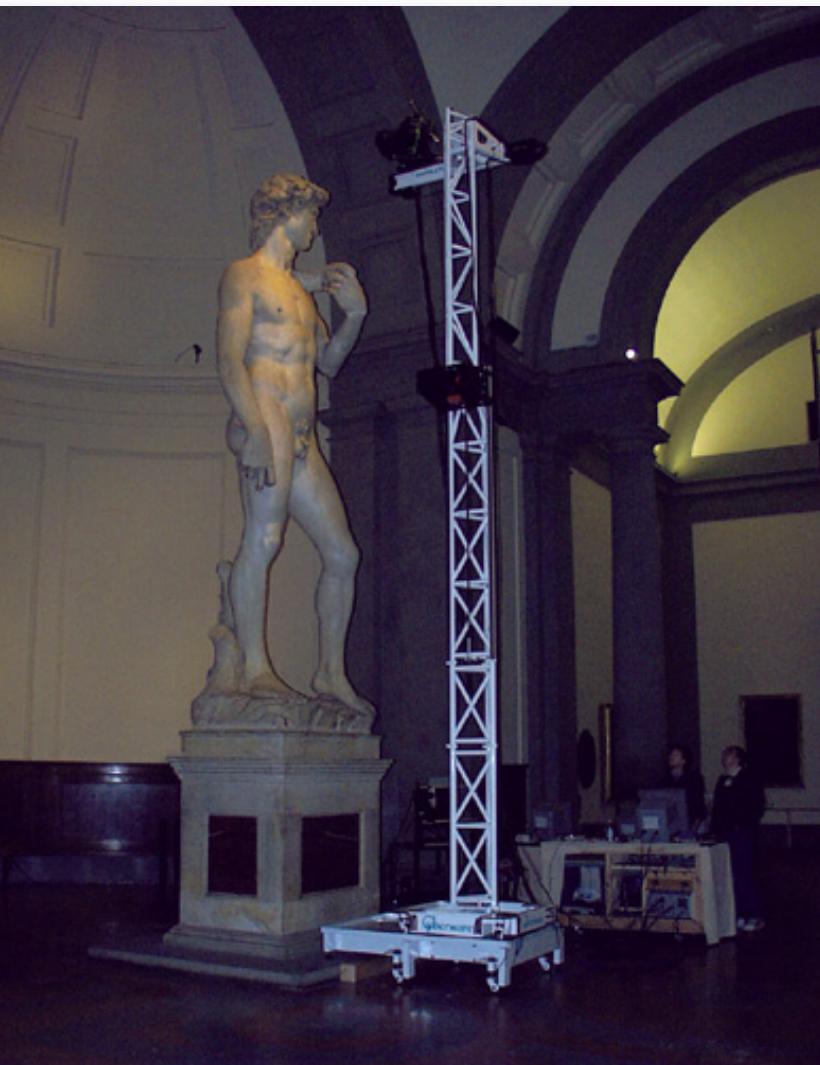
Fabrication

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



Digital Geometry Processing (DGP)

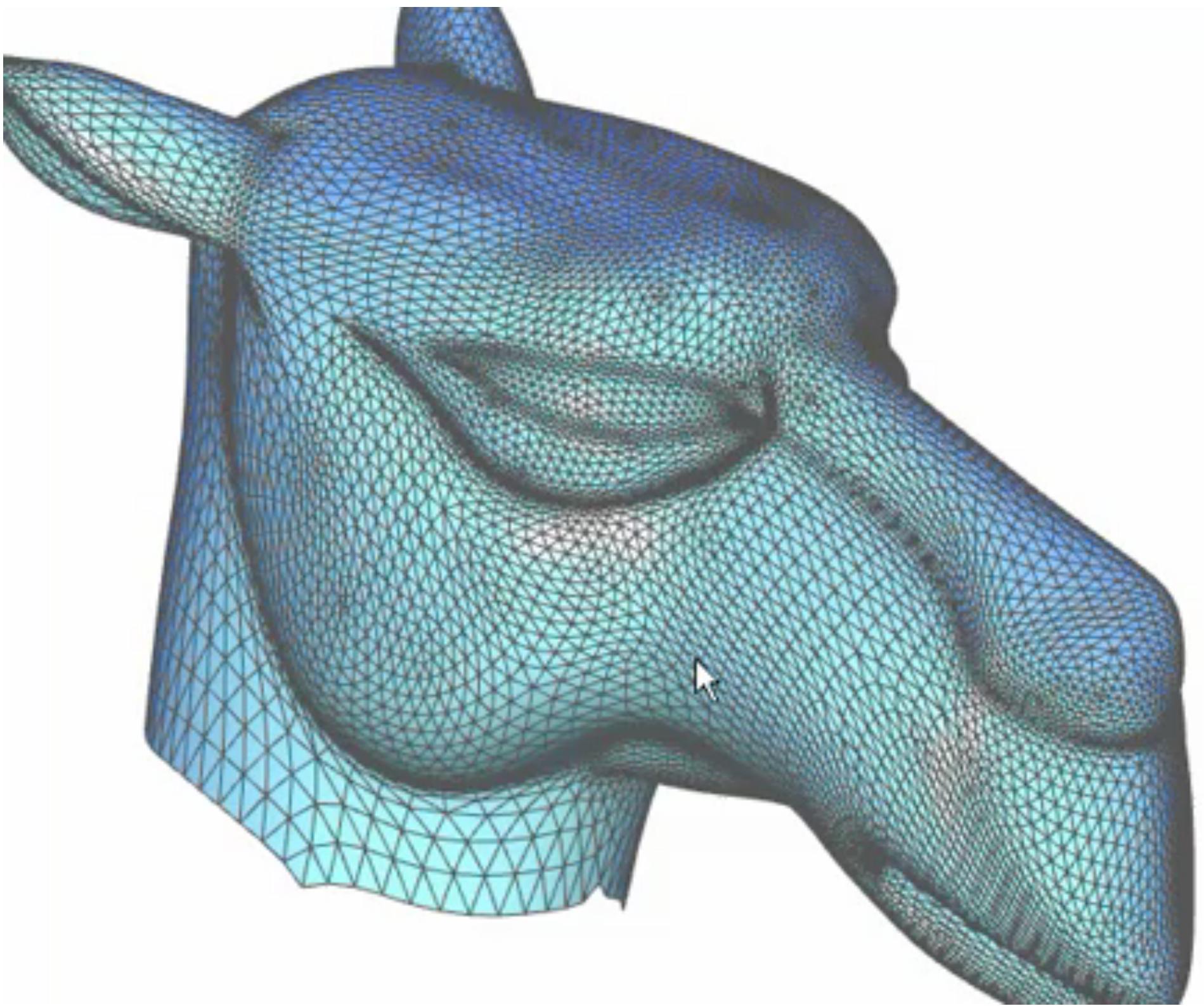
- Processing of discrete (polygonal mesh) models
- Why discrete?
 - Simplicity – ease of description
 - Efficiently rendered by graphics hardware
 - Output of most acquisition tools (CT, MRI, LIDAR, Kinect...)
 - Input to most simulation/analysis tools (FE solvers)



Copyright: The Digital Michelangelo Project

Interactive Shape Modeling

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



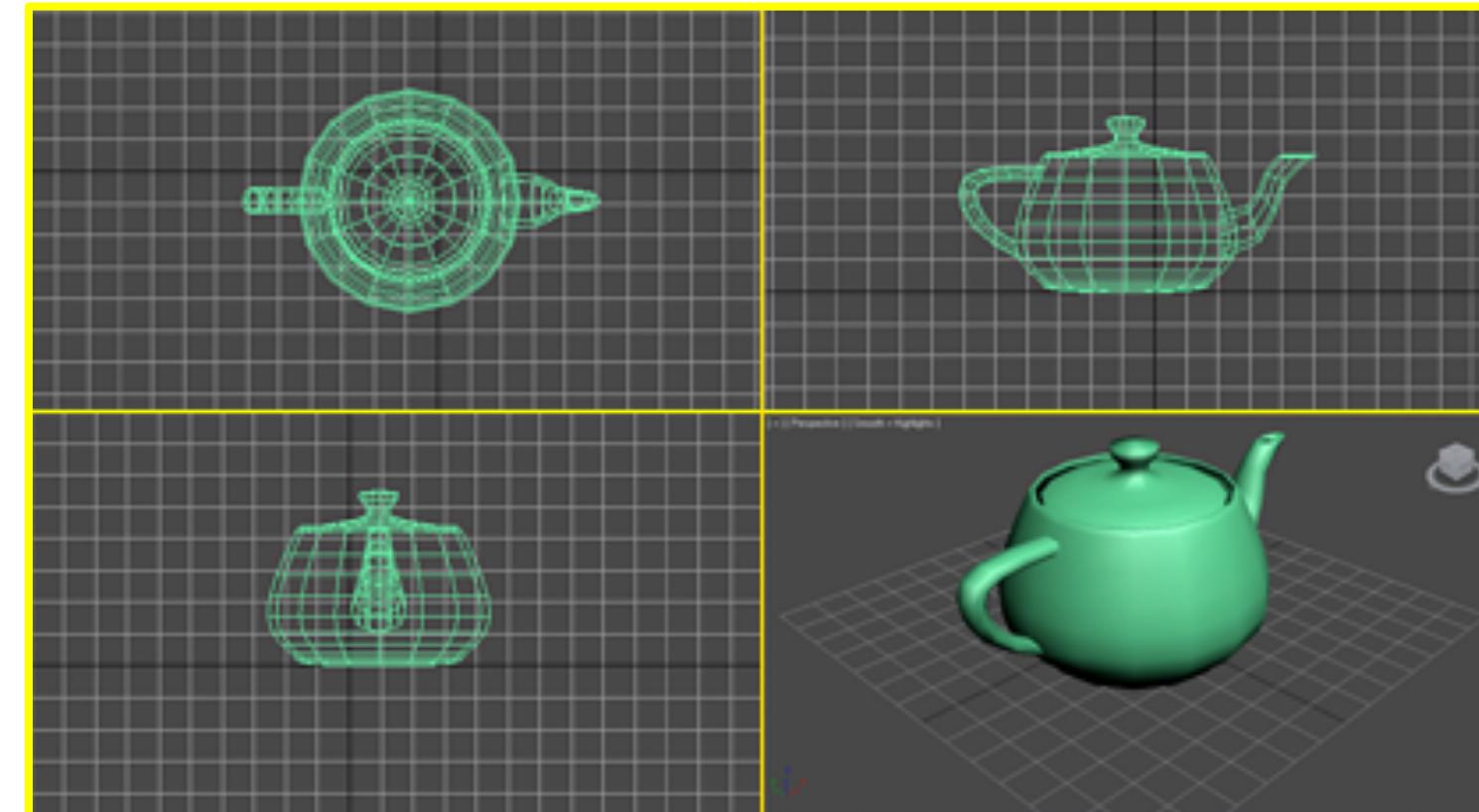
<http://youtu.be/EMx6yNe23ug>

Digital Shape Modeling

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



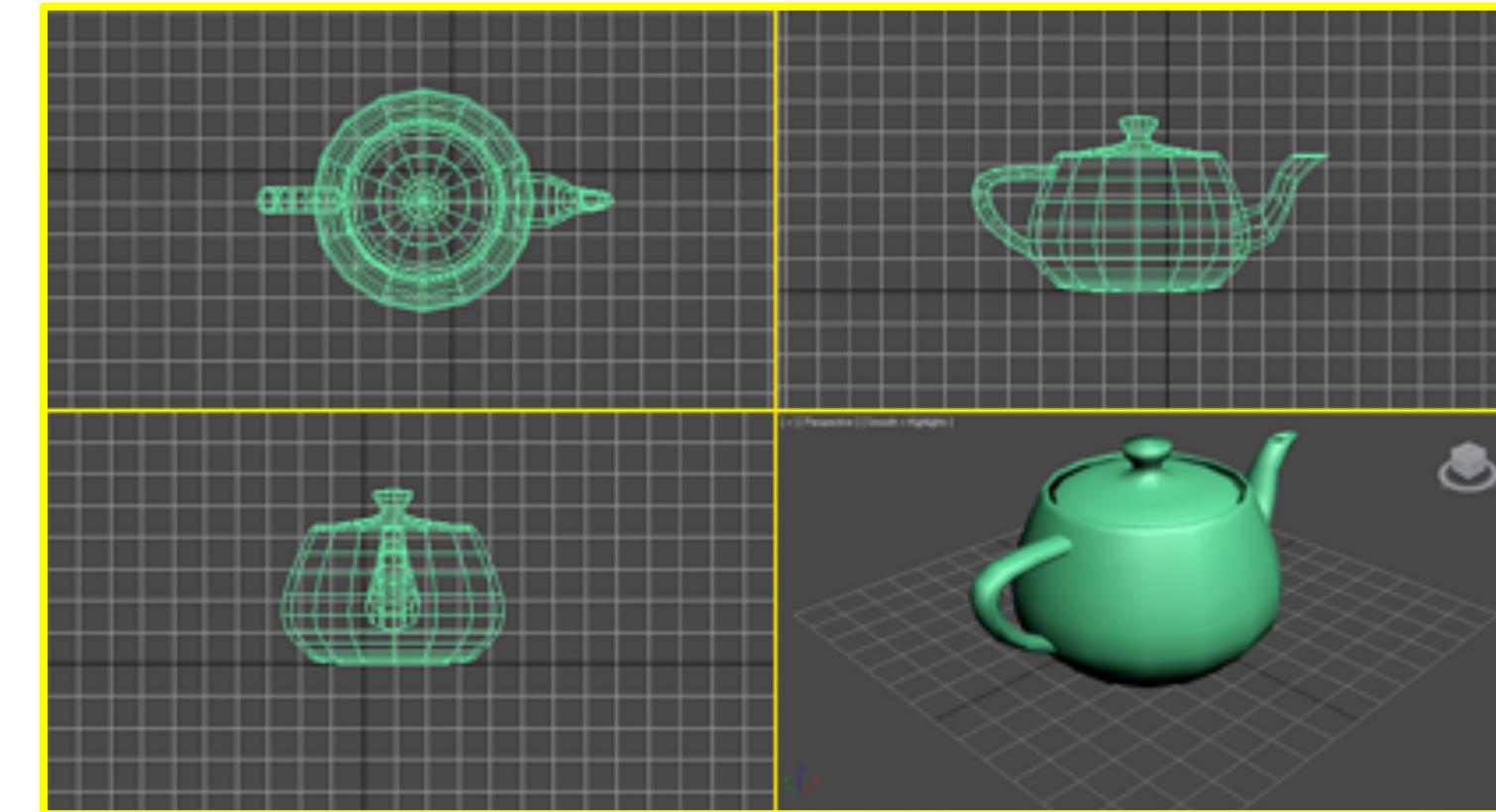
Humans have no direct
“video out”



