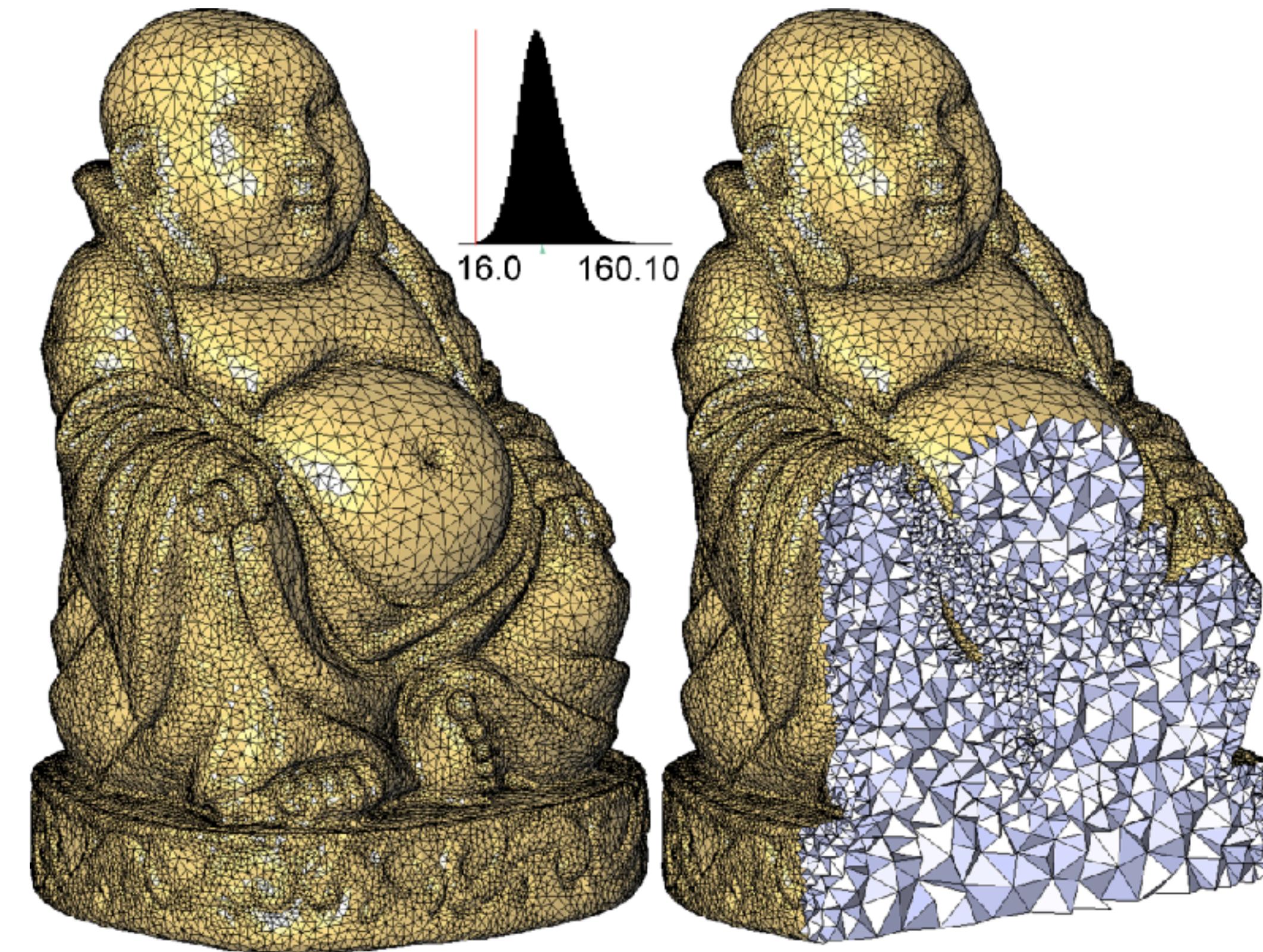


# Acquisition and Processing of 3D Geometry

## (COMP0119)

Niloy J. Mitra



[Image source: Geometrica]

# Teaching Assistants



<http://geometry.cs.ucl.ac.uk/>



Luca Morreale



Sanjeev Mk

## Research

Our research focuses on the acquisition and processing of 3D geometry. Our projects cover the whole spectrum of geometry processing, including: scene understanding, shape collections and computational design. For more details please refer to the [publications](#) page.

Also, check out our video channel on [YouTube](#).

**Join Us:** If you are interested in geometry processing and would like to join the group as a PhD student, postdoc or visiting researcher, please contact [Niloy](#) to discuss opportunities in the group.



## Selected Publications:



## Supported By:



# Thanks to ...



slides, images, videos from



Pierre Alliez  
INRIA



Bruno Lévy  
INRIA



Mark Pauly  
EPFL



Leif Kobbelt  
RWTH Aachen



Mario Botsch  
TU Dortmund



Olga Sorkine  
ETH Zurich

# General Information



# General Information



- **Time and location**
  - Lectures:
    - Wednesday, 11:00 - 12:00 Roberts G08
    - Thursday, 11:00-13:00 Drayton House B20
  - exercise:
    - Friday 13:00-14:00 Malet Place 1.03

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- [Website](#)
  - Moodle

# Tentative Syllabus



# Tentative Syllabus



**Introduction** (week 1)

# Tentative Syllabus



## Introduction (week 1)

1. What is Geometry Processing?

# Tentative Syllabus



## Introduction (week 1)

1. What is Geometry Processing?
2. Surface representations

# Tentative Syllabus



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1. 3D acquisition using laser scanners + SfM

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2. Local registration (ICP and variants)

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## Advanced topics (week 10)

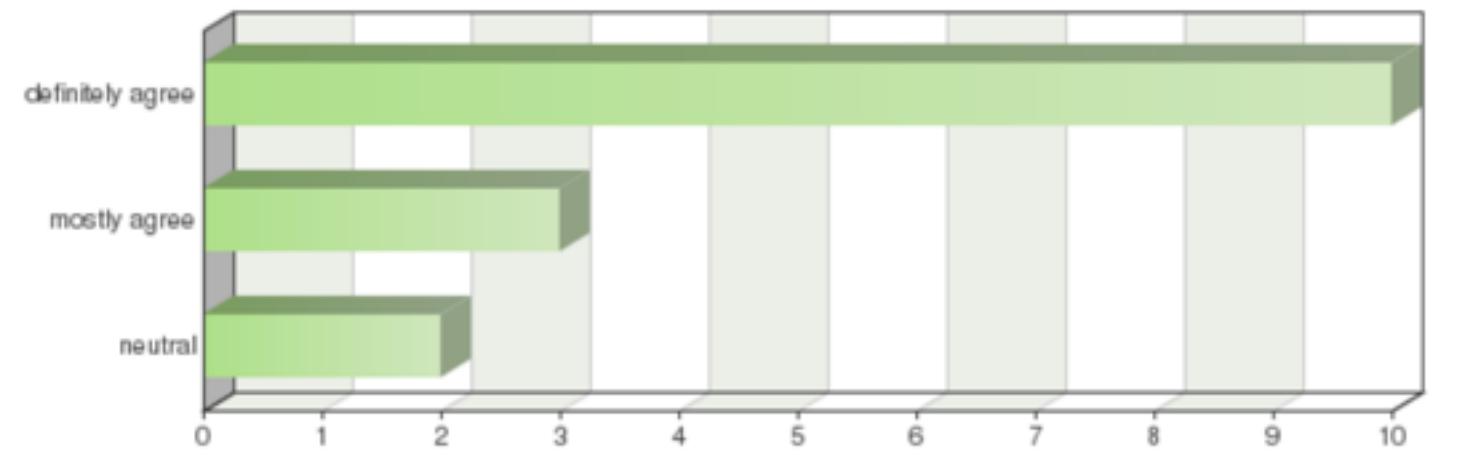
# What Past Students Like/Dislike?



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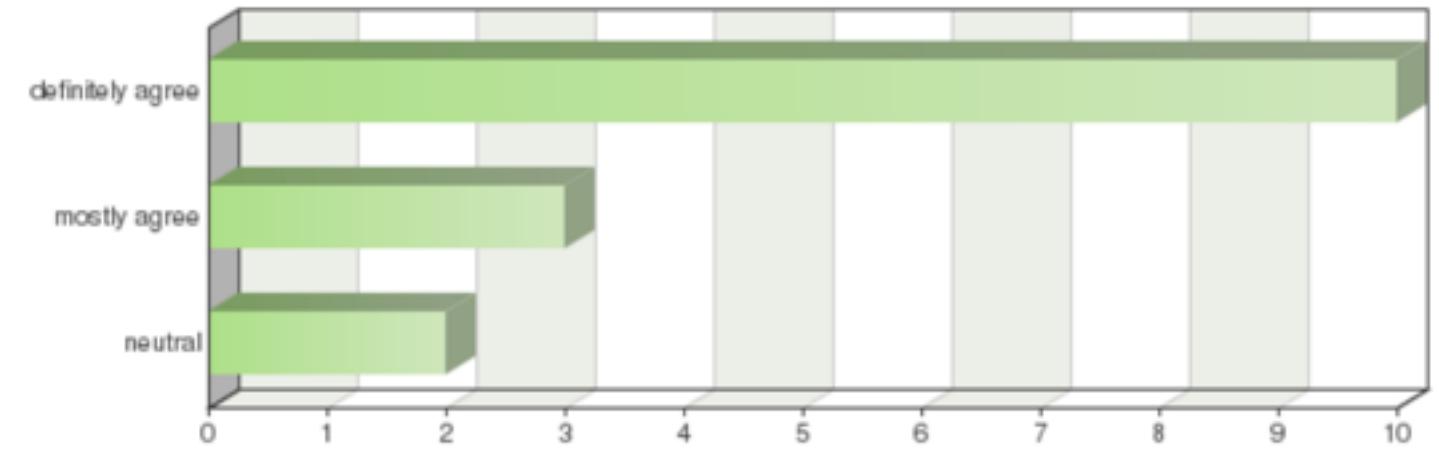
Levels The module was well organised and ran smoothly



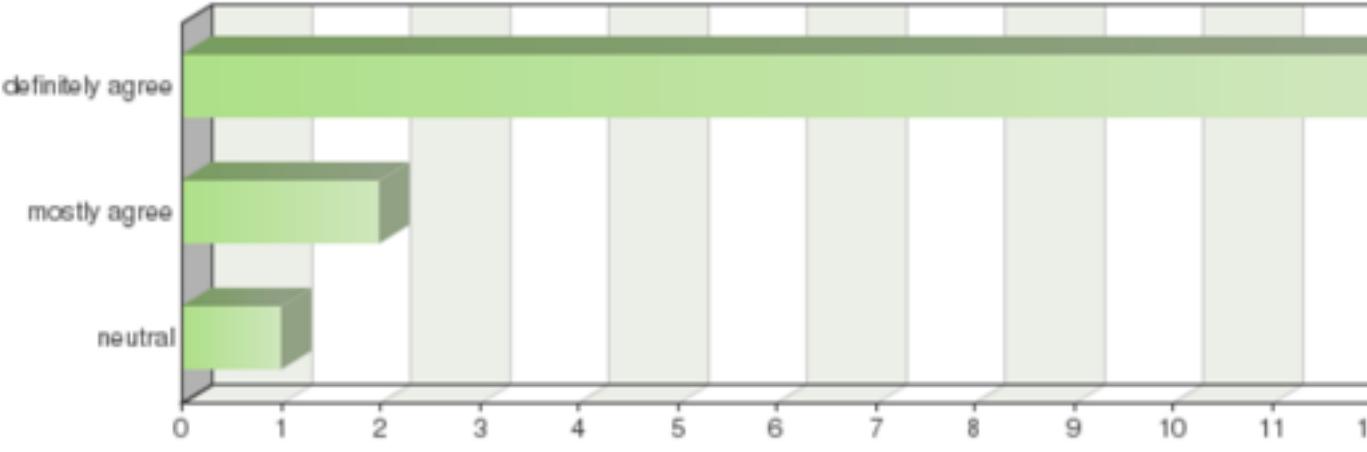
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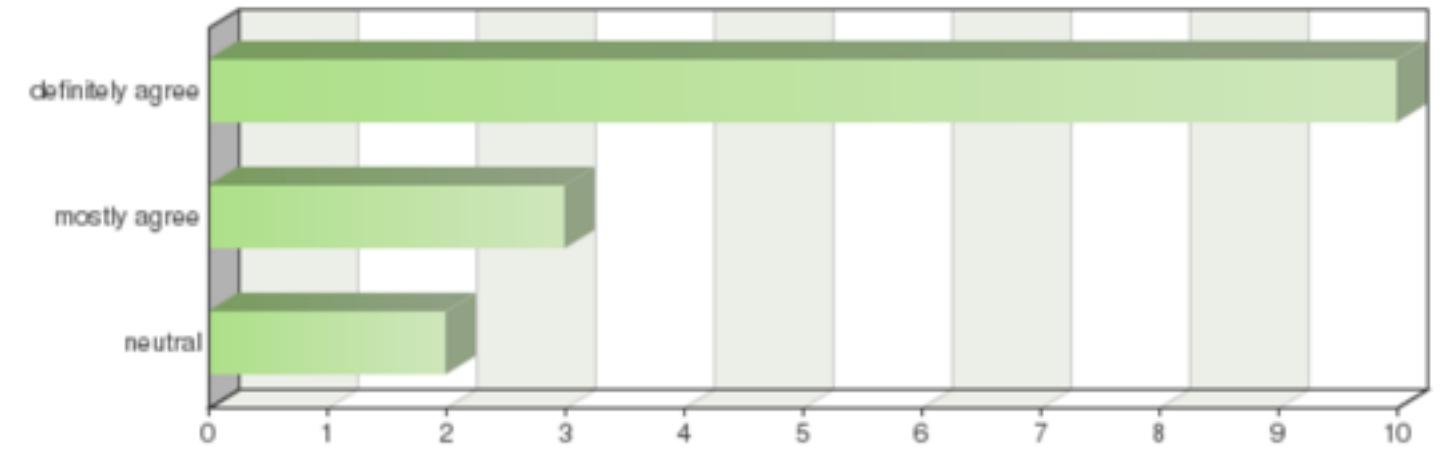
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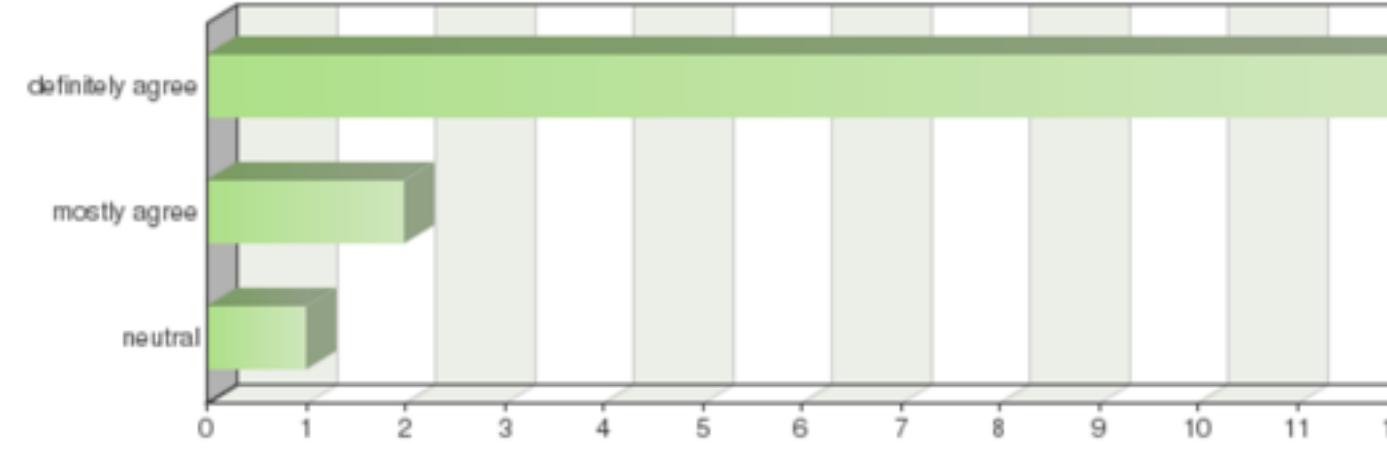
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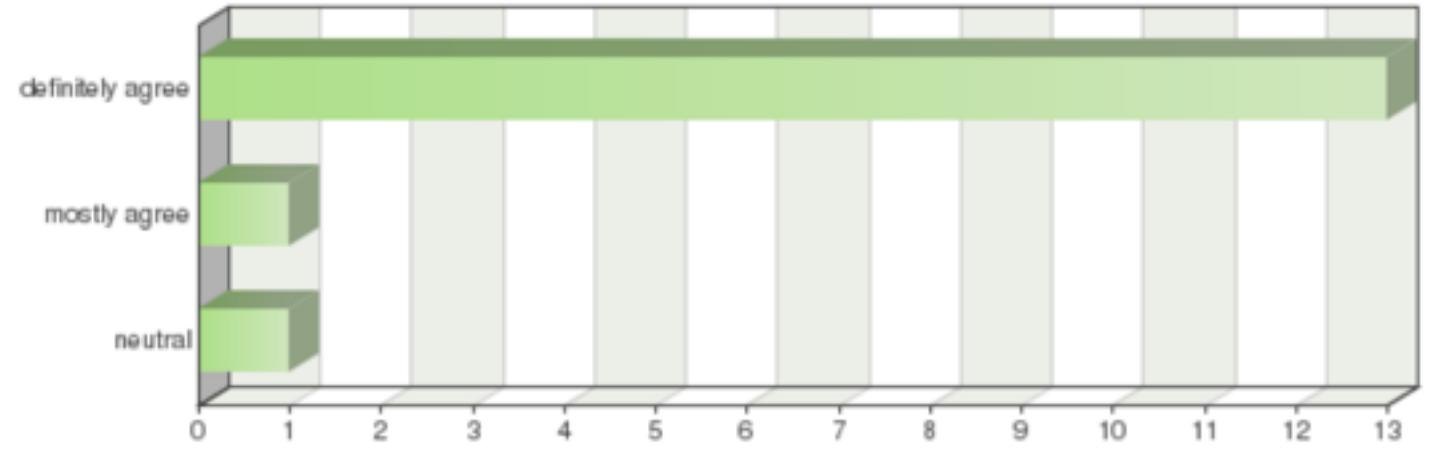
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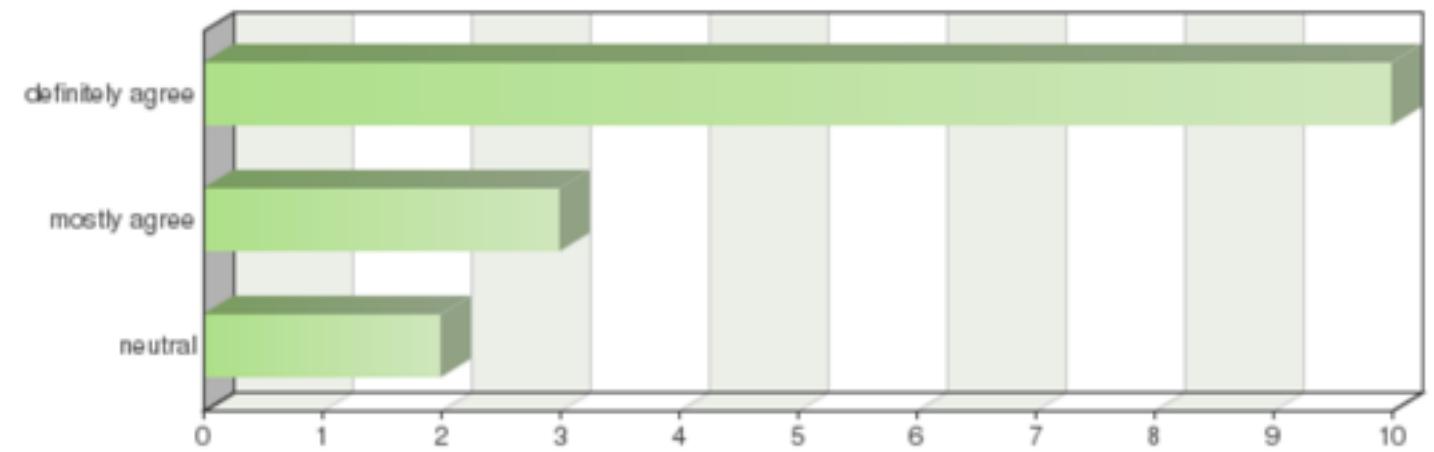
Levels The taught sessions enhanced my learning and understanding of the subject