“Translation” from 2D to
3D is hard

Digital Shape Modeling

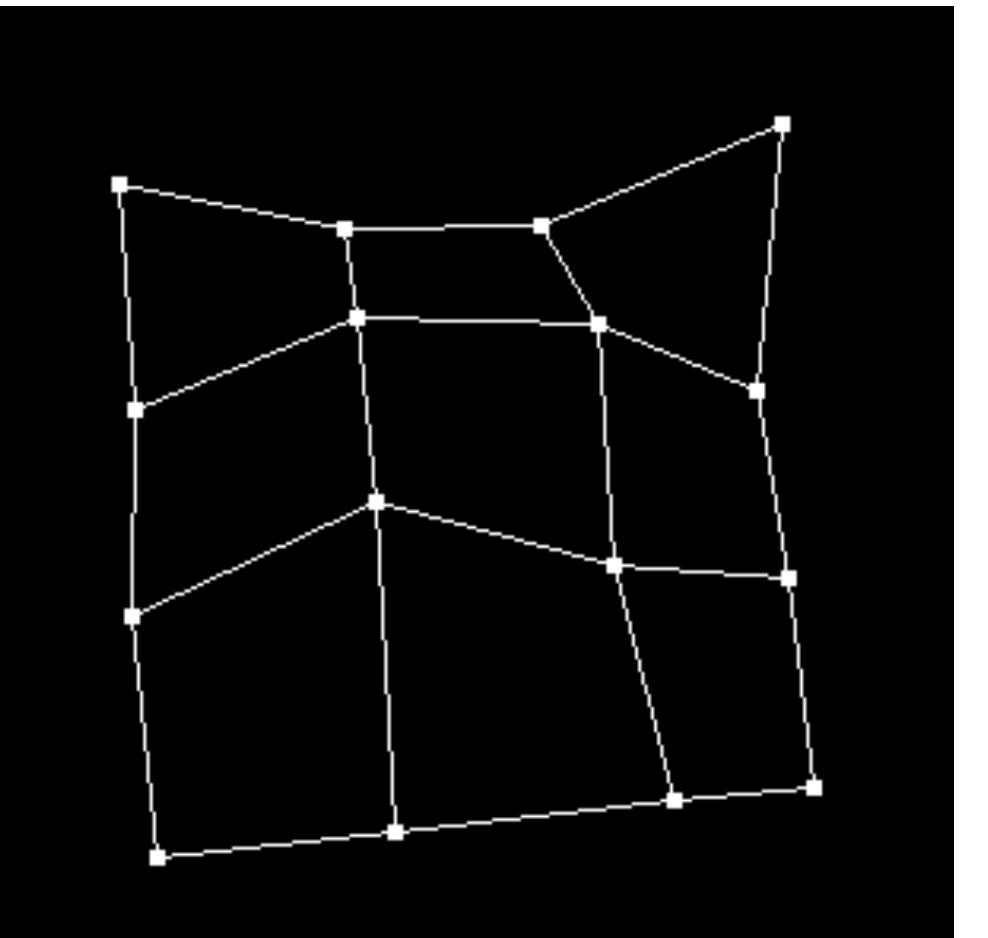
- How do shapes find their way into computers?
 - Geometric modeling is difficult



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

Computer-Aided Geometric Design

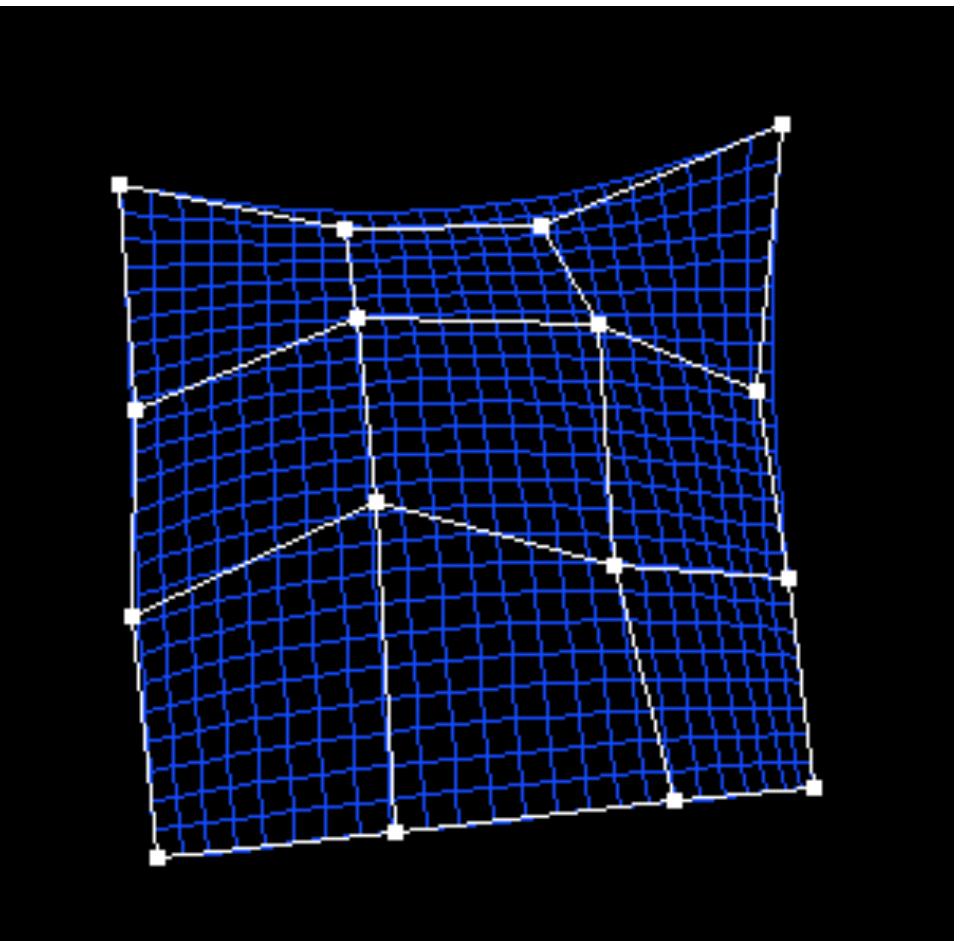
- Traditional pipeline for modeling shapes from scratch



User defines a layout
of surface patches
and control points

Computer-Aided Geometric Design

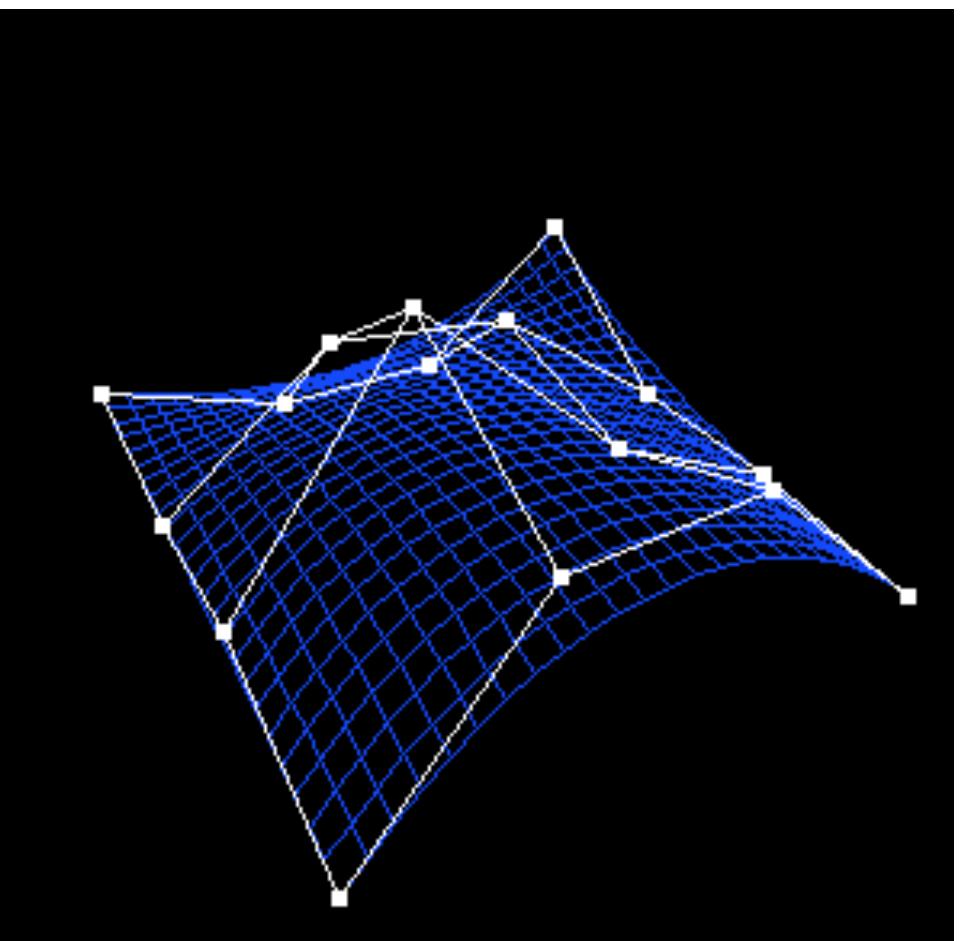
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User defines a layout
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Computer-Aided Geometric Design

- Traditional pipeline for modeling shapes from scratch

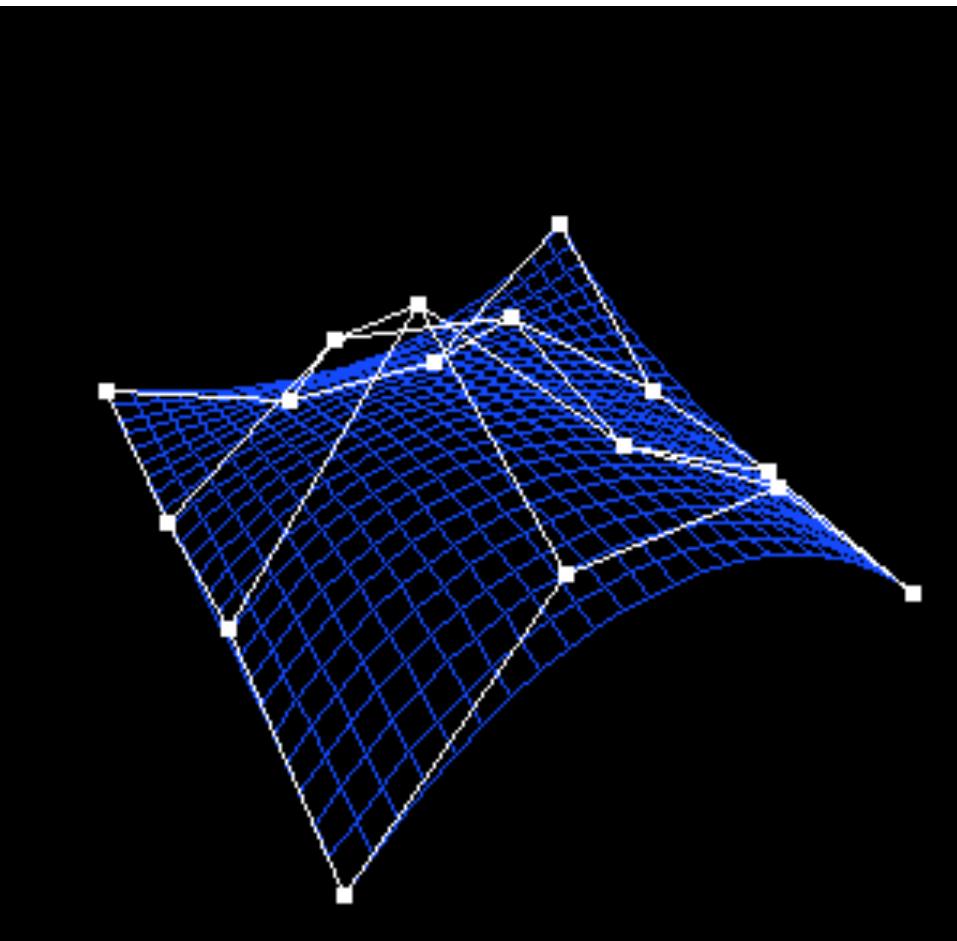


User defines a layout
of surface patches
and control points

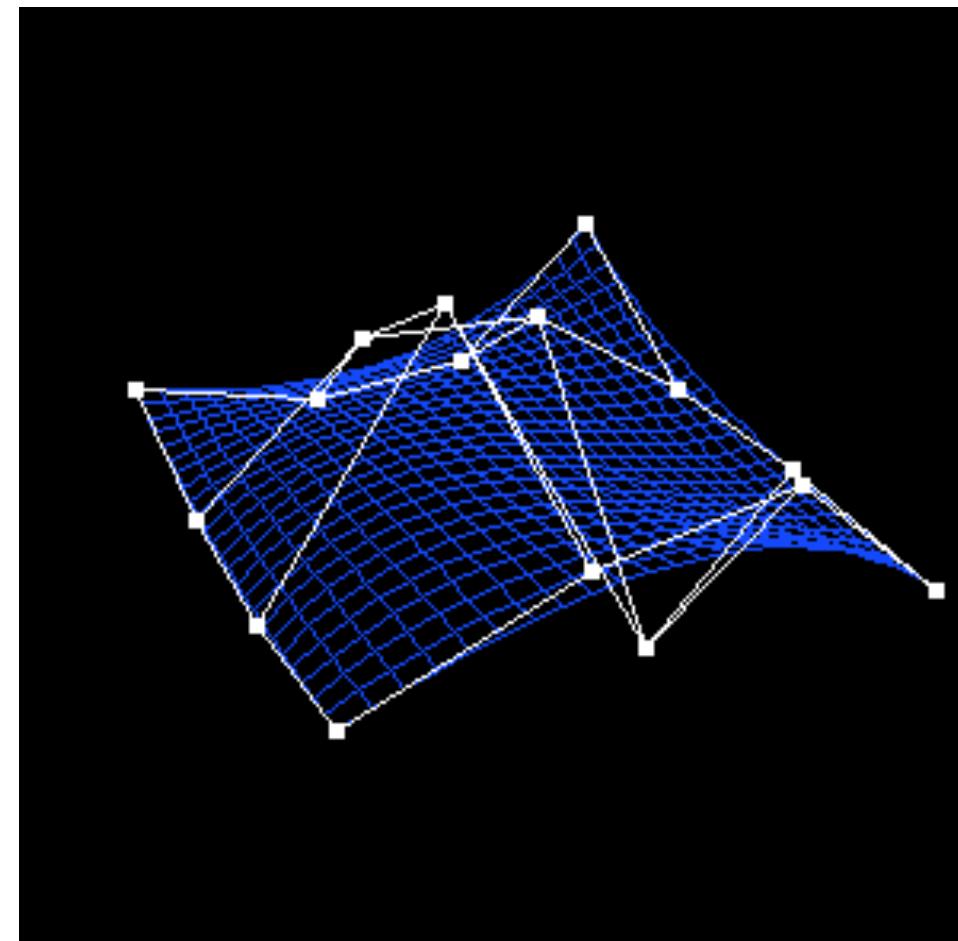
Editing is performed
by moving control
points and/or
prescribing tangents