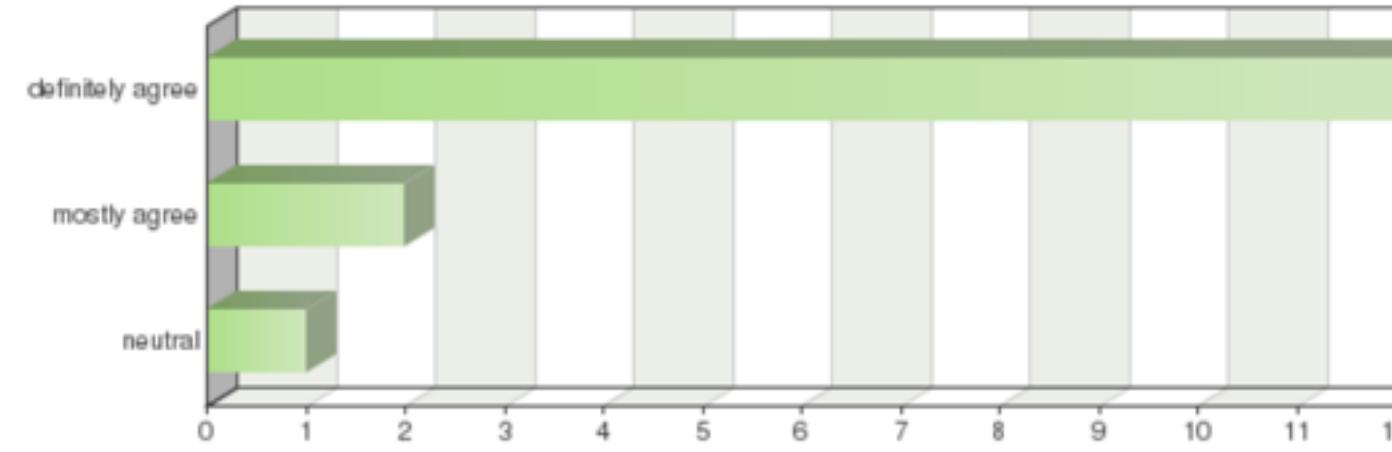
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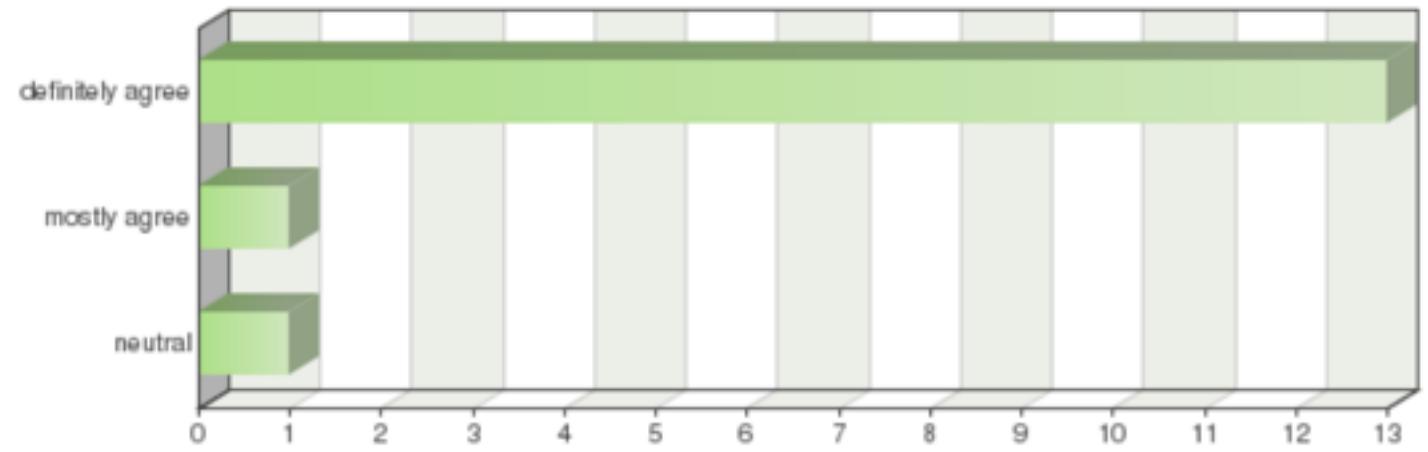
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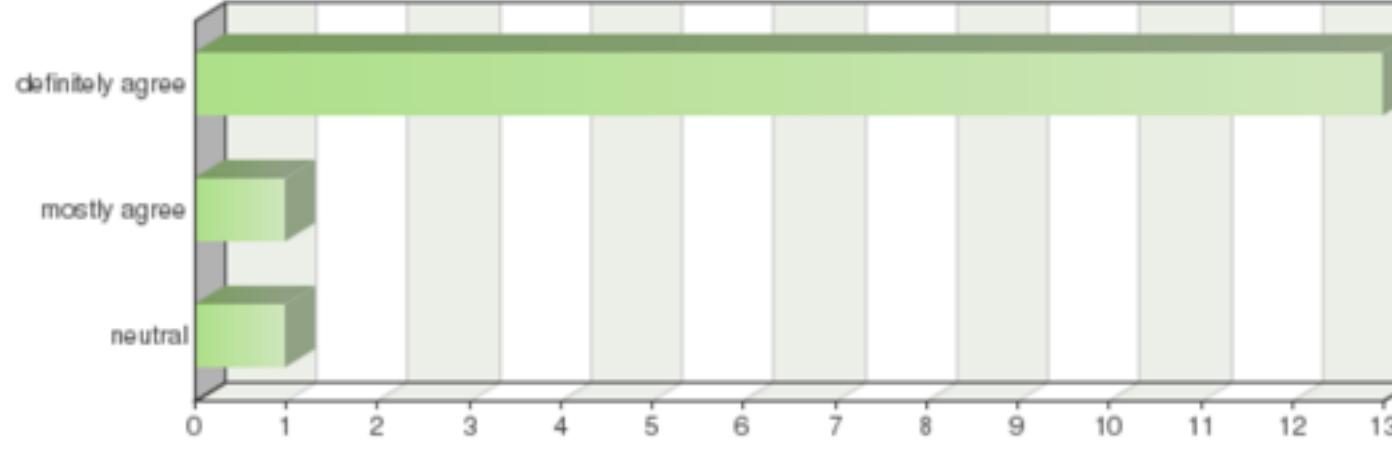
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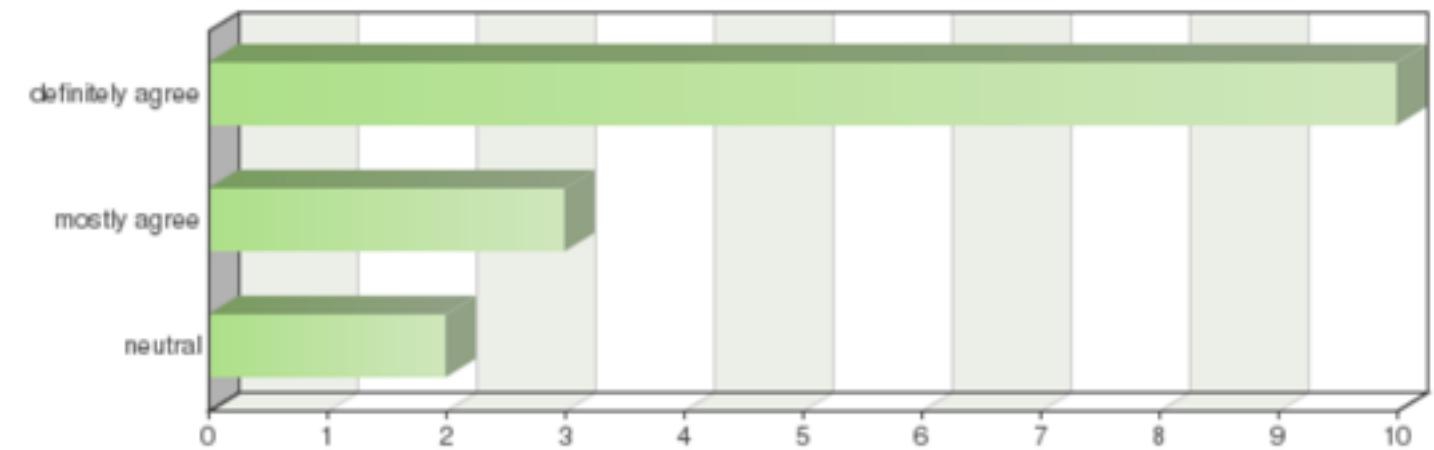
Levels I was challenged to learn something new in the module



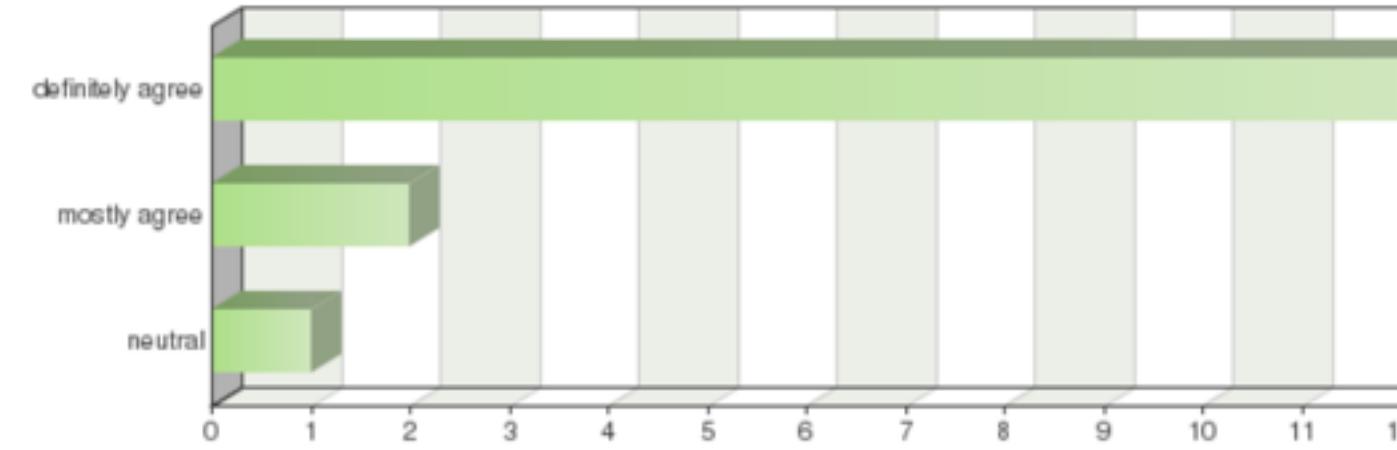
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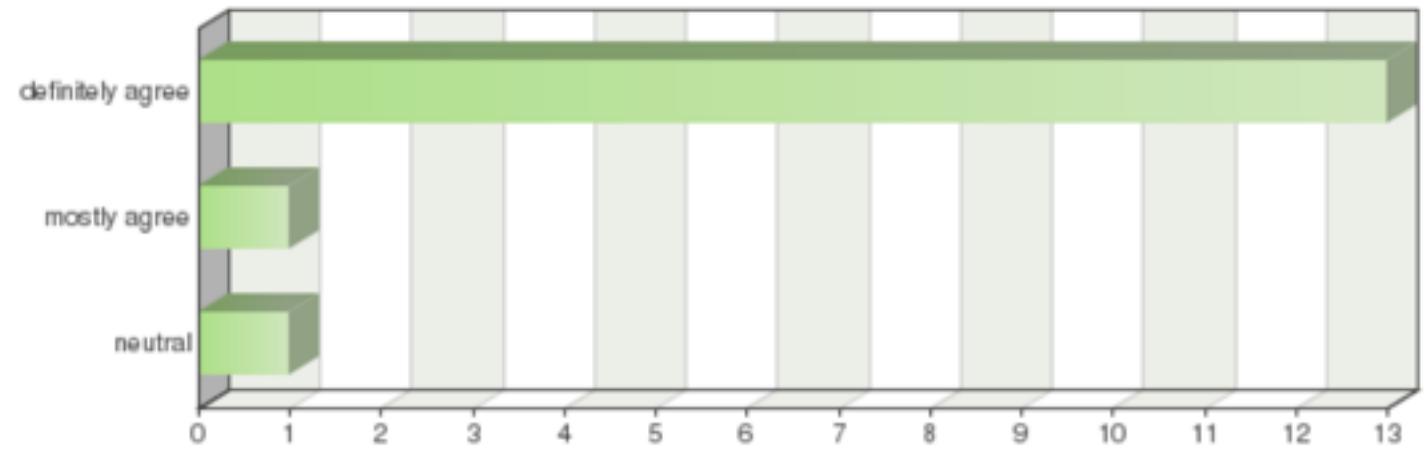
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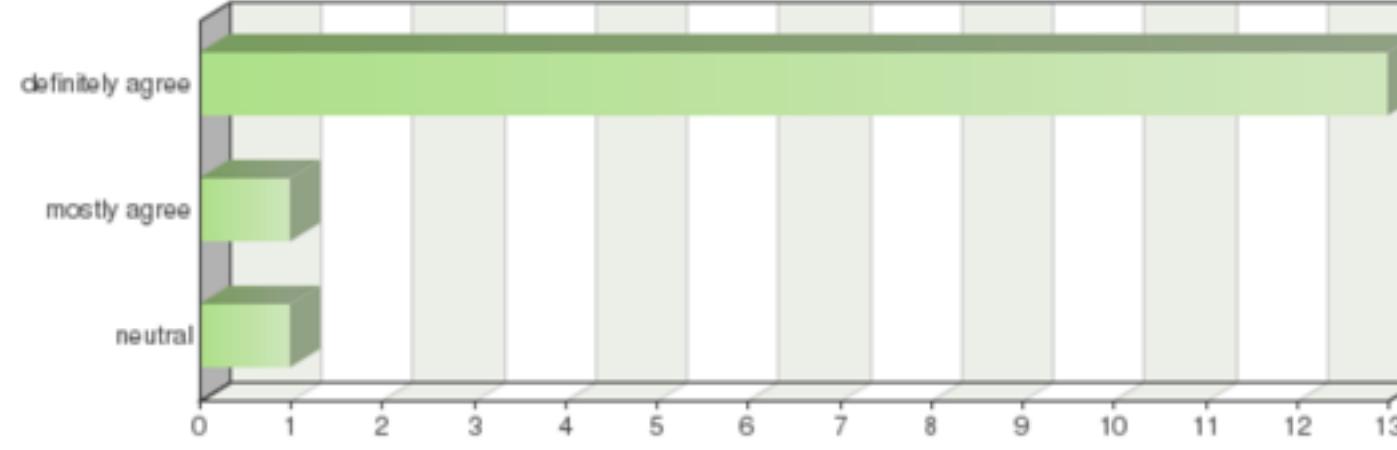
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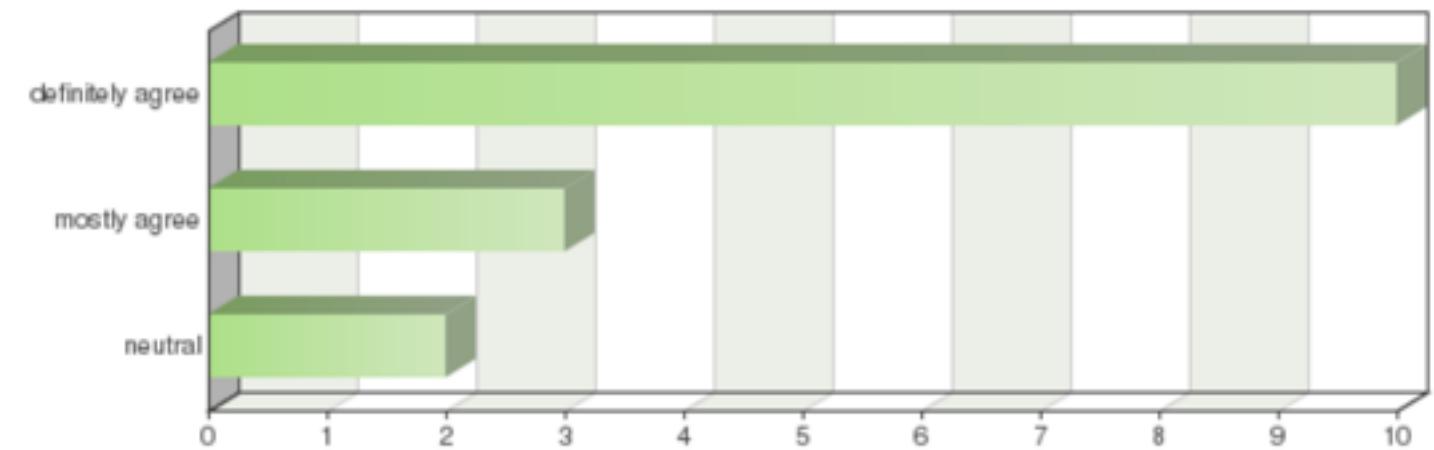


## Check Moodle for Full Reports

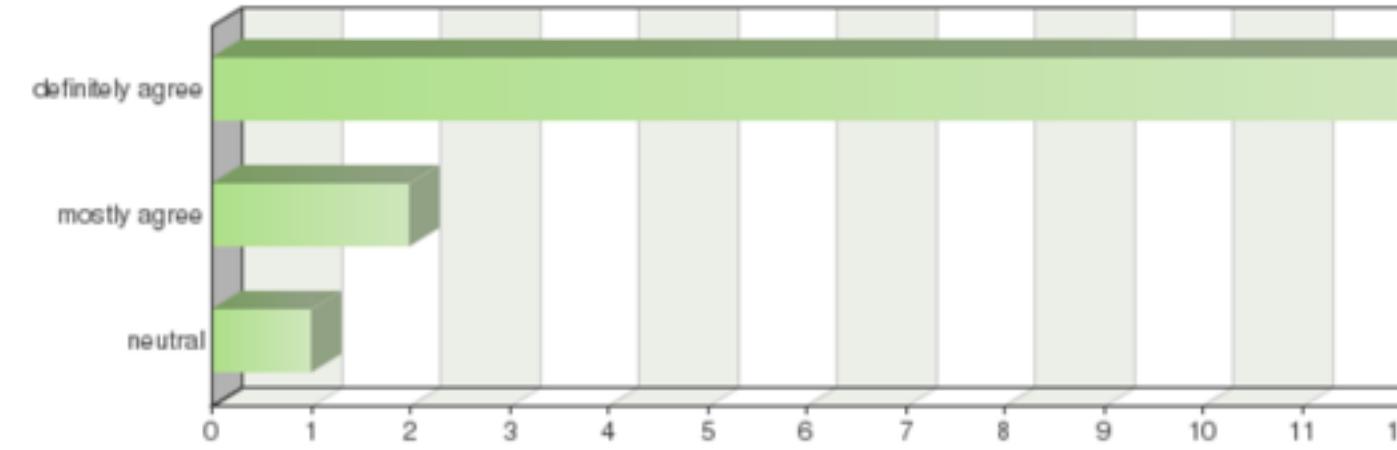
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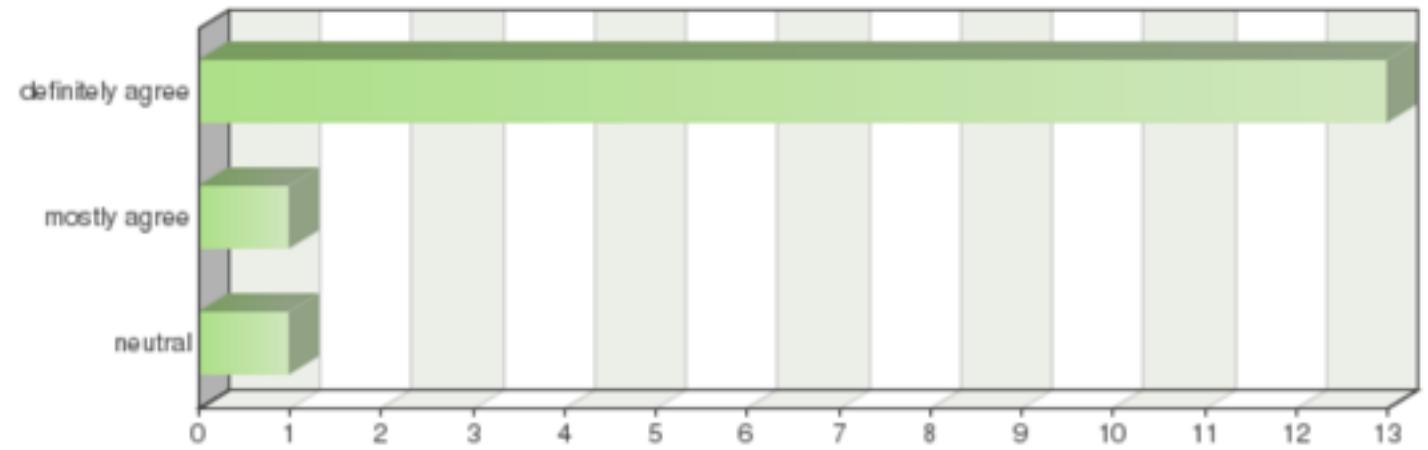
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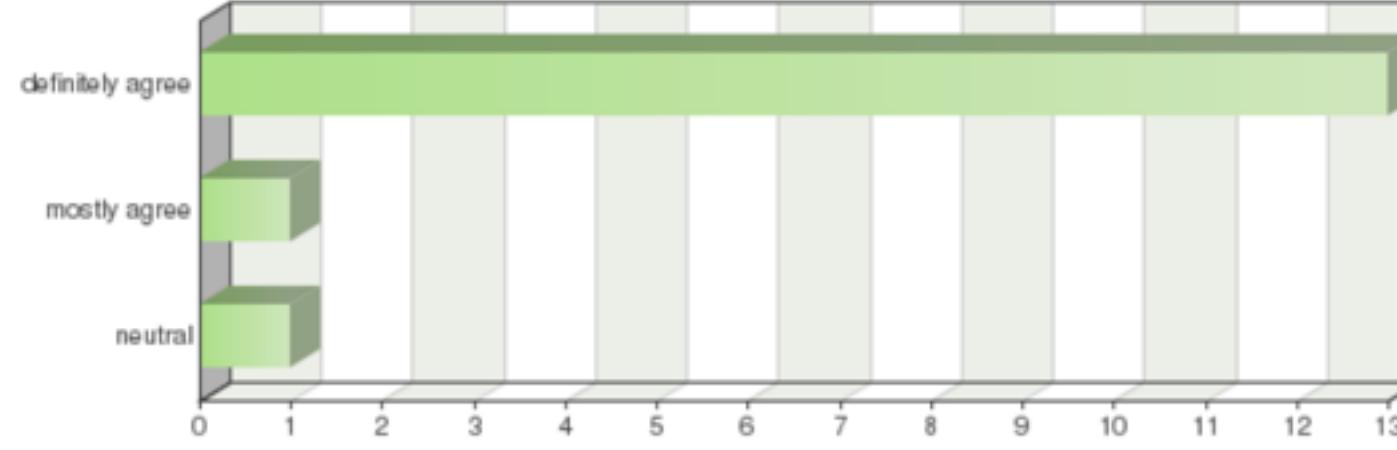