Computer-Aided Geometric Design

- Traditional pipeline for modeling shapes from scratch



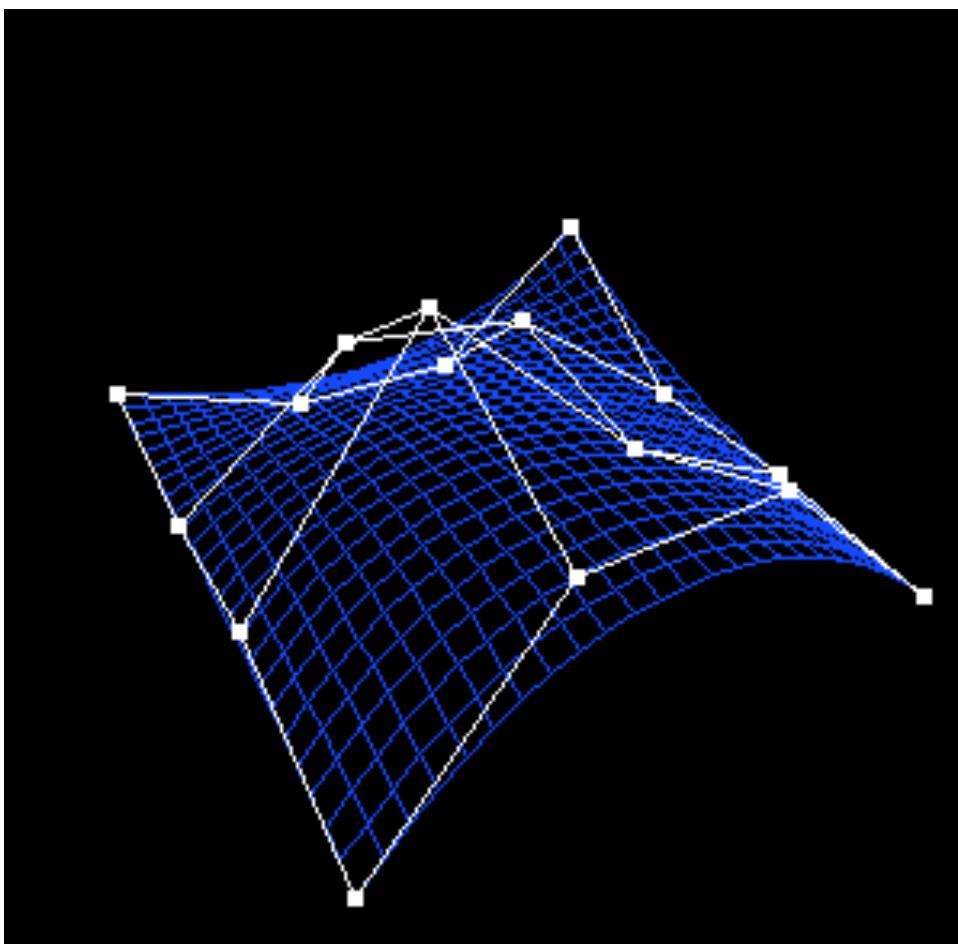
User defines a layout
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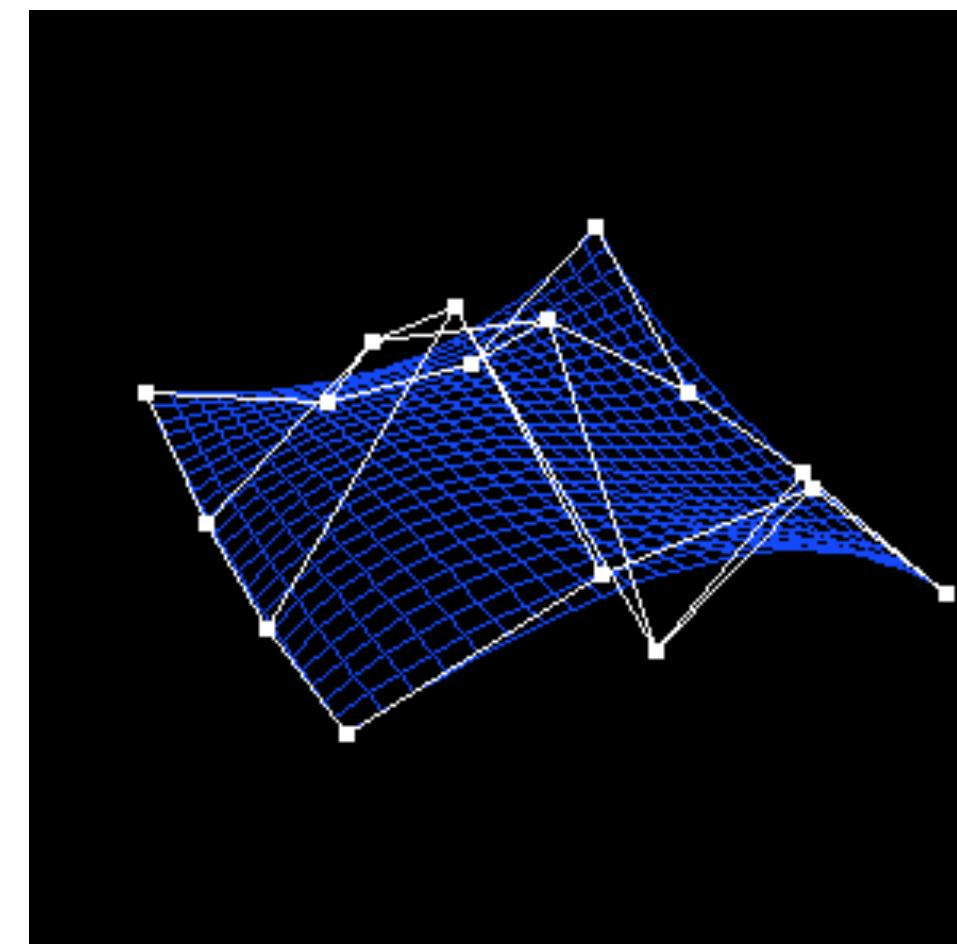
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Computer-Aided Geometric Design

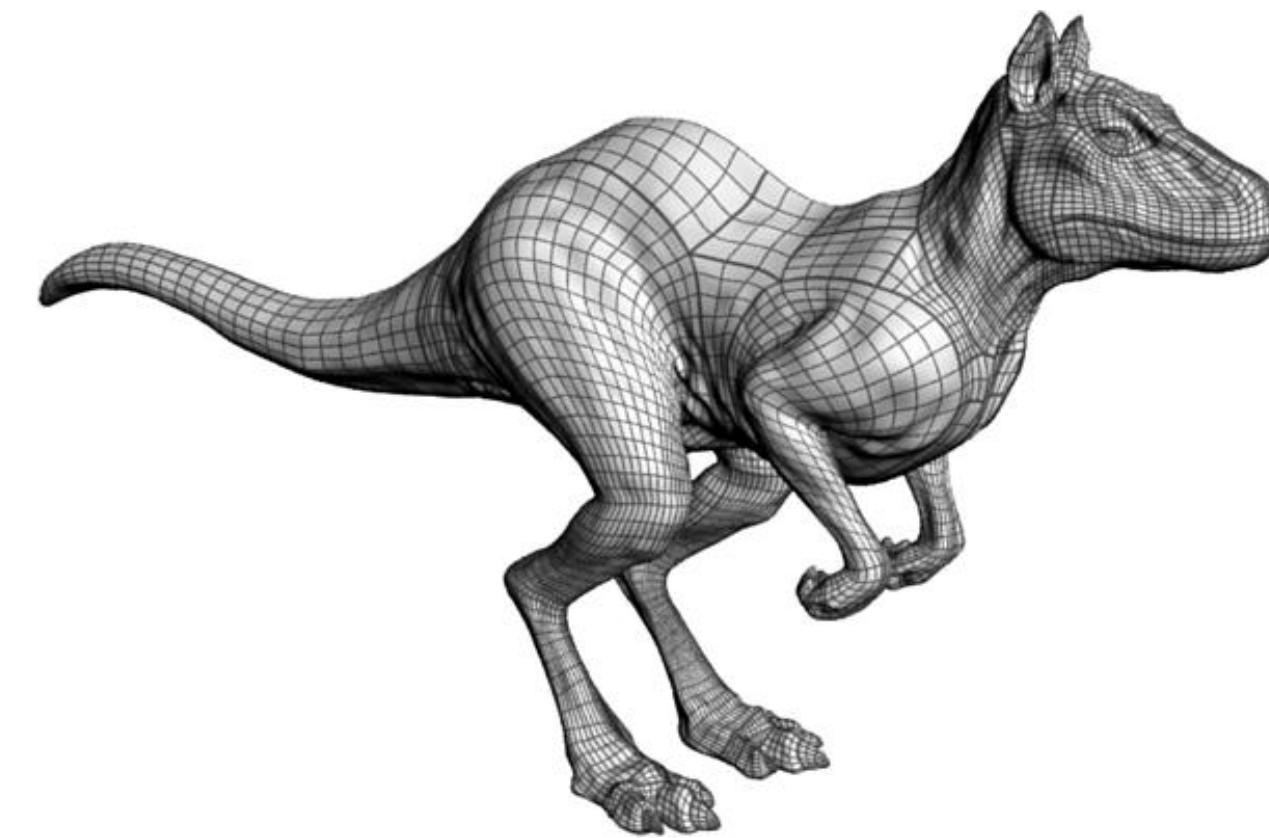
- Traditional pipeline for modeling: shapes from scratch



User defines a layout
of surface patches
and control points



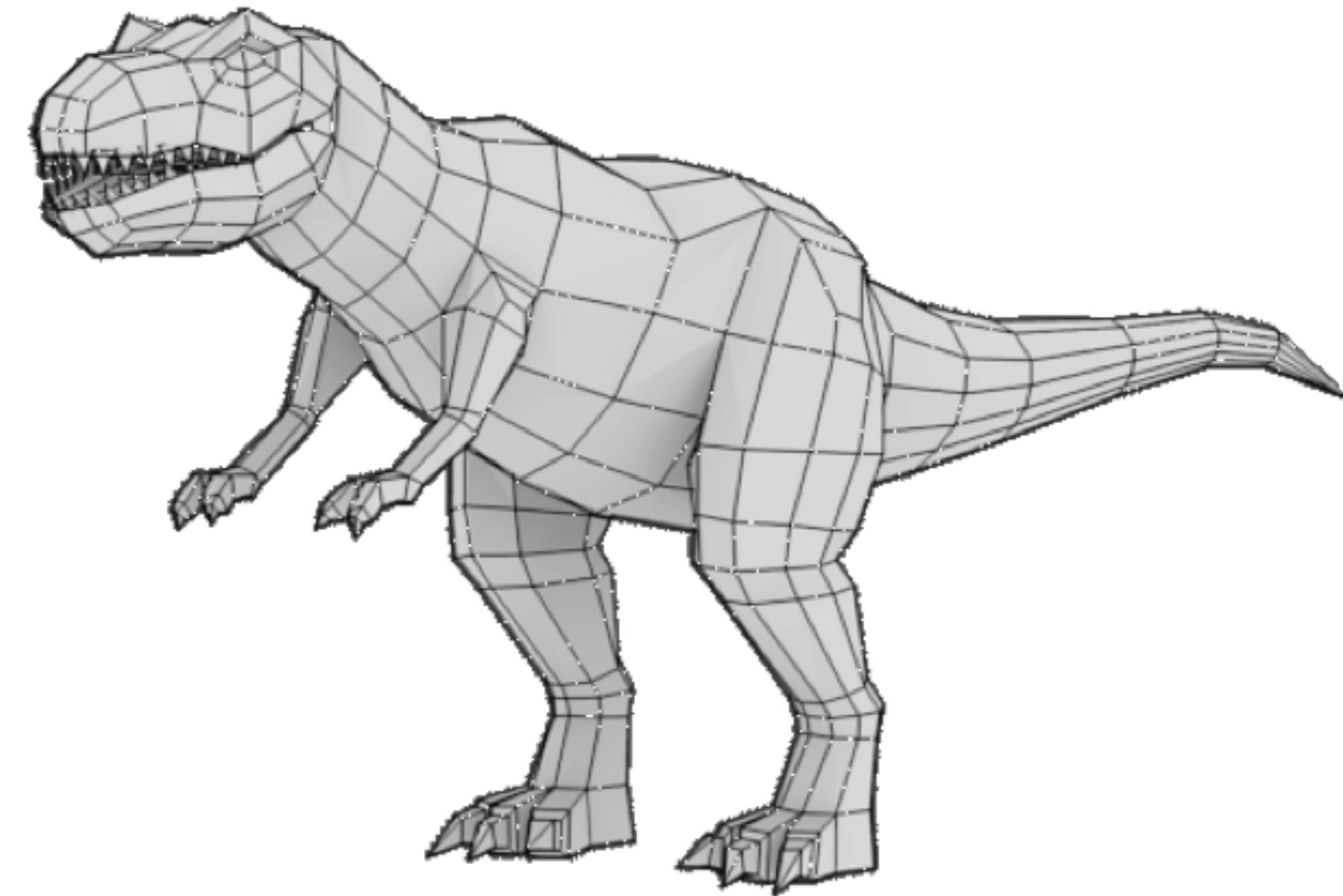
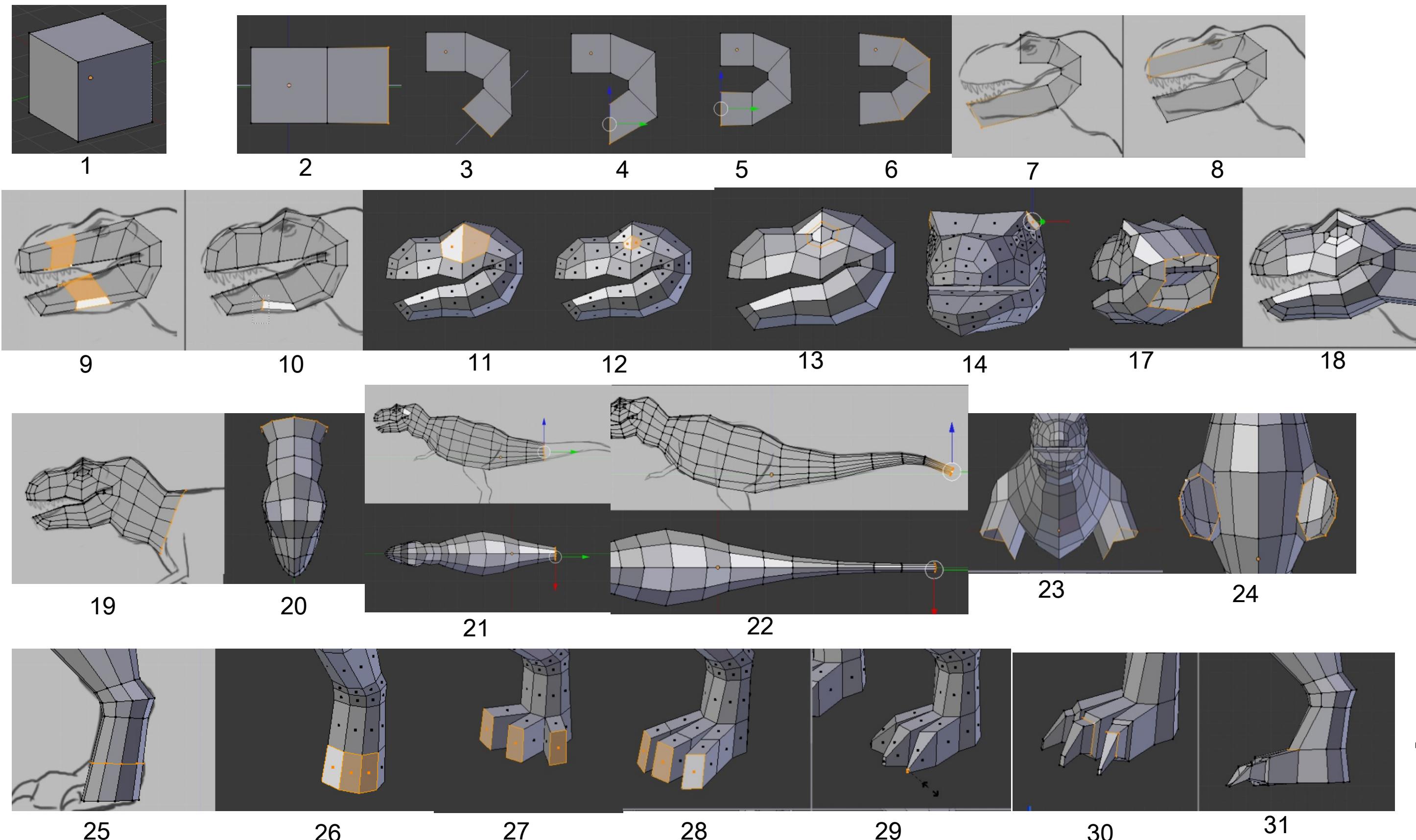
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Patch-based
construction of a surface

Computer-Aided Geometric Design

- Low polygonal modeling:
control structure coincident with surface



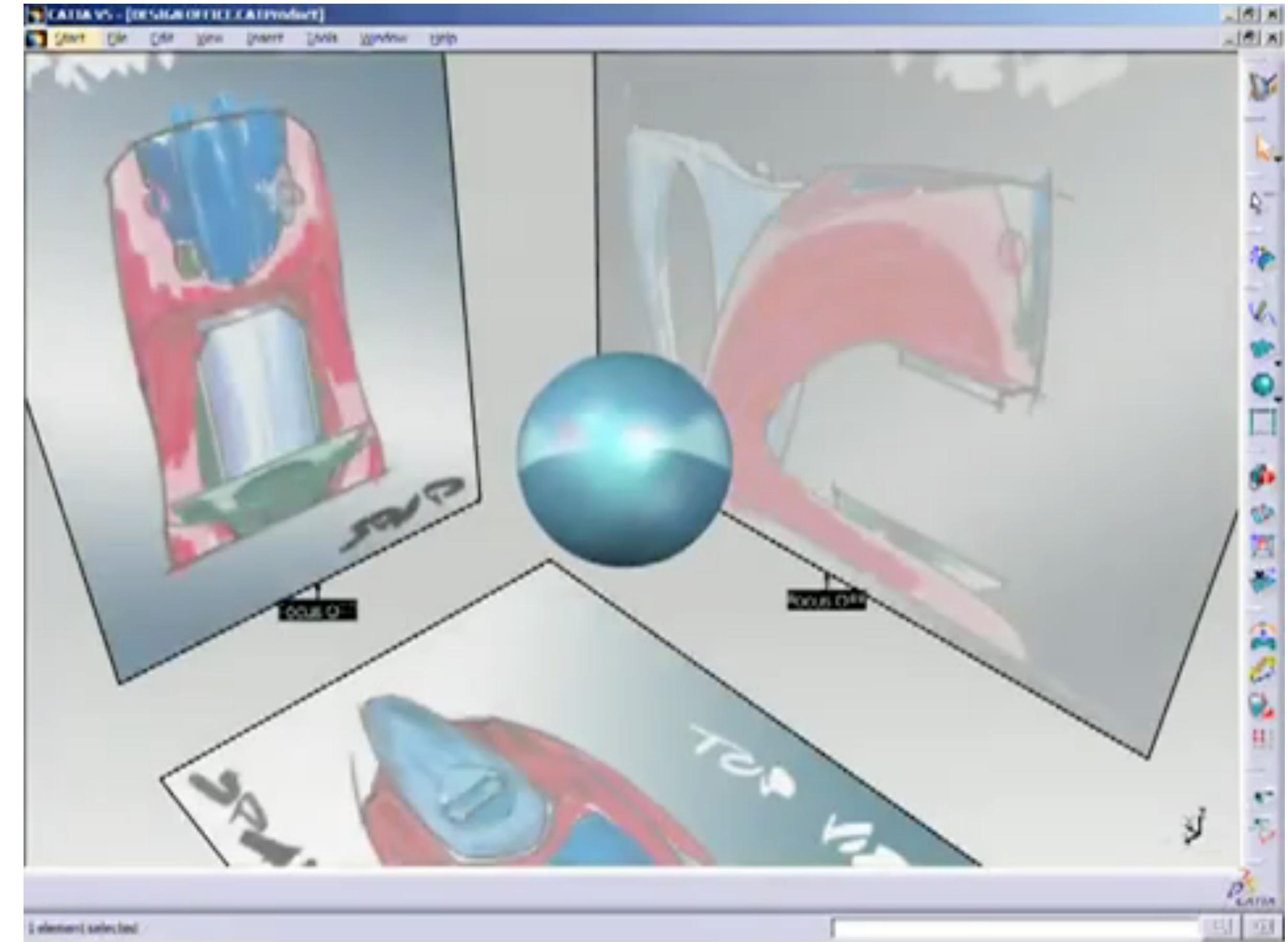
Blender Demo



<https://www.youtube.com/watch?v=sGx0ui3j7mM>

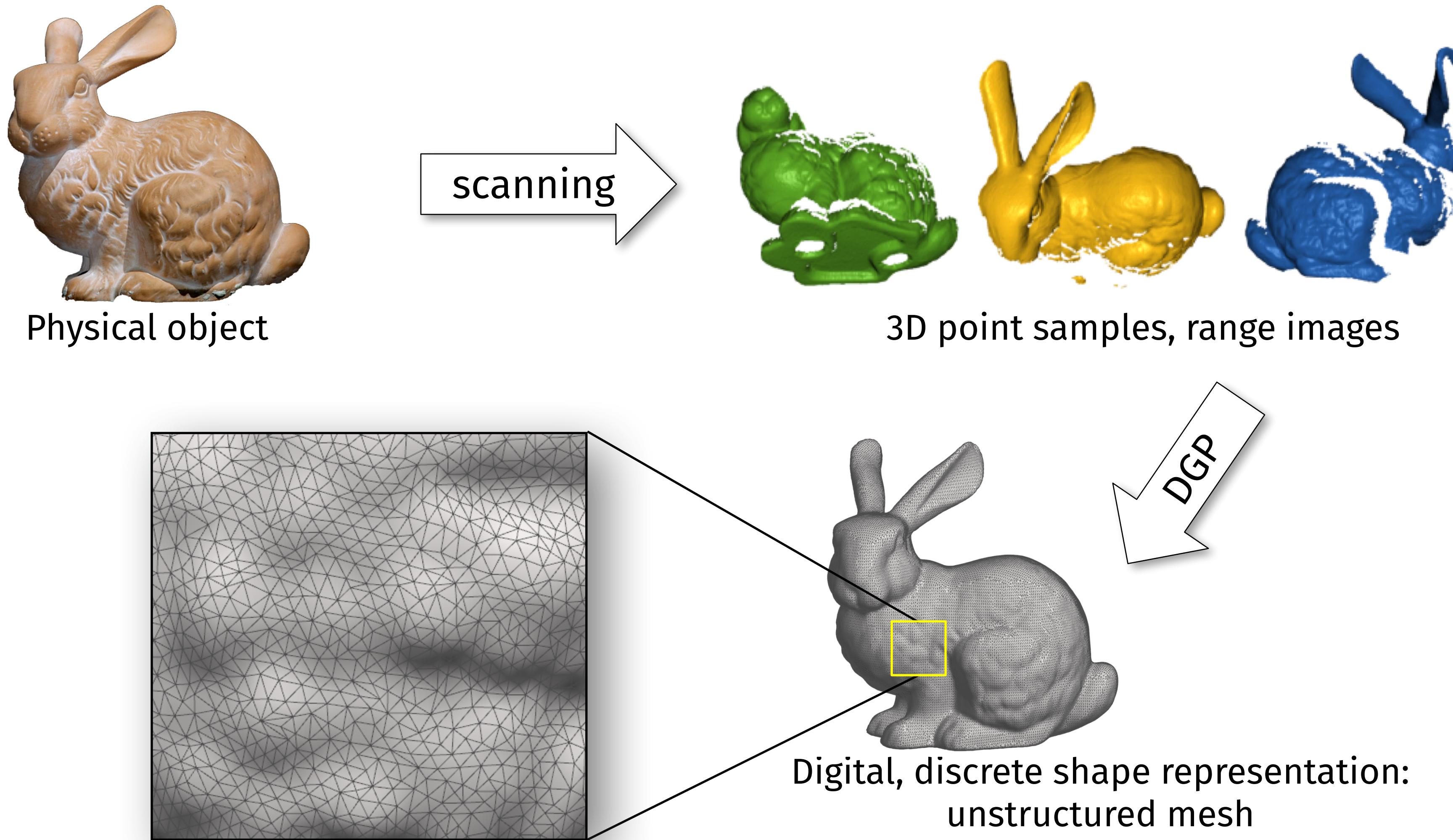
Computer-Aided Geometric Design

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



CATIA, Dassault Systems

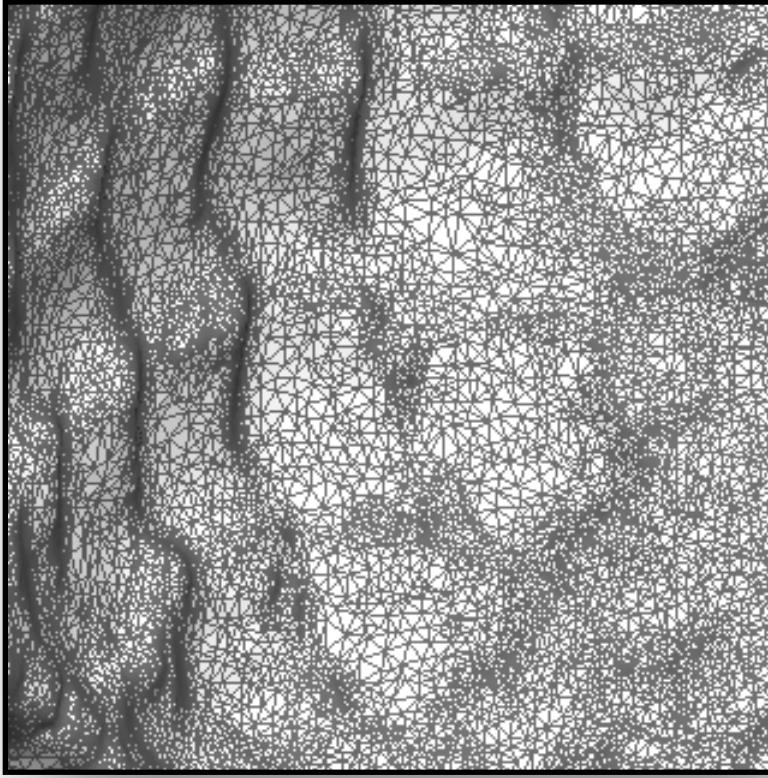
Modern Geometry Acquisition Pipeline



The Stanford Bunny, Stanford 3D Scanning Repository

Unstructured Digital Shapes

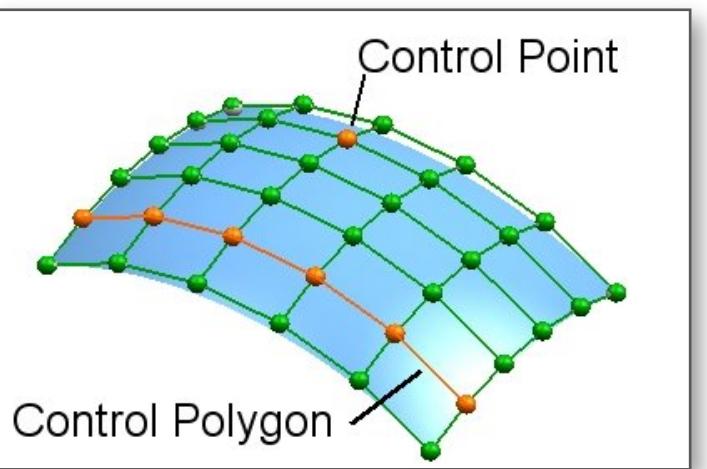
- How to **edit** and **animate**?
- How to convert to a **structured representation**?
- Computational challenge:
very large amounts of data,
yet modeling has to remain
interactive



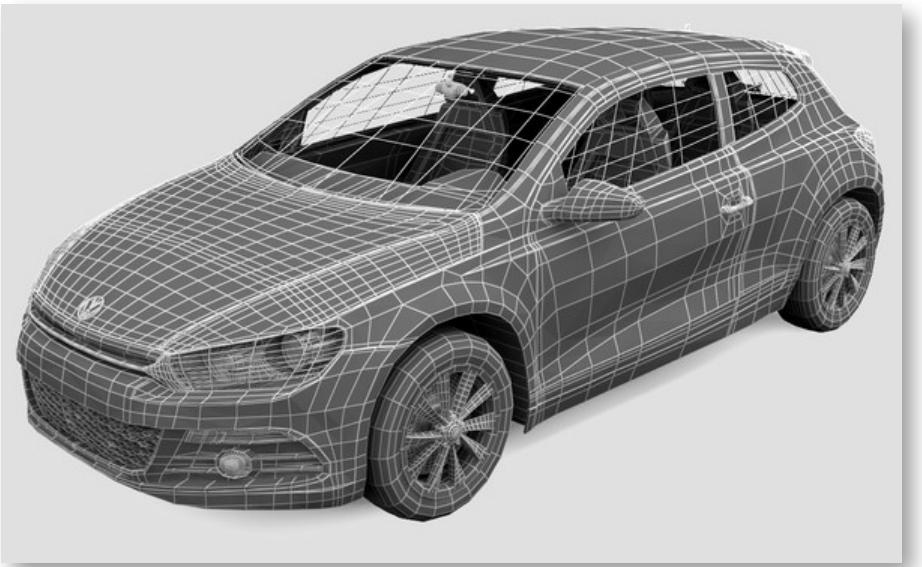
Thai statue, 10M triangles, Stanford 3D Scanning Repository