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16 January  
6 February  
13 March

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Check Moodle for Full Reports

# Announcements



# Announcements



- how to contact me
  - office hours: by appointment (email)
  - by email

# Announcements



- how to contact me
  - office hours: by appointment (email)
  - by email
- plans for Friday sessions

# Your Background



# Your Background



- Linear algebra

# Your Background



- Linear algebra
- Computer graphics and/or image processing

# Your Background



- Linear algebra
- Computer graphics and/or image processing
- Basics of machine learning

# Your Background



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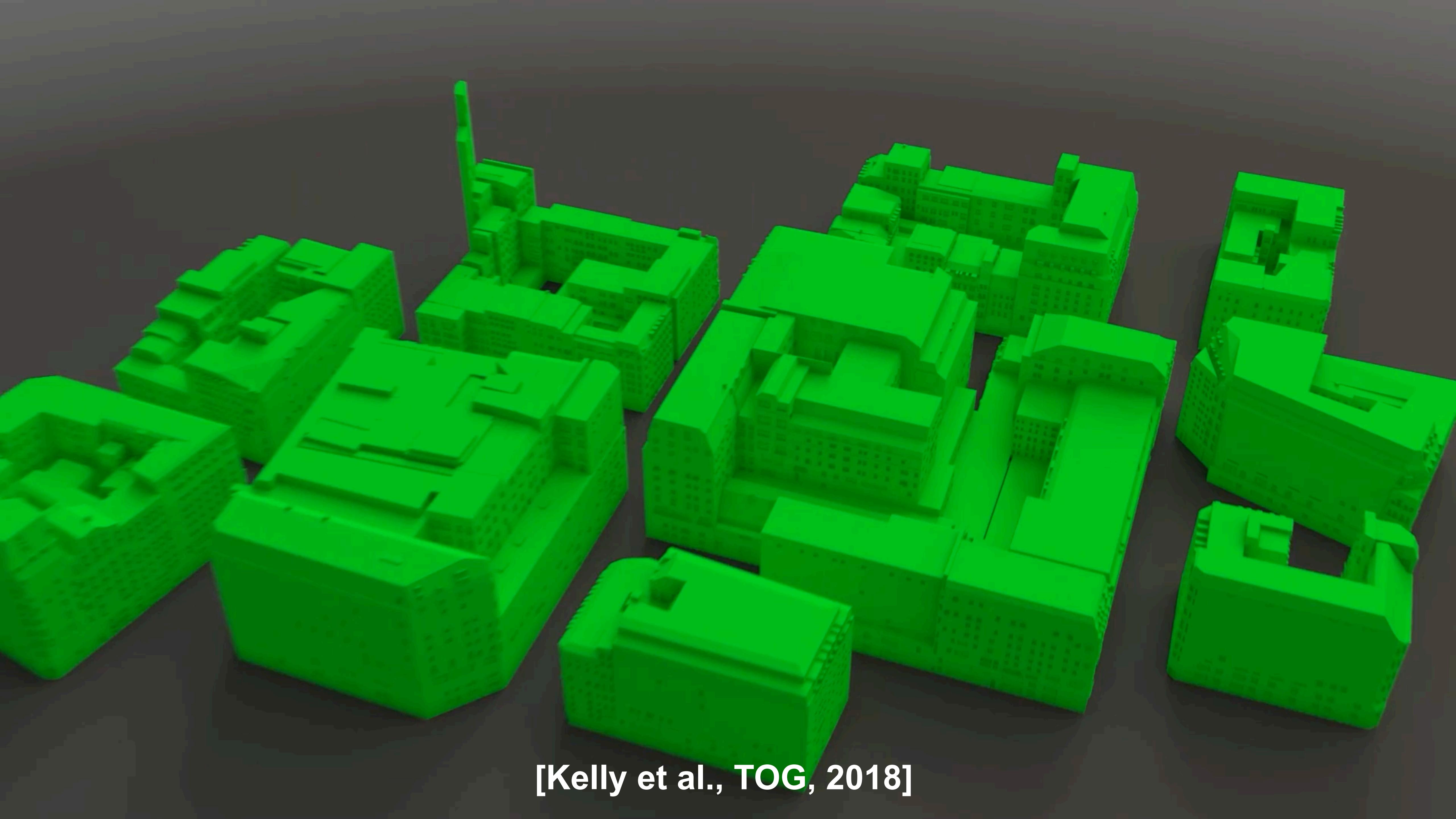


- Linear algebra
- Computer graphics and/or image processing
- Basics of machine learning
- Programming
  - Python, C/C++, Matlab
  - OpenGL
  - ligGL, meshLab

# Grading

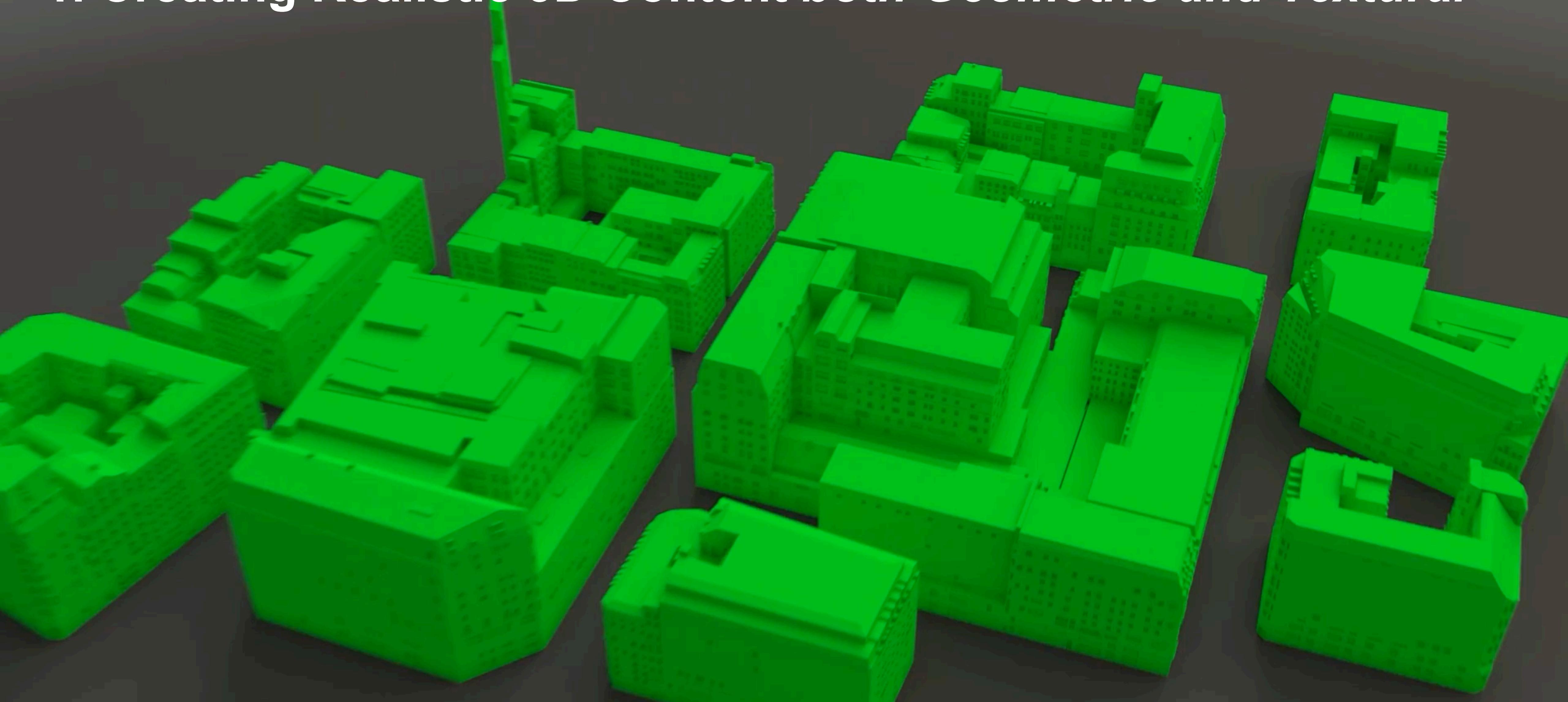


- **Coursework:** 60% (individual; 2 courseworks, 30% each)
  - CW1 February 1
  - CW2 March xx
- **Project:** 40% (groups of 2)
  - April/May



[Kelly et al., TOG, 2018]

# 1. Creating Realistic 3D Content *both Geometric and Textural*



[Kelly et al., TOG, 2018]



[Monszpart et al., TOG, 2016]



[Monszpart et al., TOG, 2016]

# moving objects and people



[Monszpart et al., TOG, 2016]

moving objects and people

occlusion

[Monszpart et al., TOG, 2016]

moving objects and people

occlusion

light, texture, ...

[Monszpart et al., TOG, 2016]

A photograph of a man with a beard and short hair, wearing a dark t-shirt, sitting at a marimba and playing it. A white ball is captured in mid-air, having just been struck or about to be caught, positioned between the man's hands and the instrument. The setting appears to be a room with a whiteboard and a red curtain in the background.

moving objects and people

occlusion

light, texture, ...

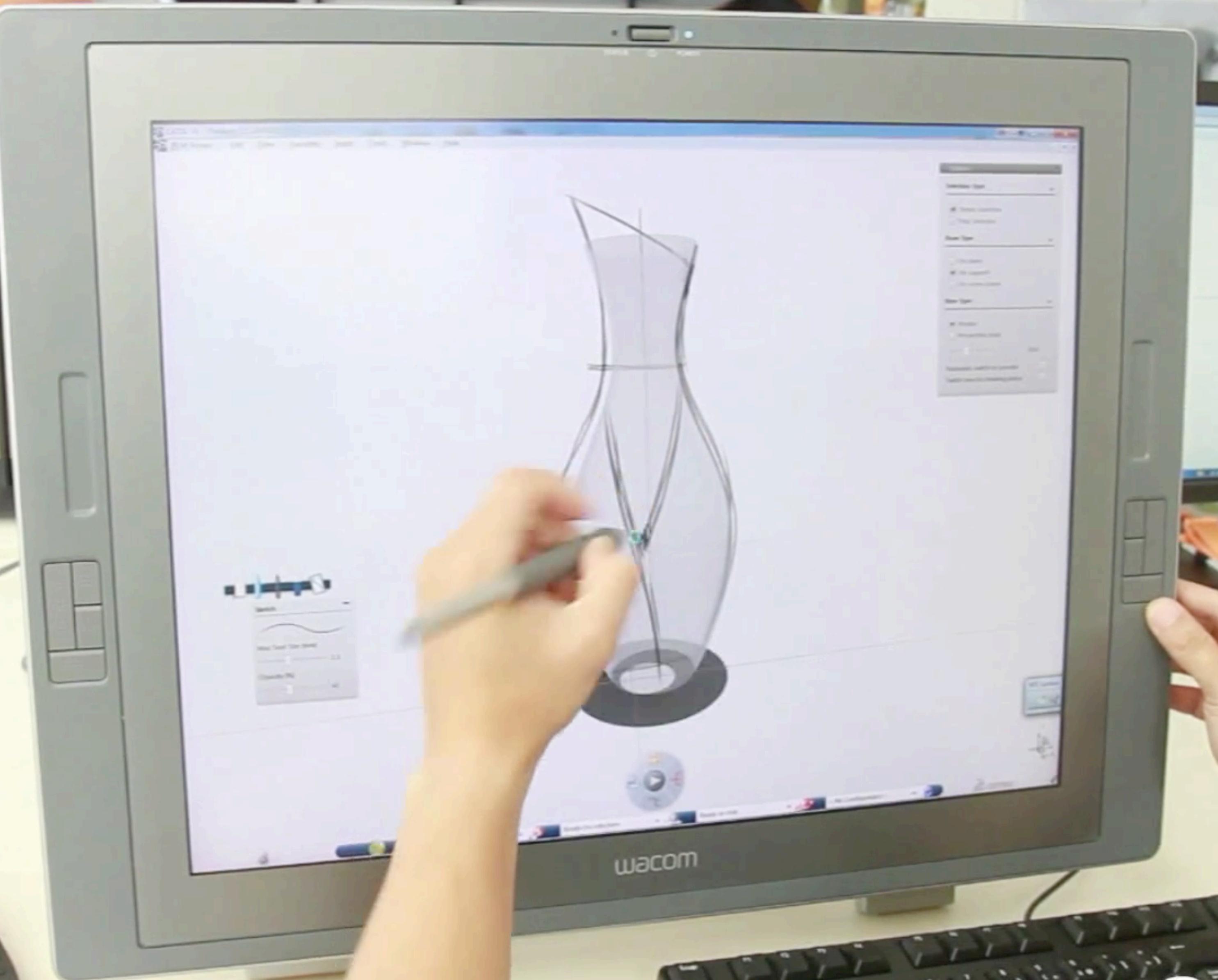