Traditional CAD vs Modern Mesh Modeling

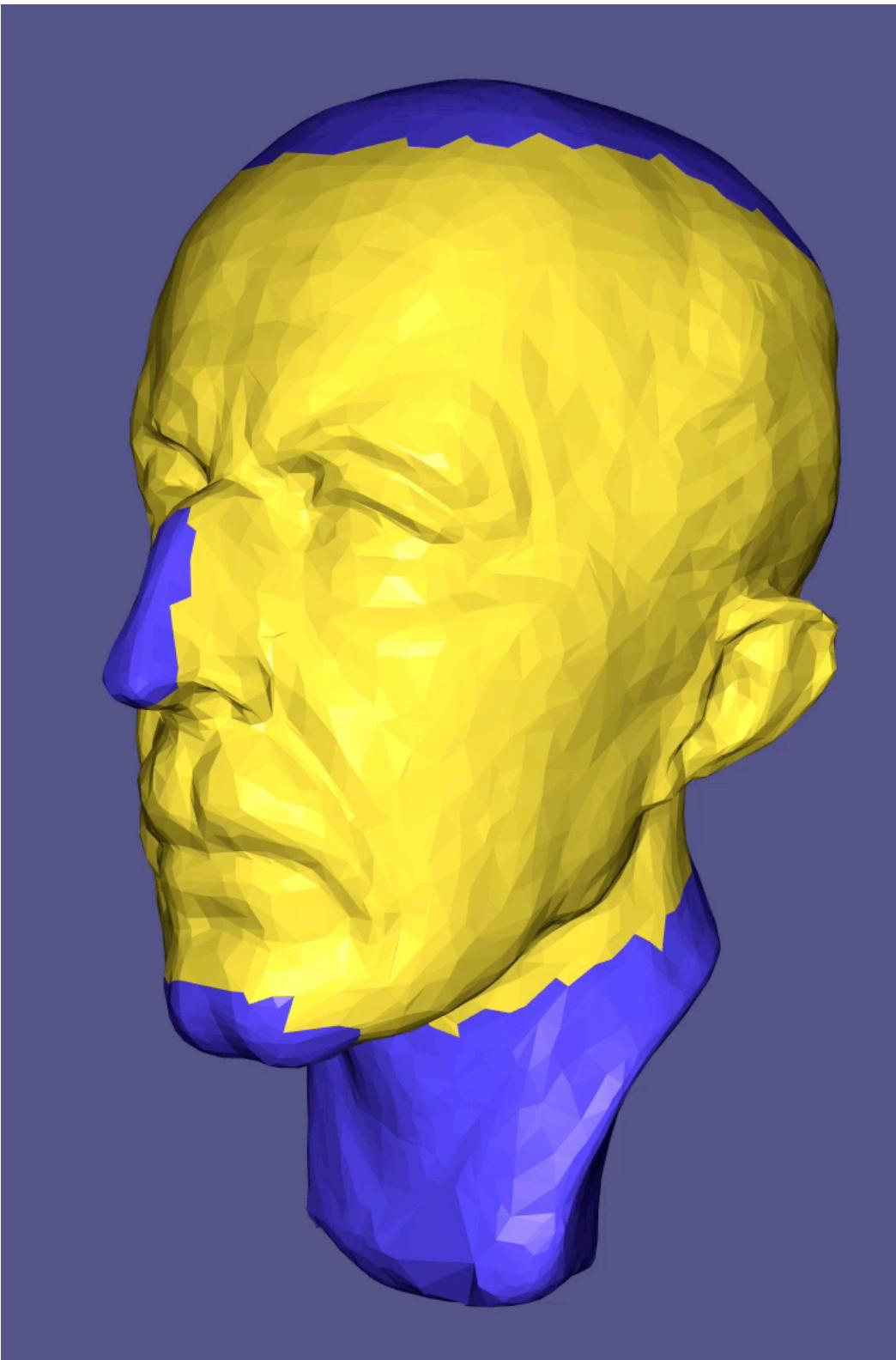
Traditional CAD



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



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 bases, points, vectors, matrices and linear systems, the course will be difficult 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.
- AulaWeb
 - will be used to distribute course material and to submit your homework

Organization

- Communication through the AulaWeb course module (forum)
- Mail for private communication only
- Weekly lectures: on Aulaweb main page
- Office hours: take an appointment

Lectures

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

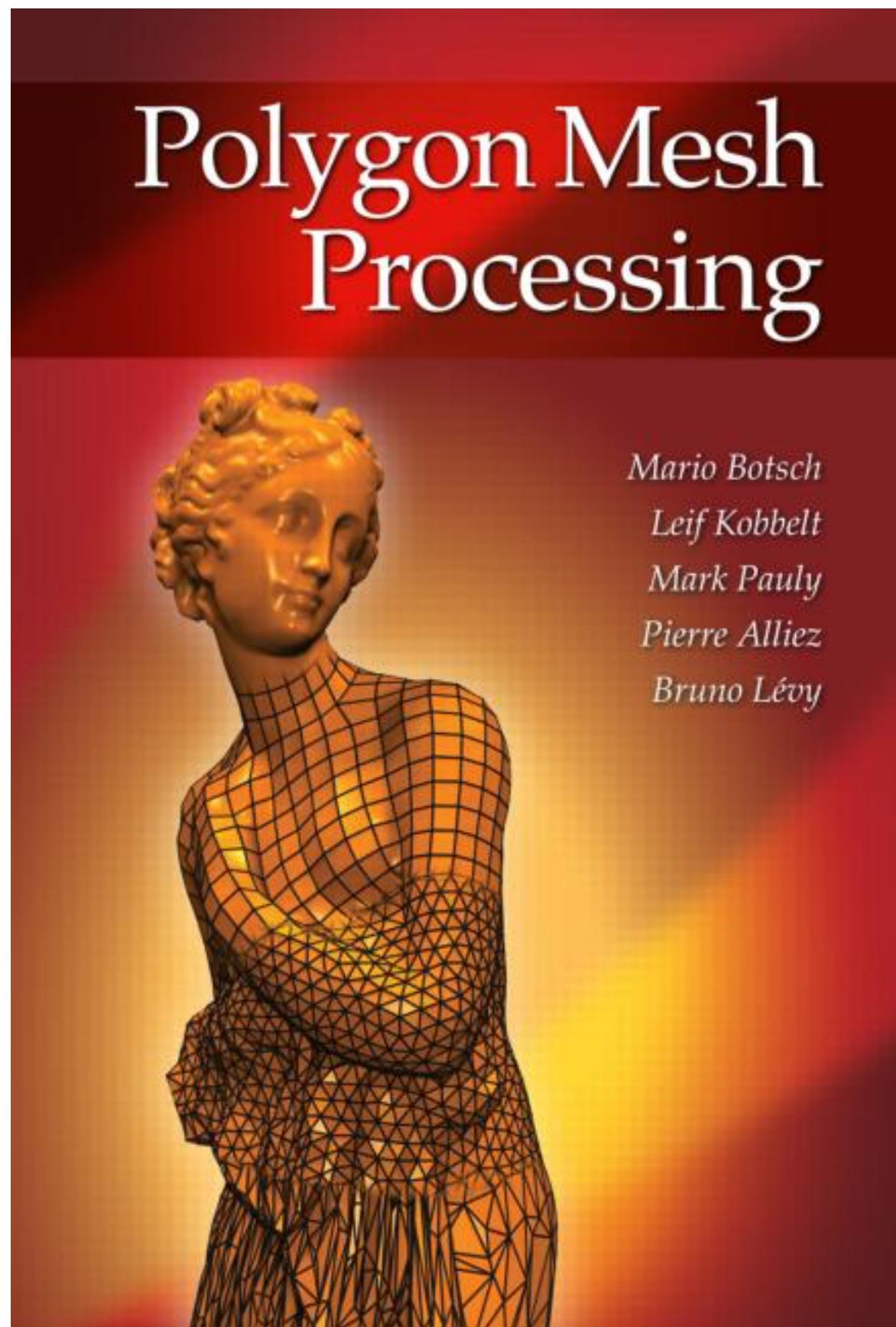
Lectures

- **Please interrupt me at any time to ask questions**

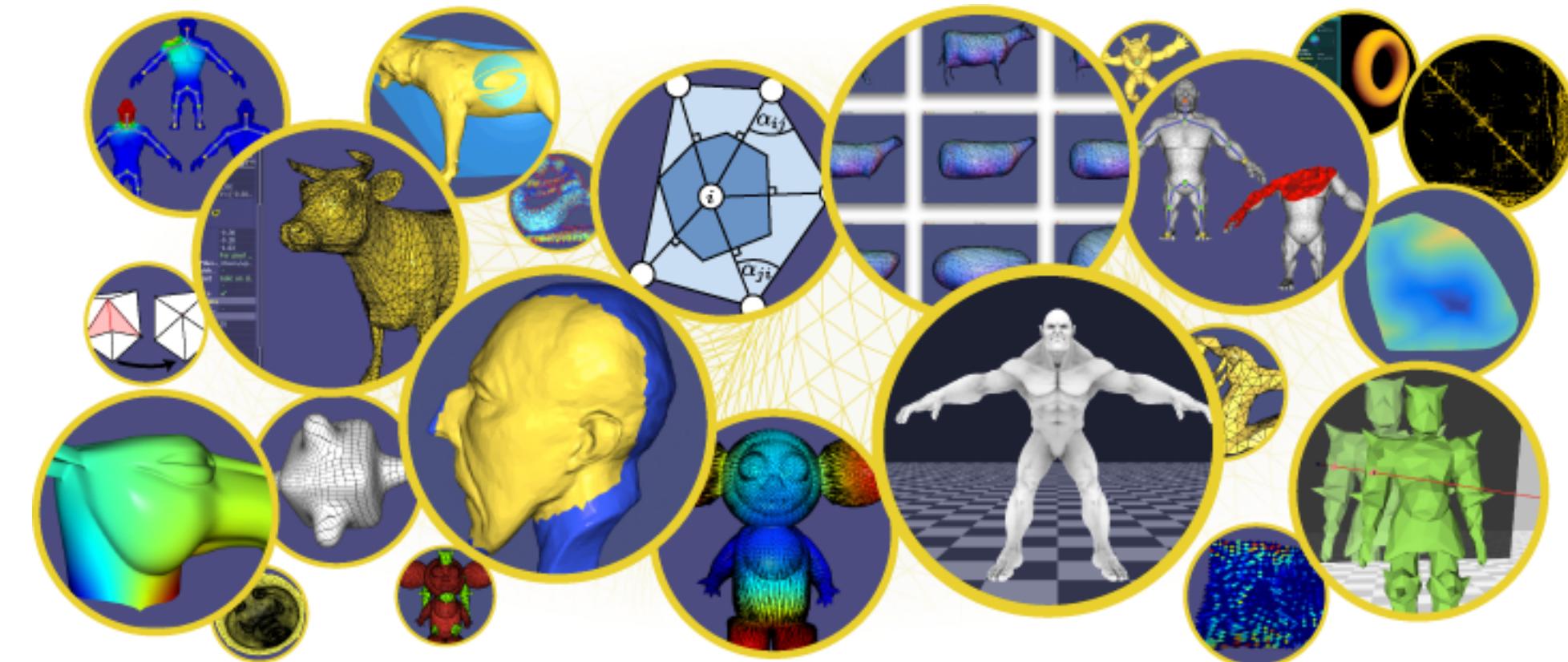
Coding: Homework & Final Project

- Assignments during semester: small work, hard deadlines, **strictly individual work**
- Group project (2 people): 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



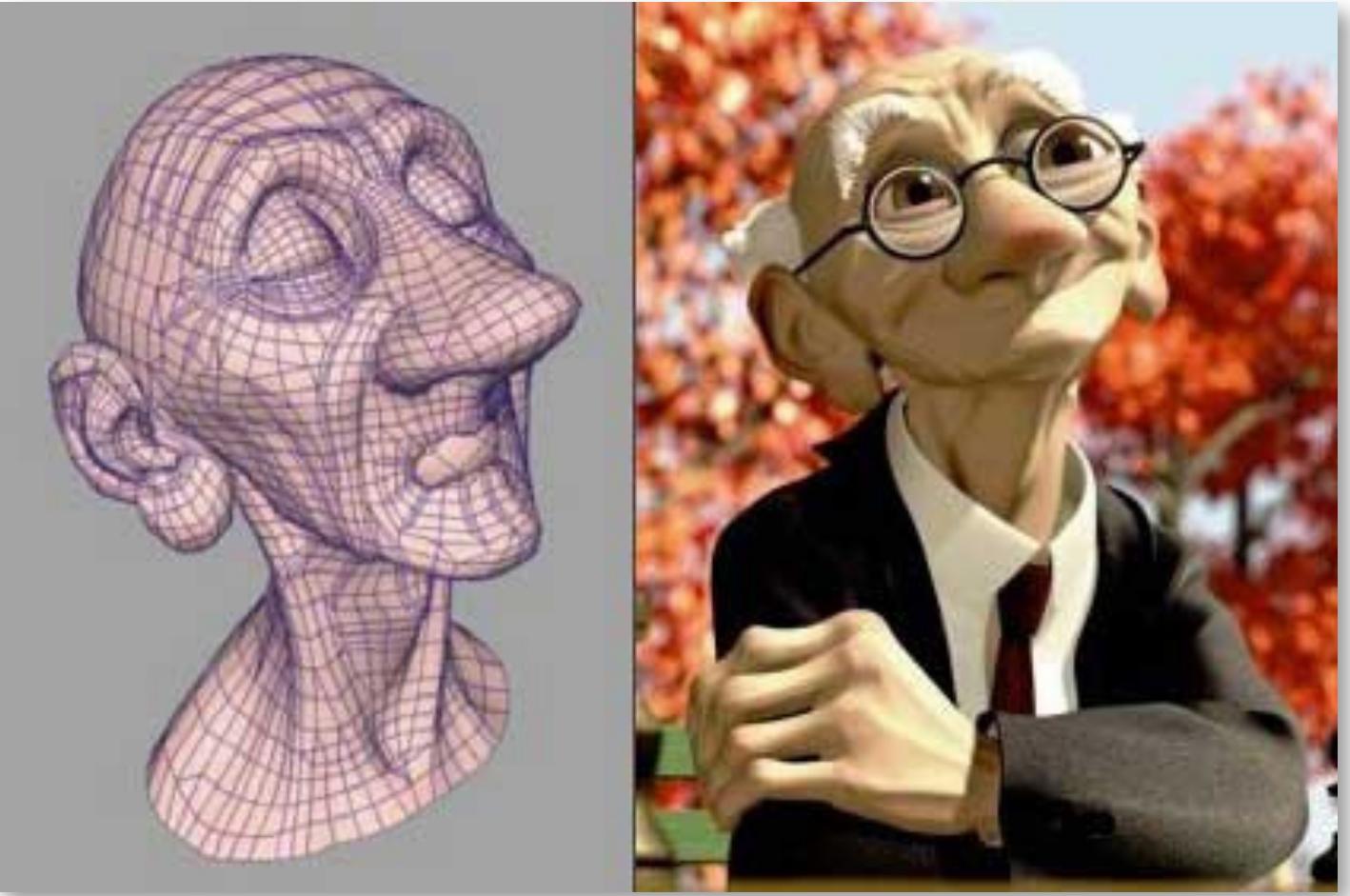
<https://libigl.github.io/libigl-python-bindings/>



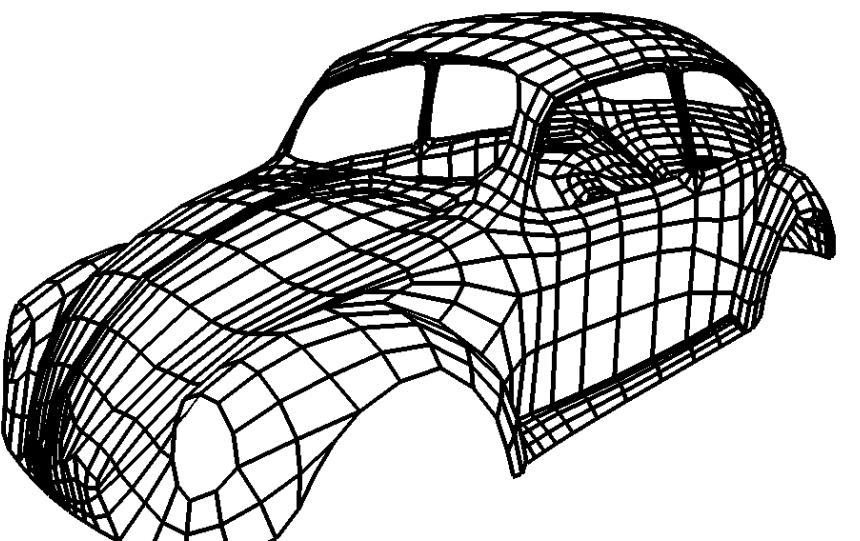
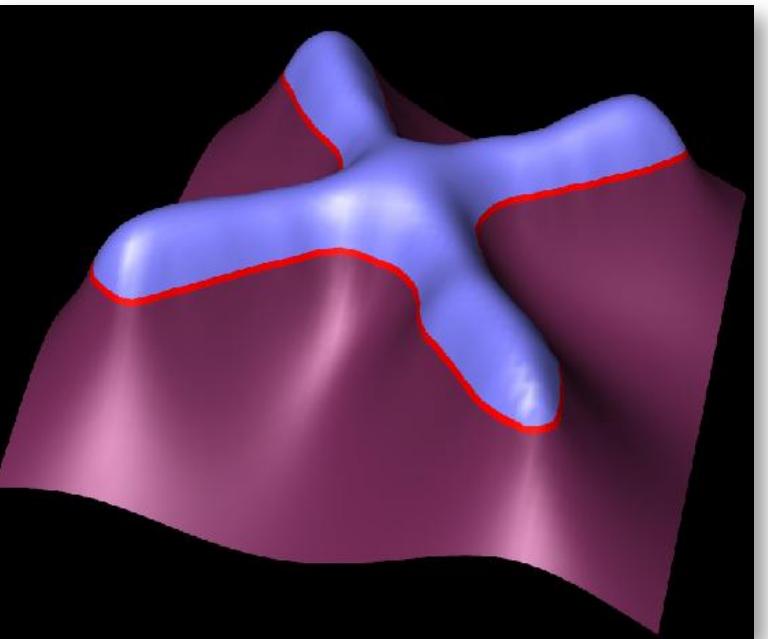
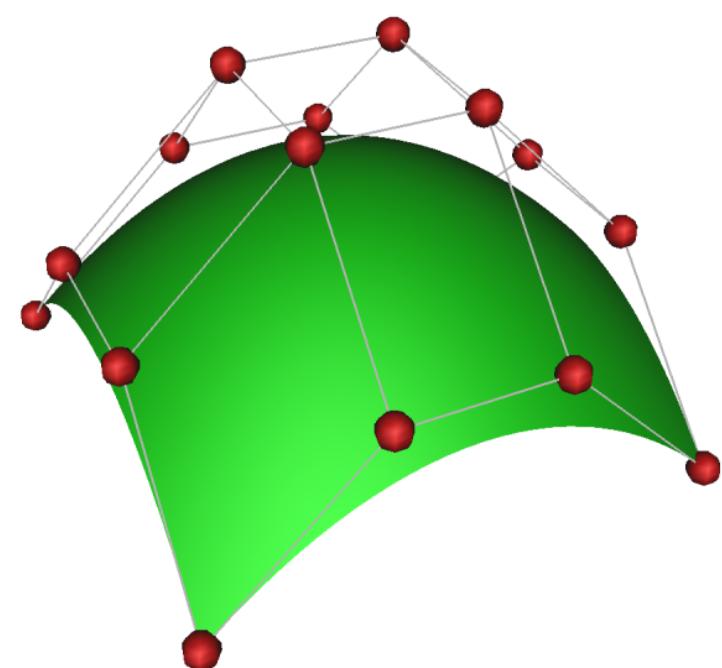
<https://www.wikipedia.org>

Course Topics

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

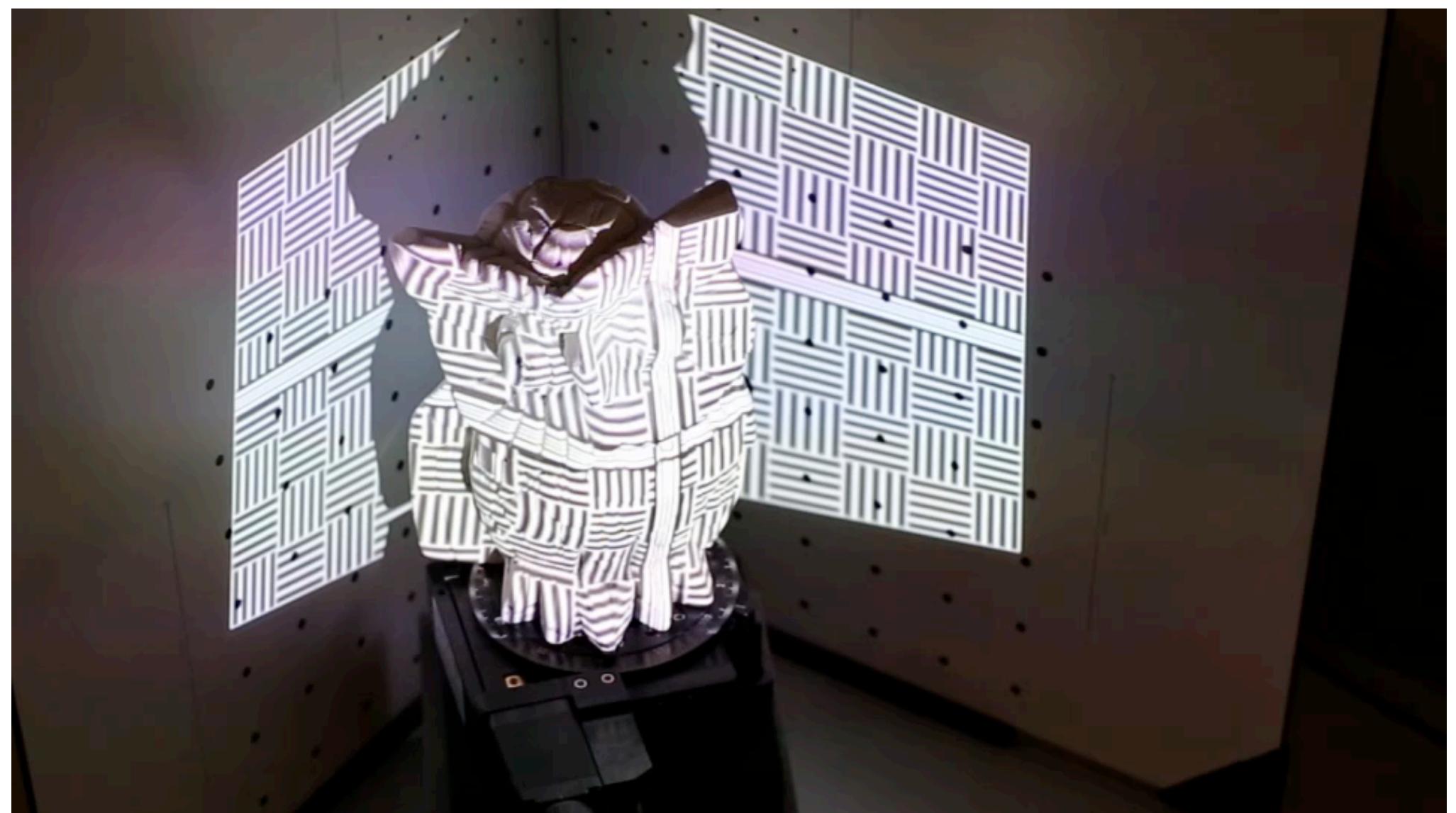
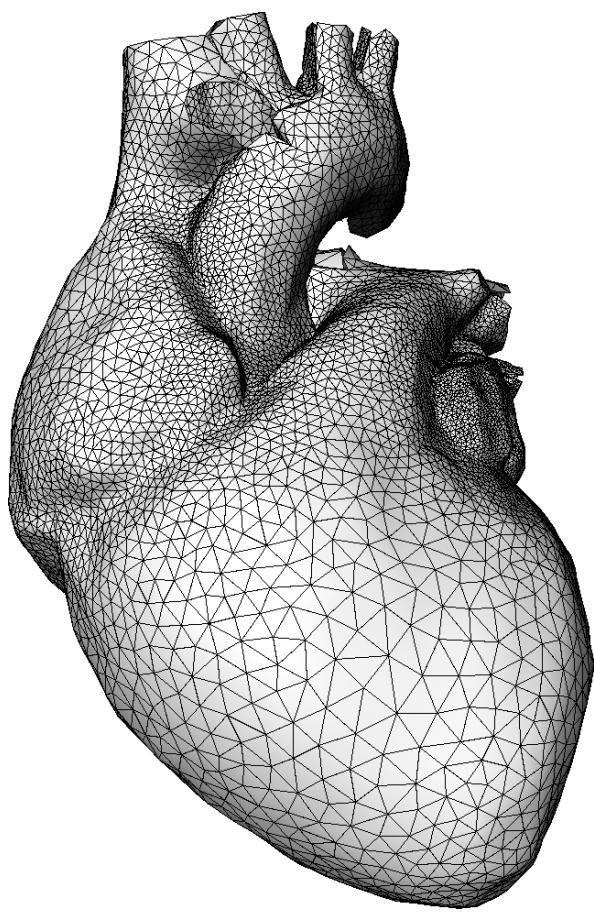
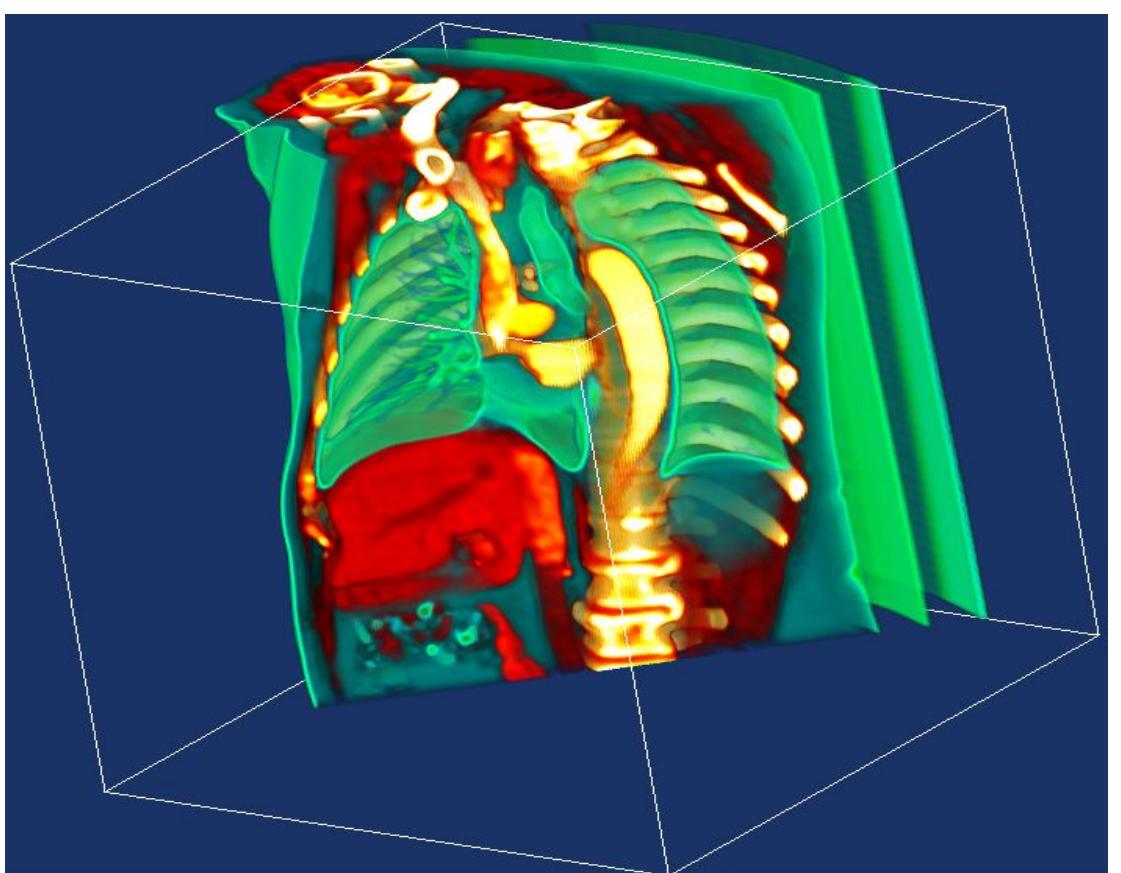
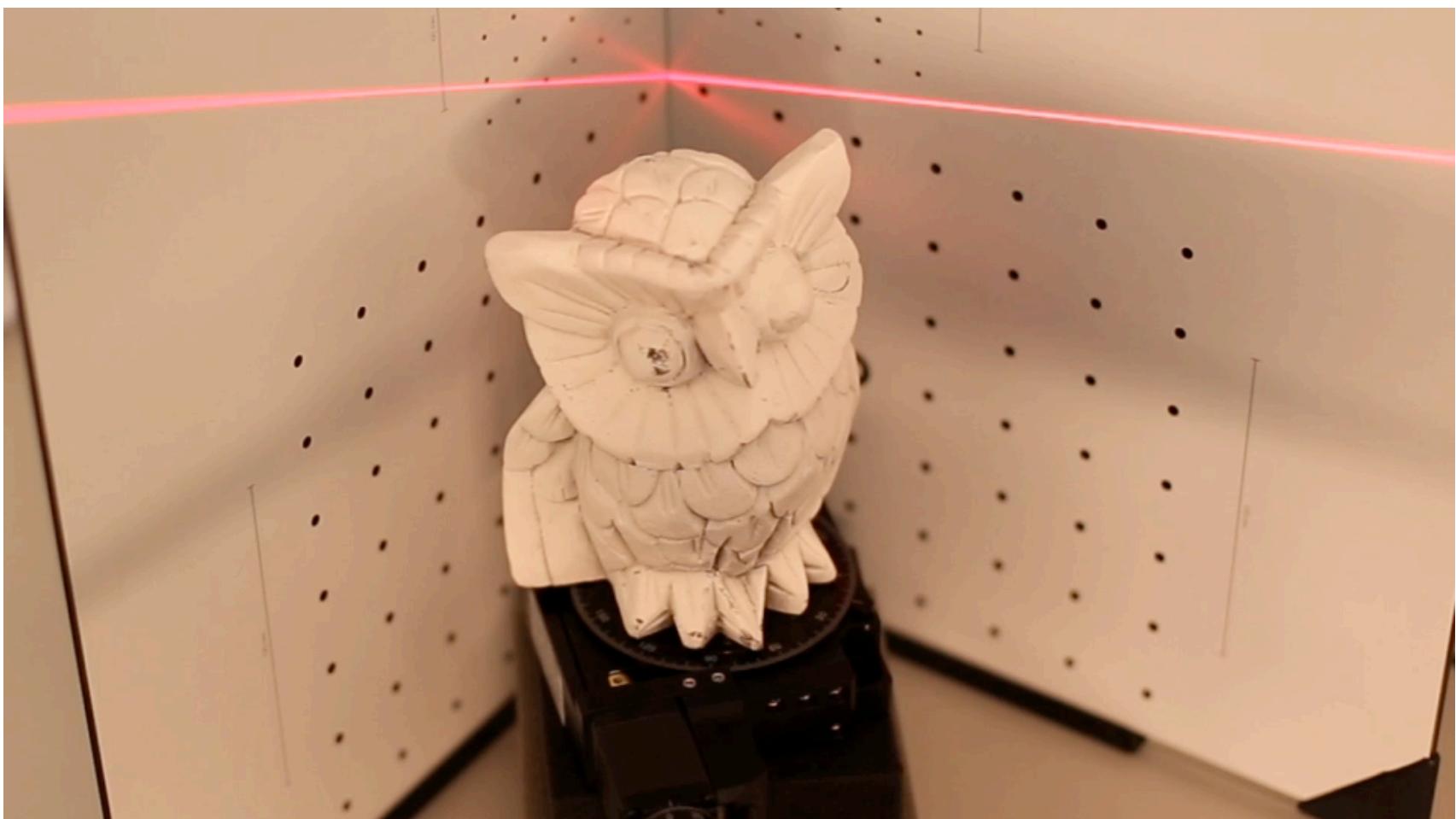