physics and interactions



## 2. Inverse Modeling: Capturing & Replaying Realistic Interactions

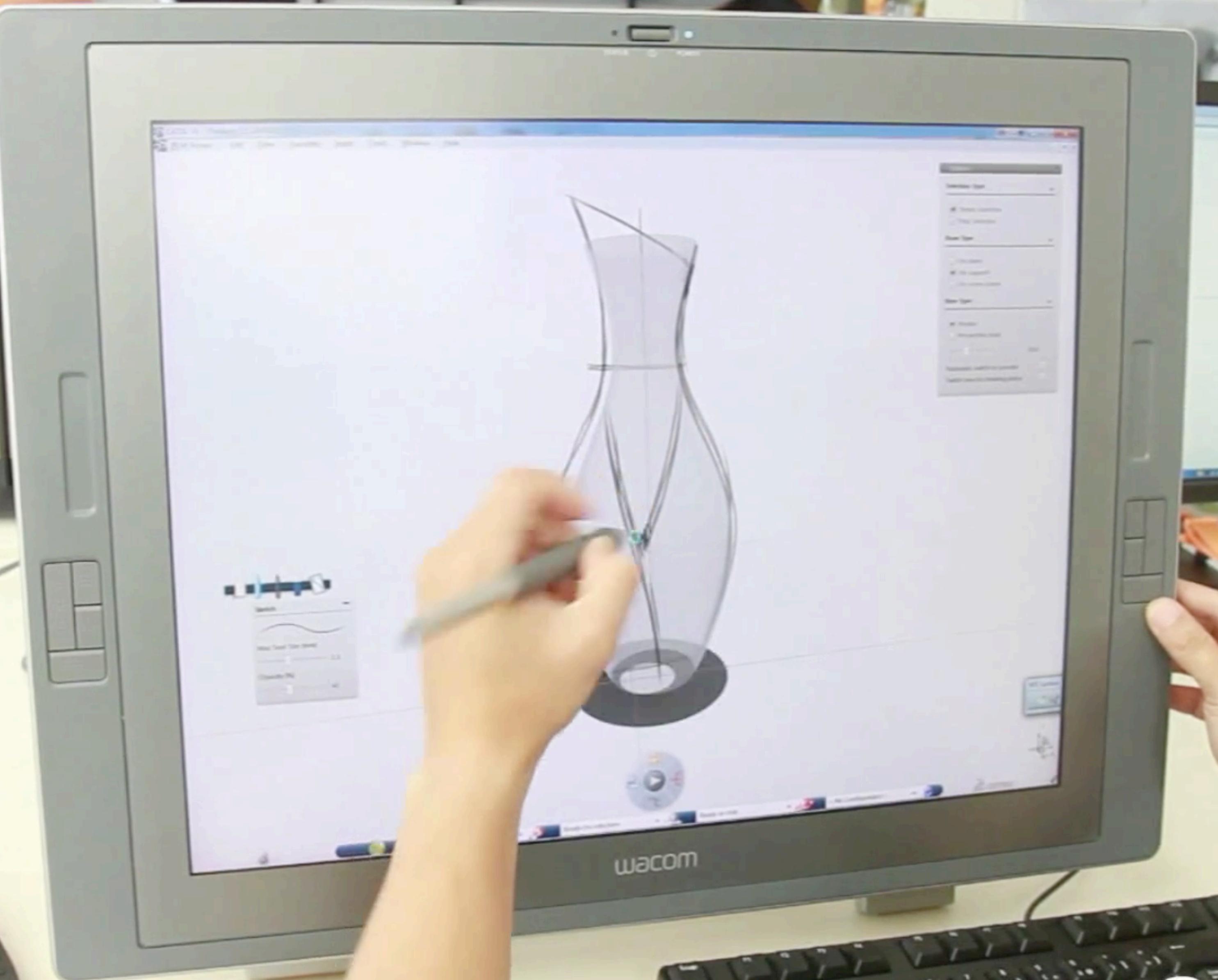


Conveying Design Intent

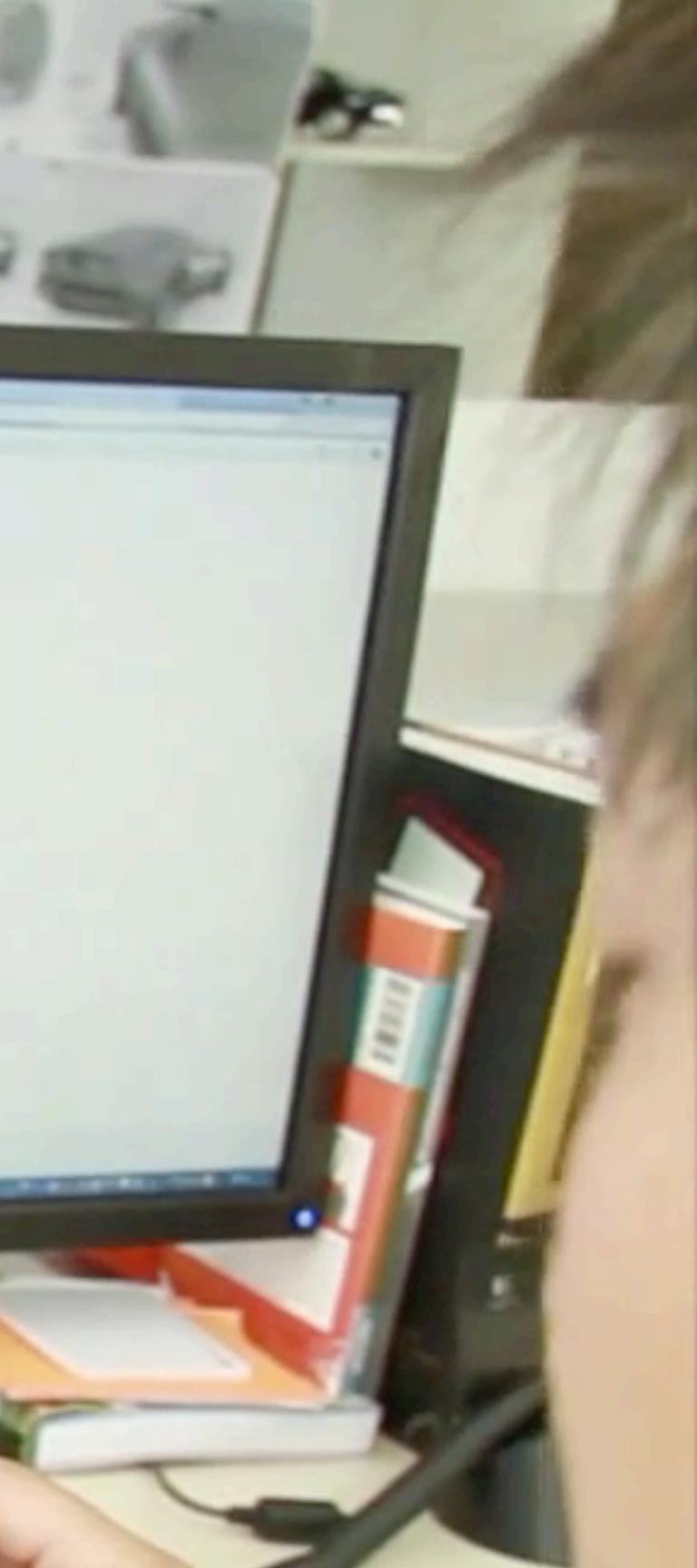


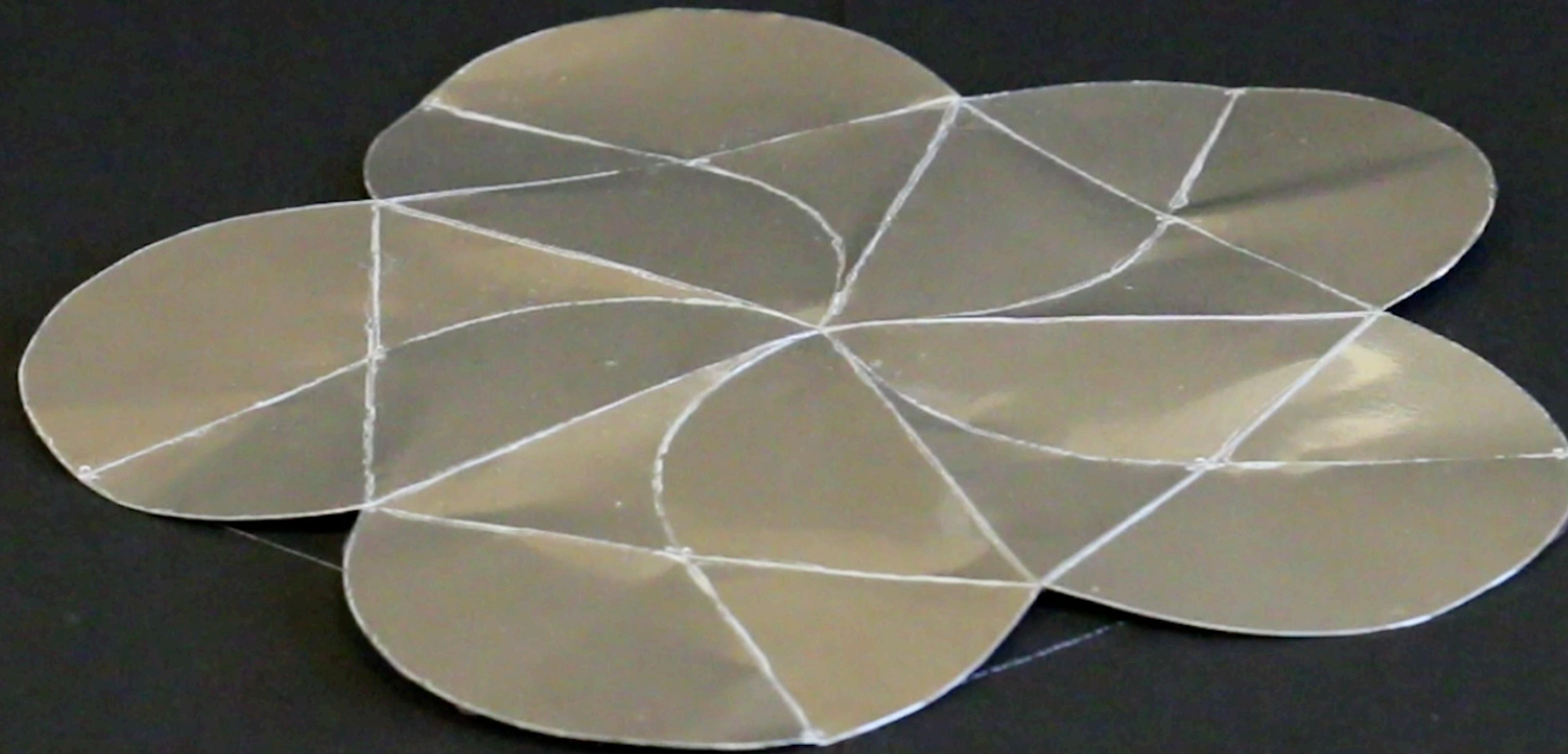
3S CATIA

Conveying Design Intent



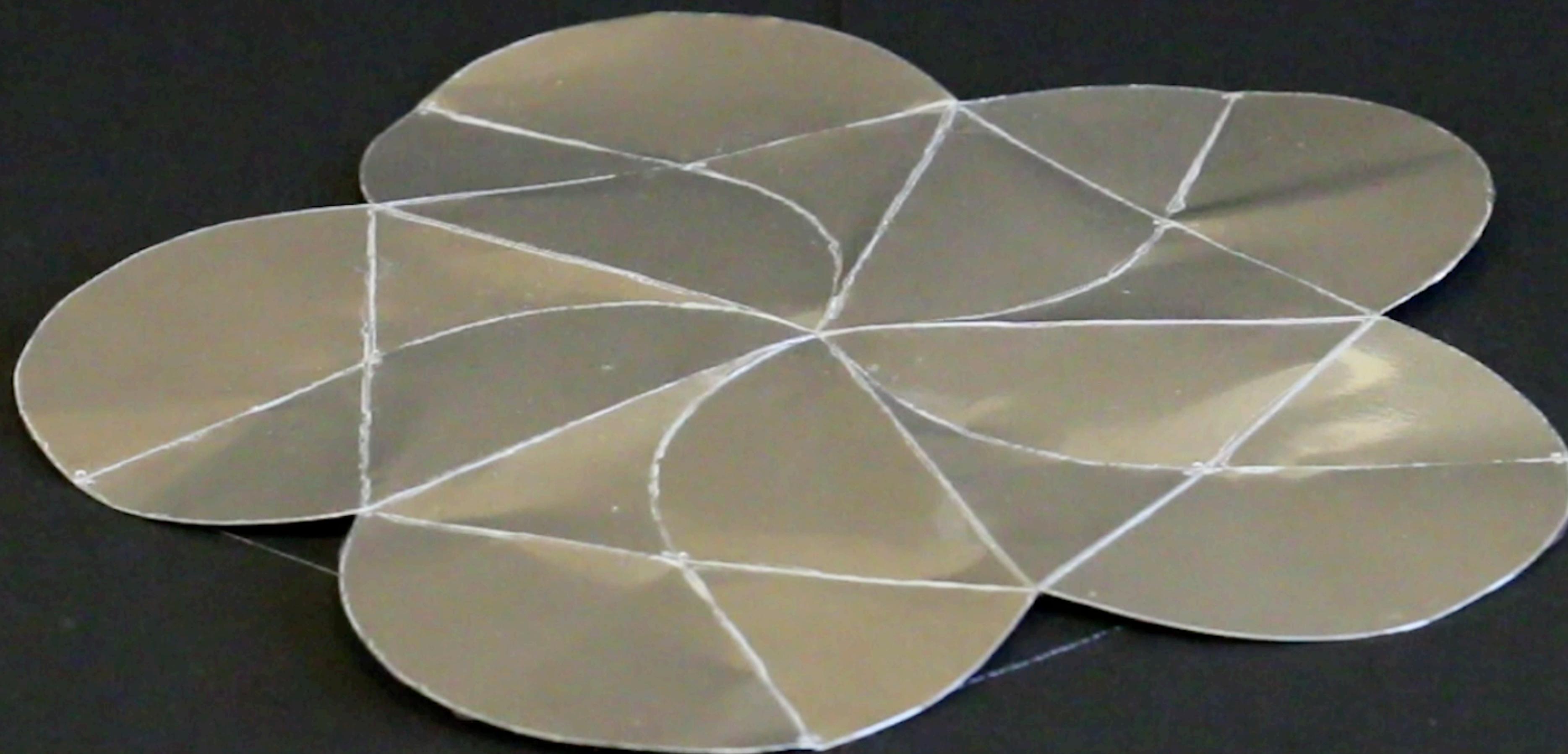
DS CATIA





physical prototype [Kilian et al., TOG, 2017]

### 3. Creating Aesthetic and Fabricatable Shapes



physical prototype [Kilian et al., TOG, 2017]