Pixar



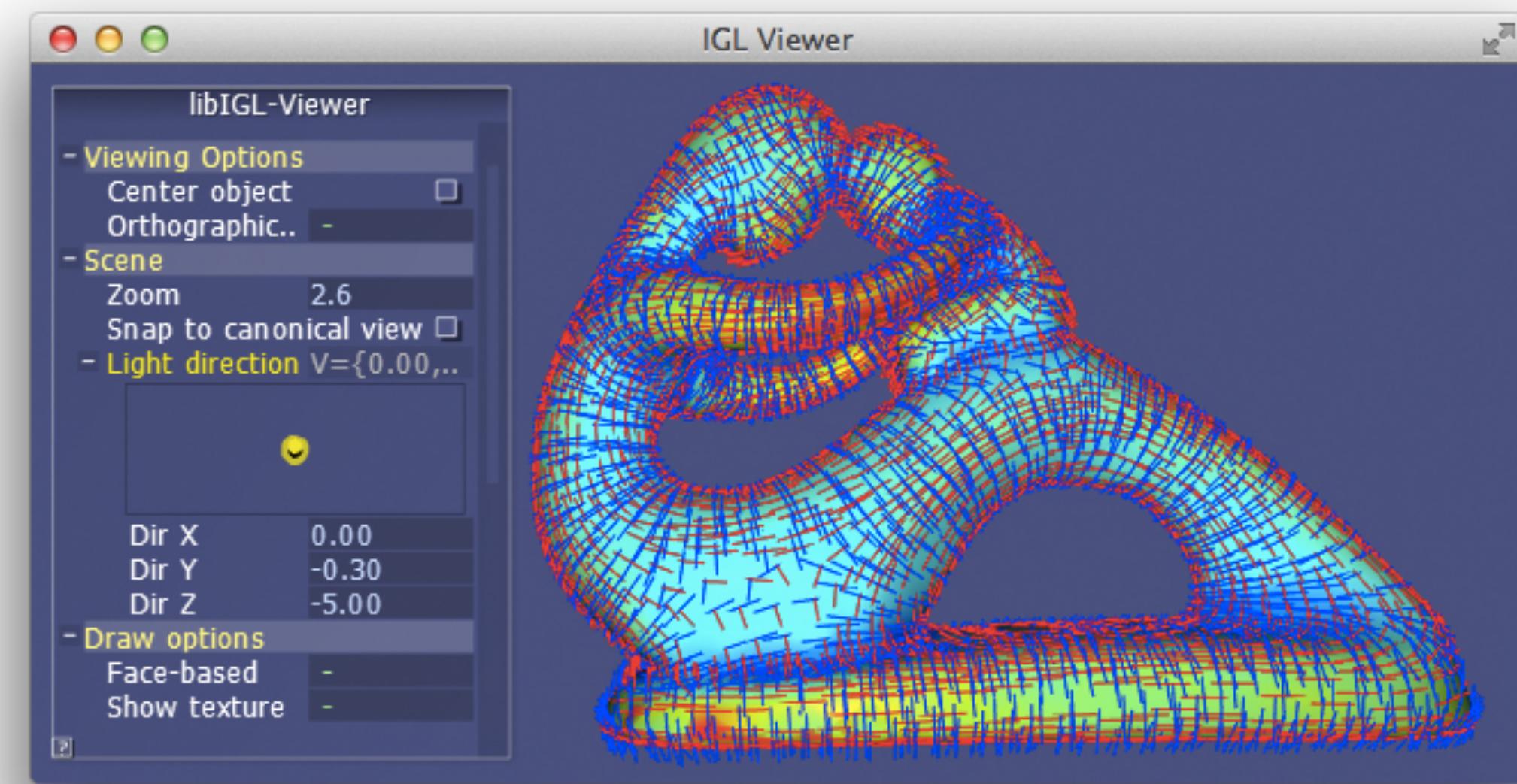
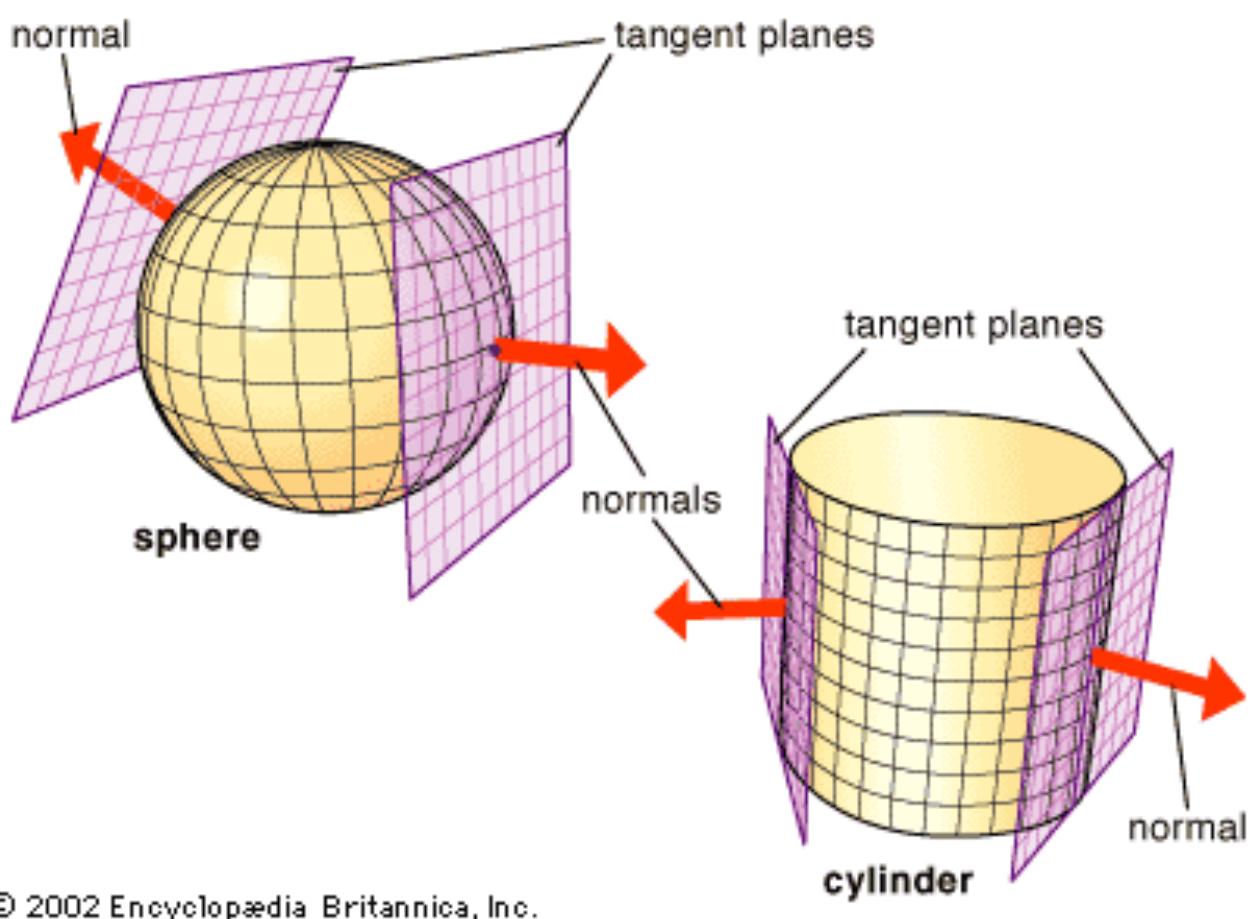
Course Topics

- Shape reconstruction
 - from scanning data



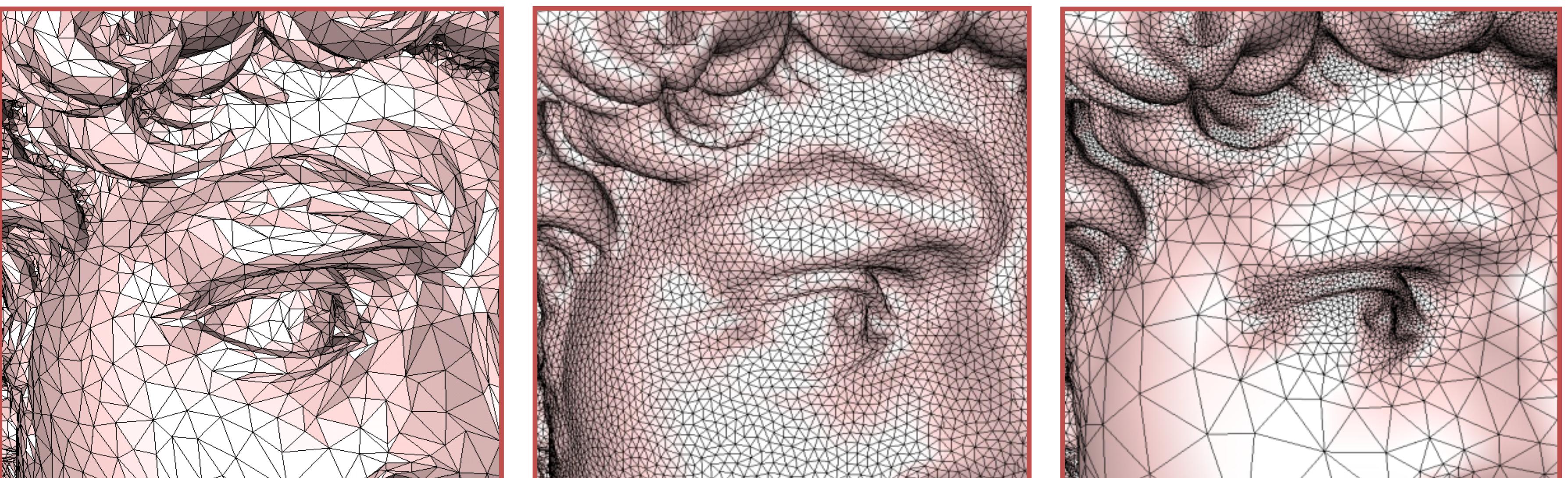
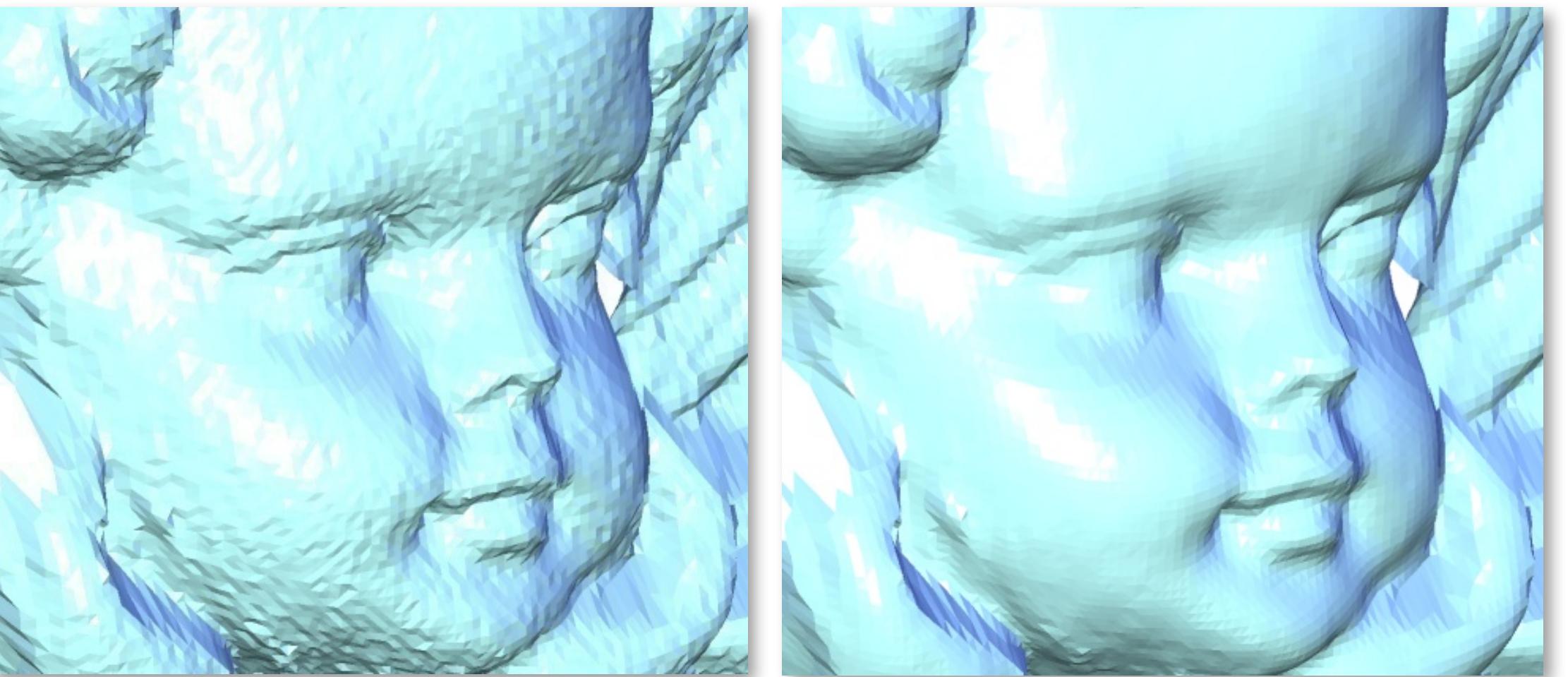
Course Topics

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



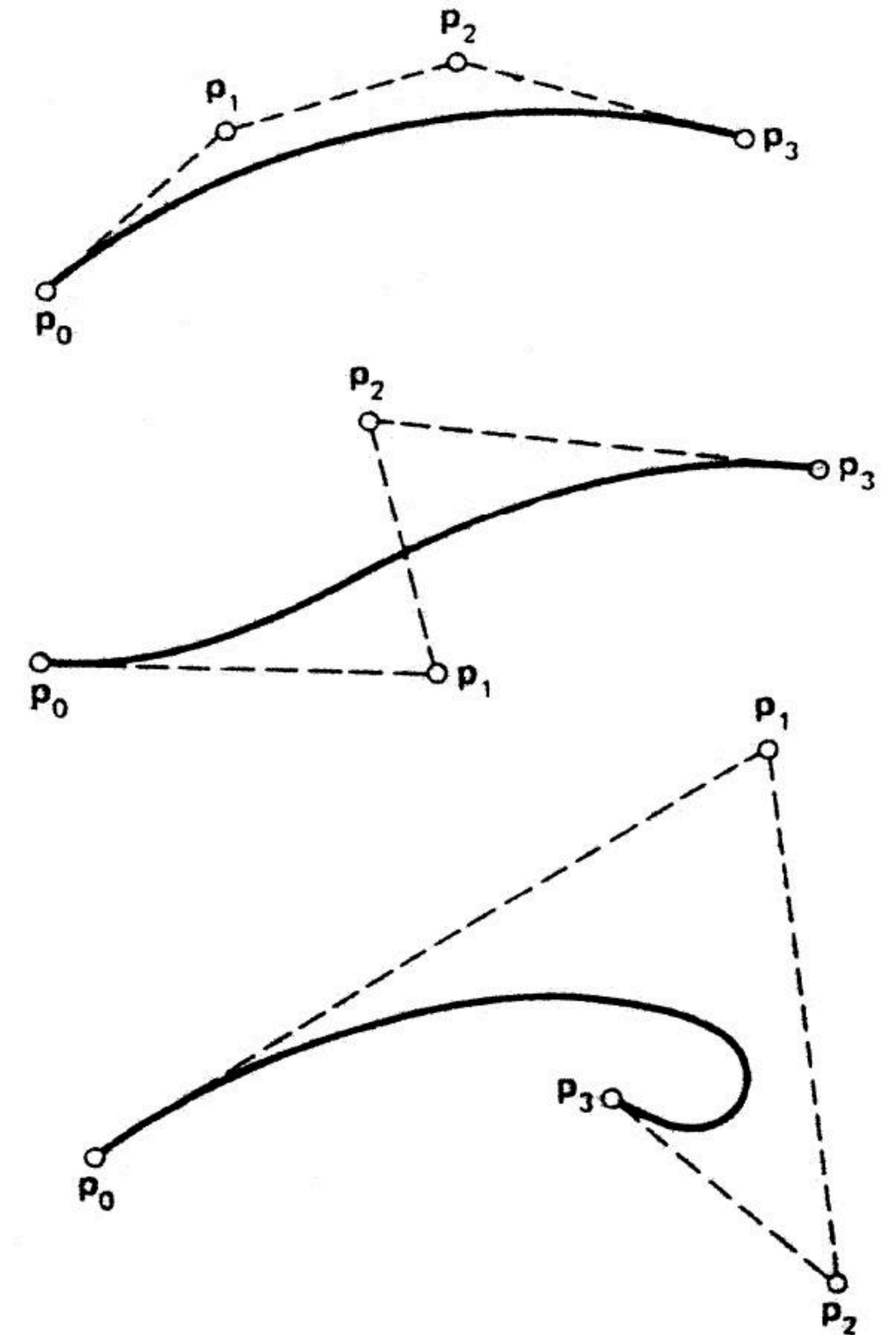
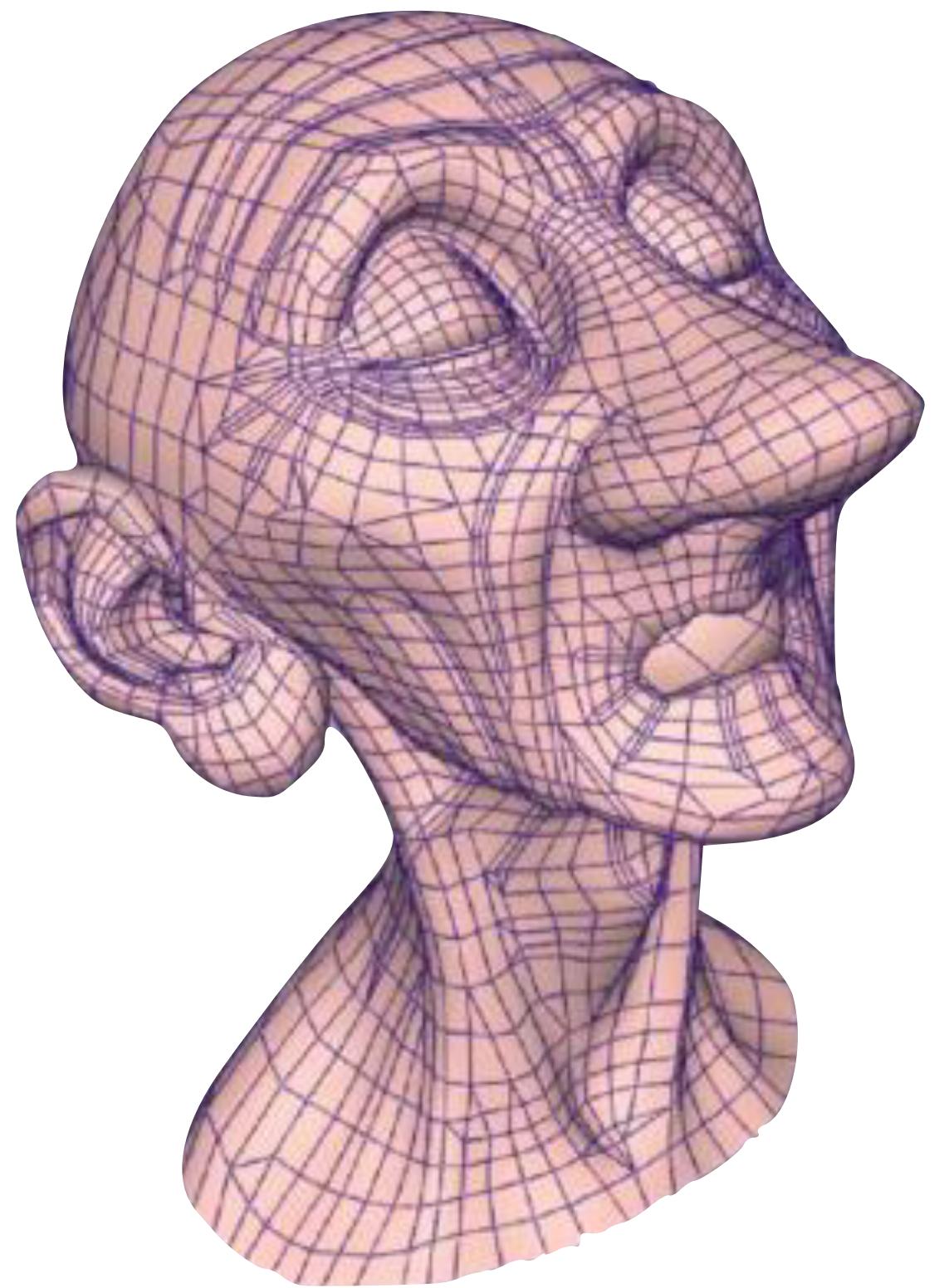
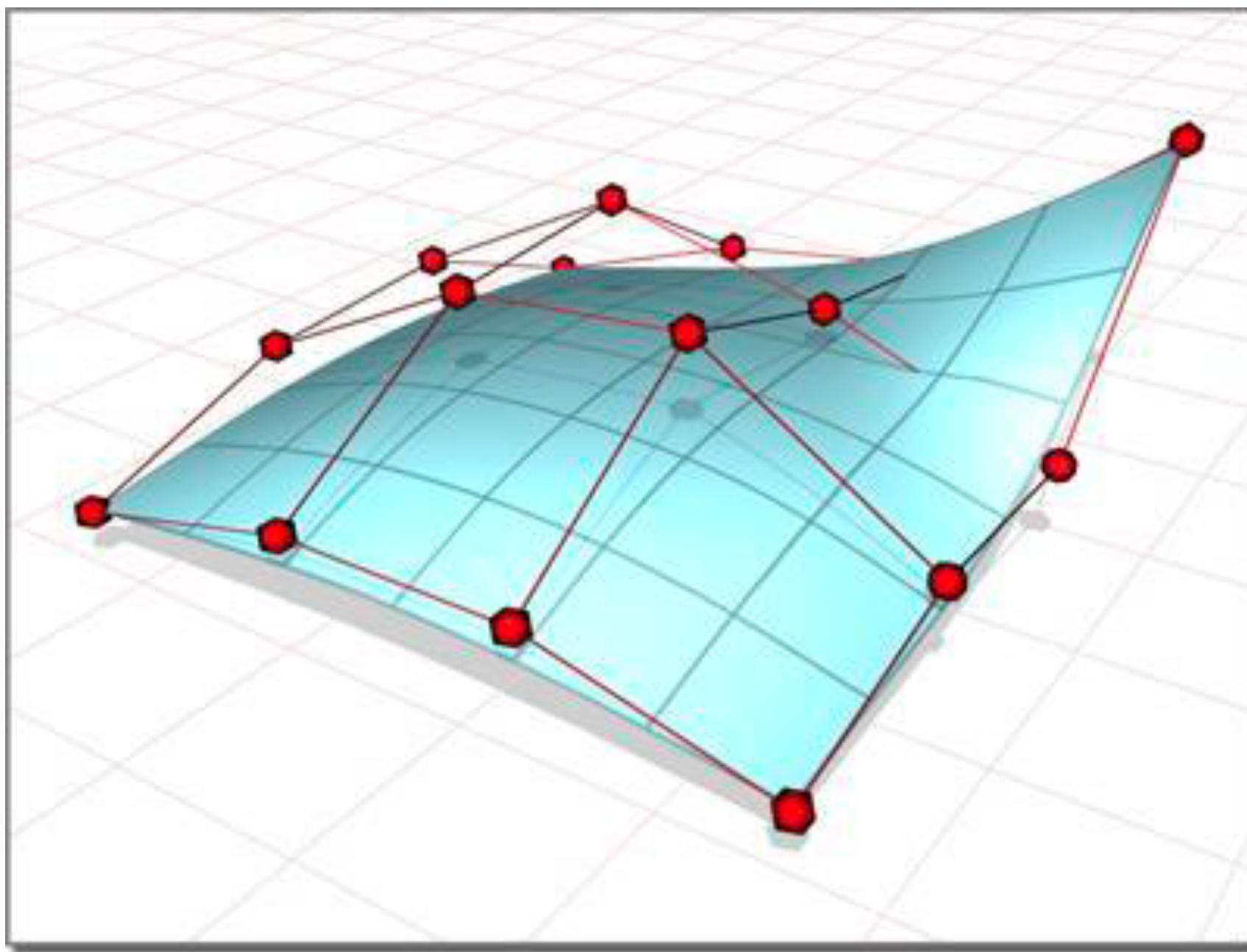
Course Topics

- Digital geometry processing
 - Smoothing, simplification, remeshing, parameterization



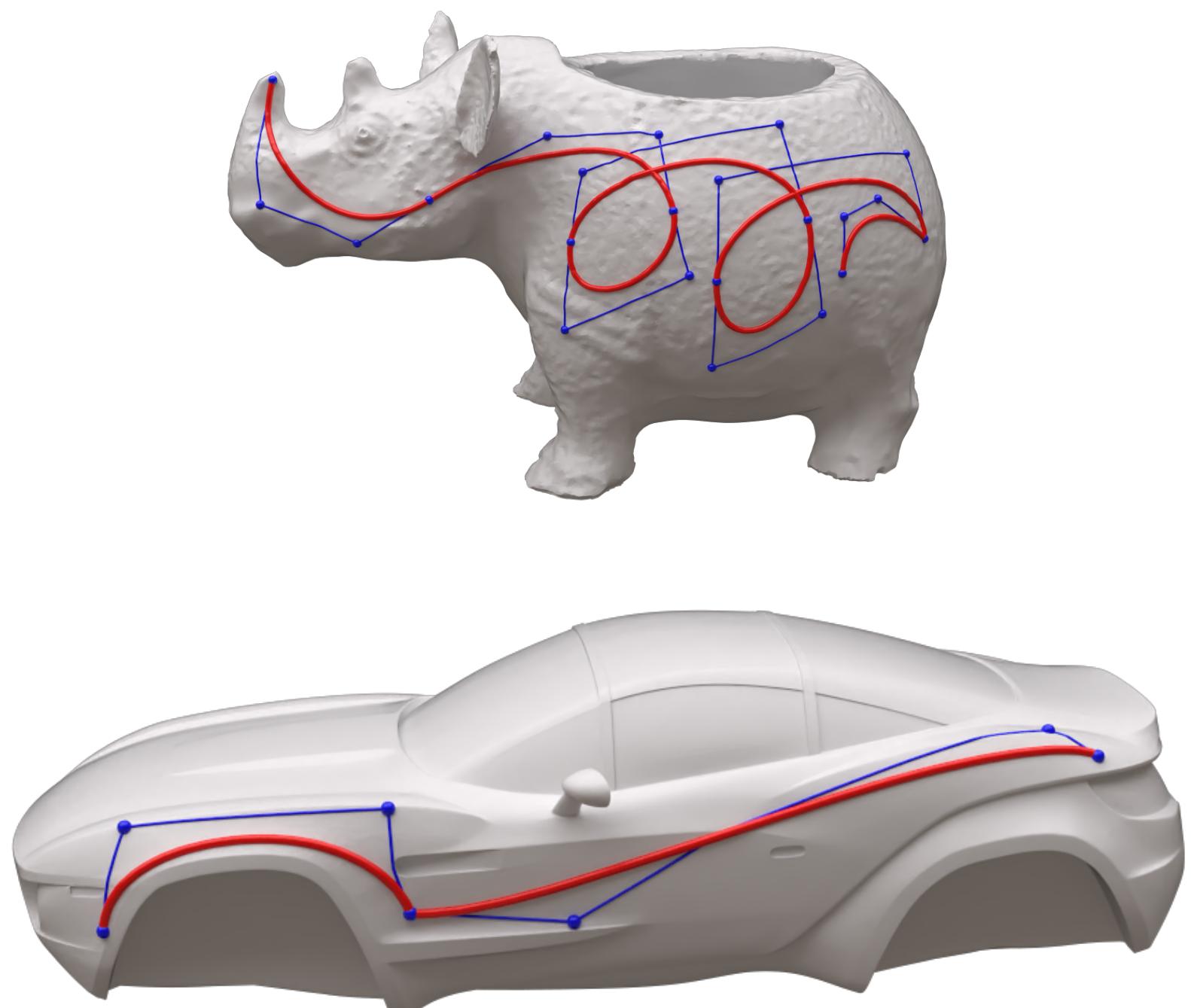
Course Topics

- Spline and subdivision curves and surfaces



Course Topics

- Vector graphics on meshes



Thank you