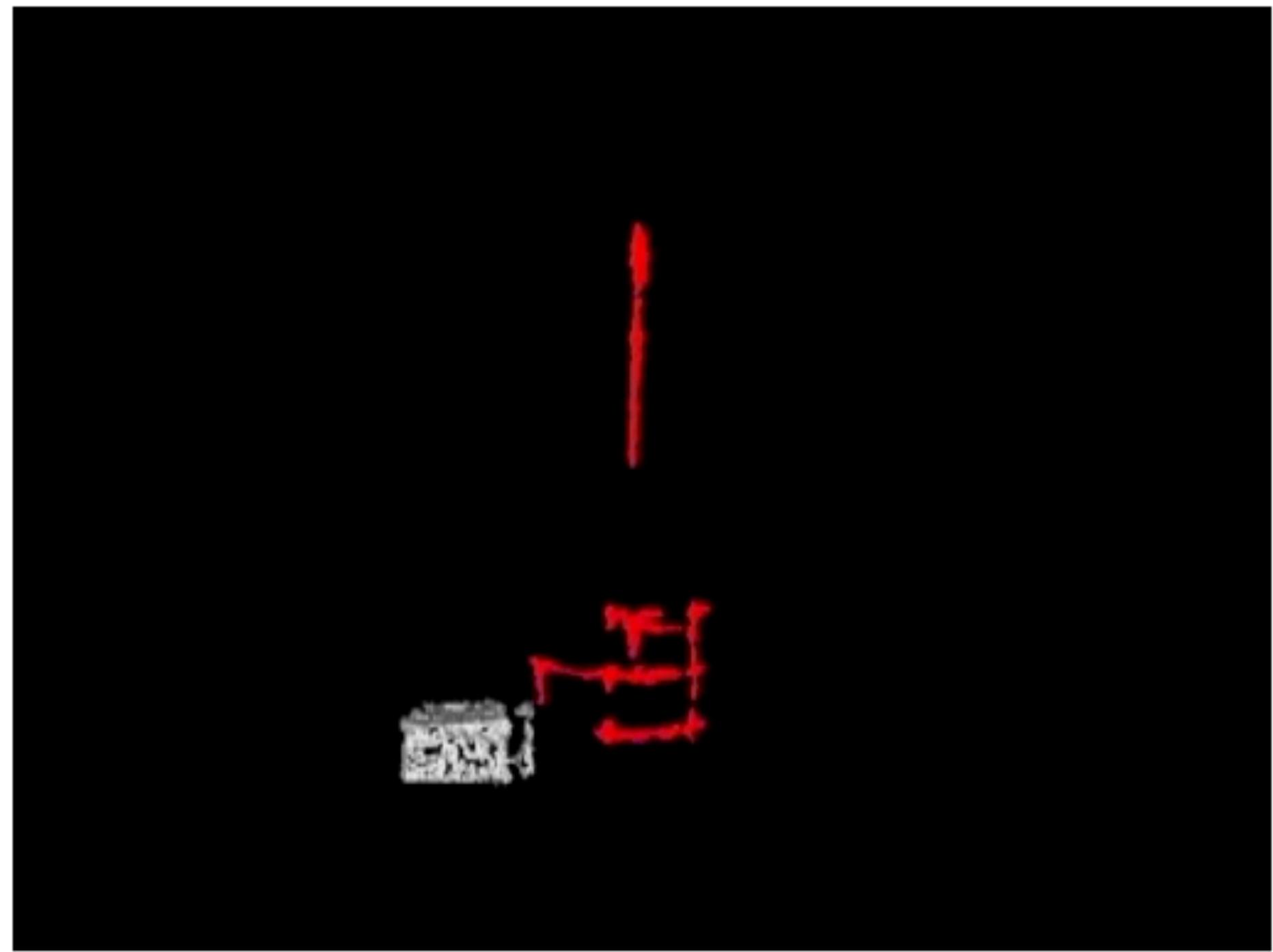
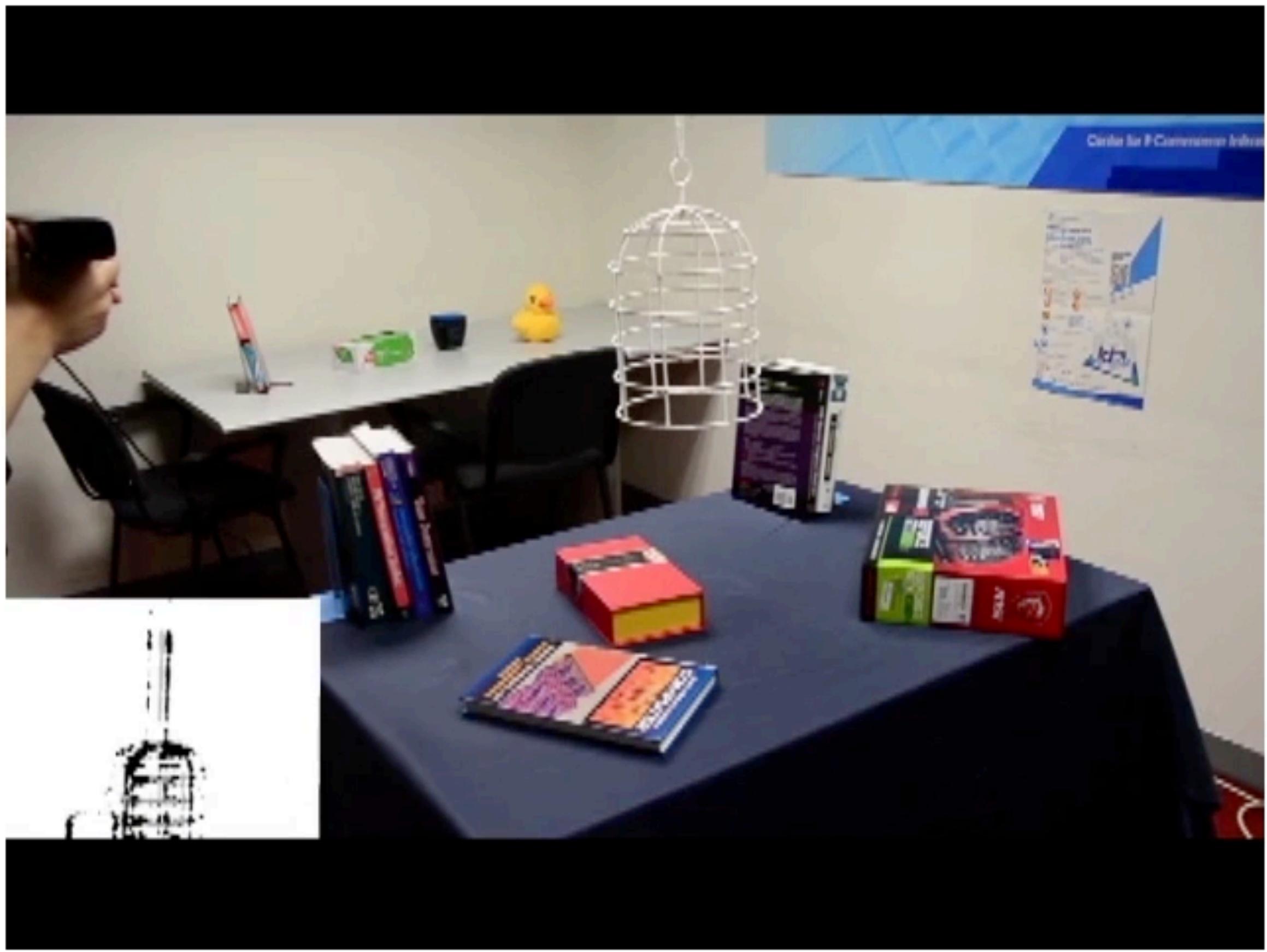


image difference set

## 4. Scanning and Modeling

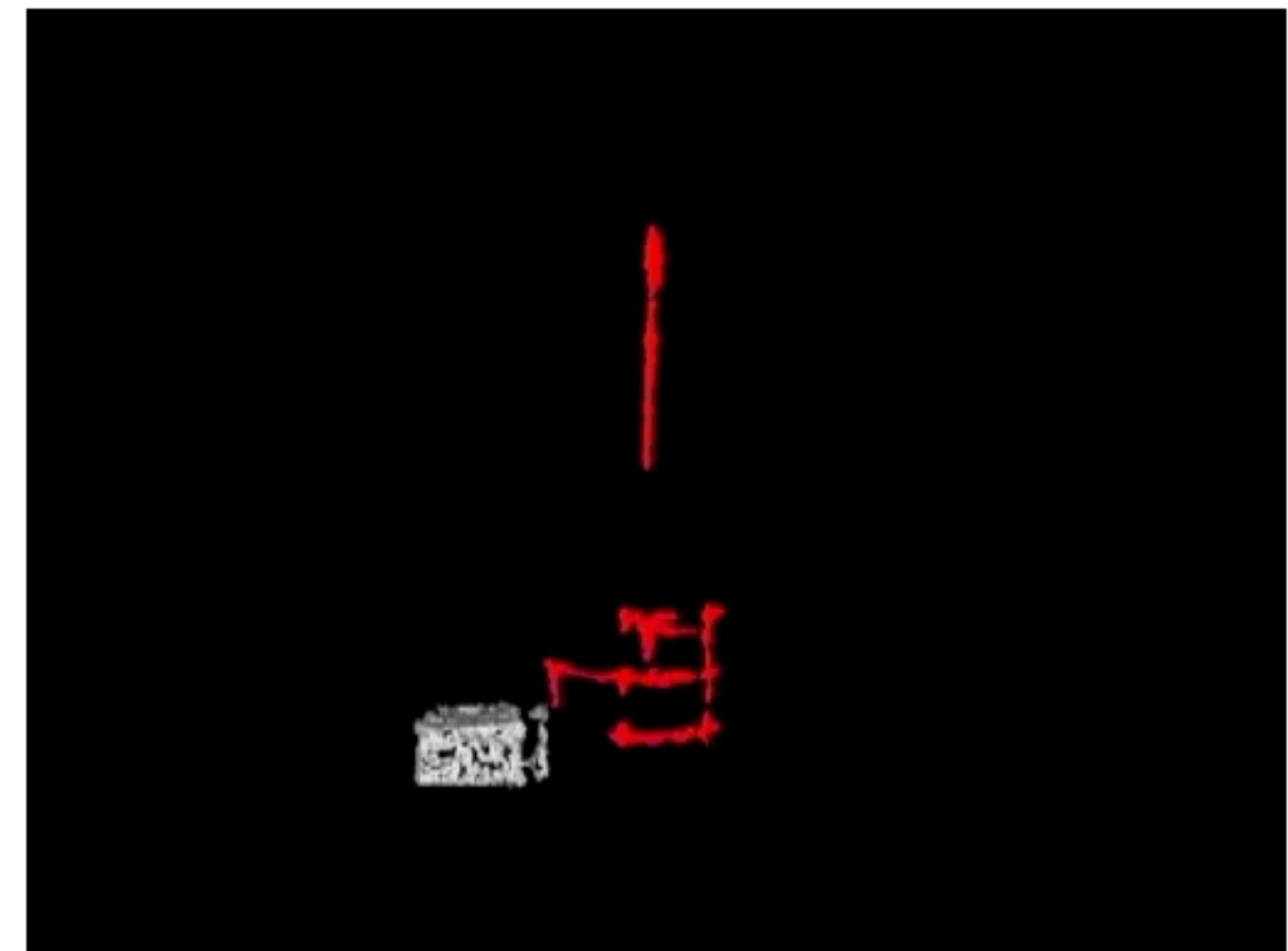
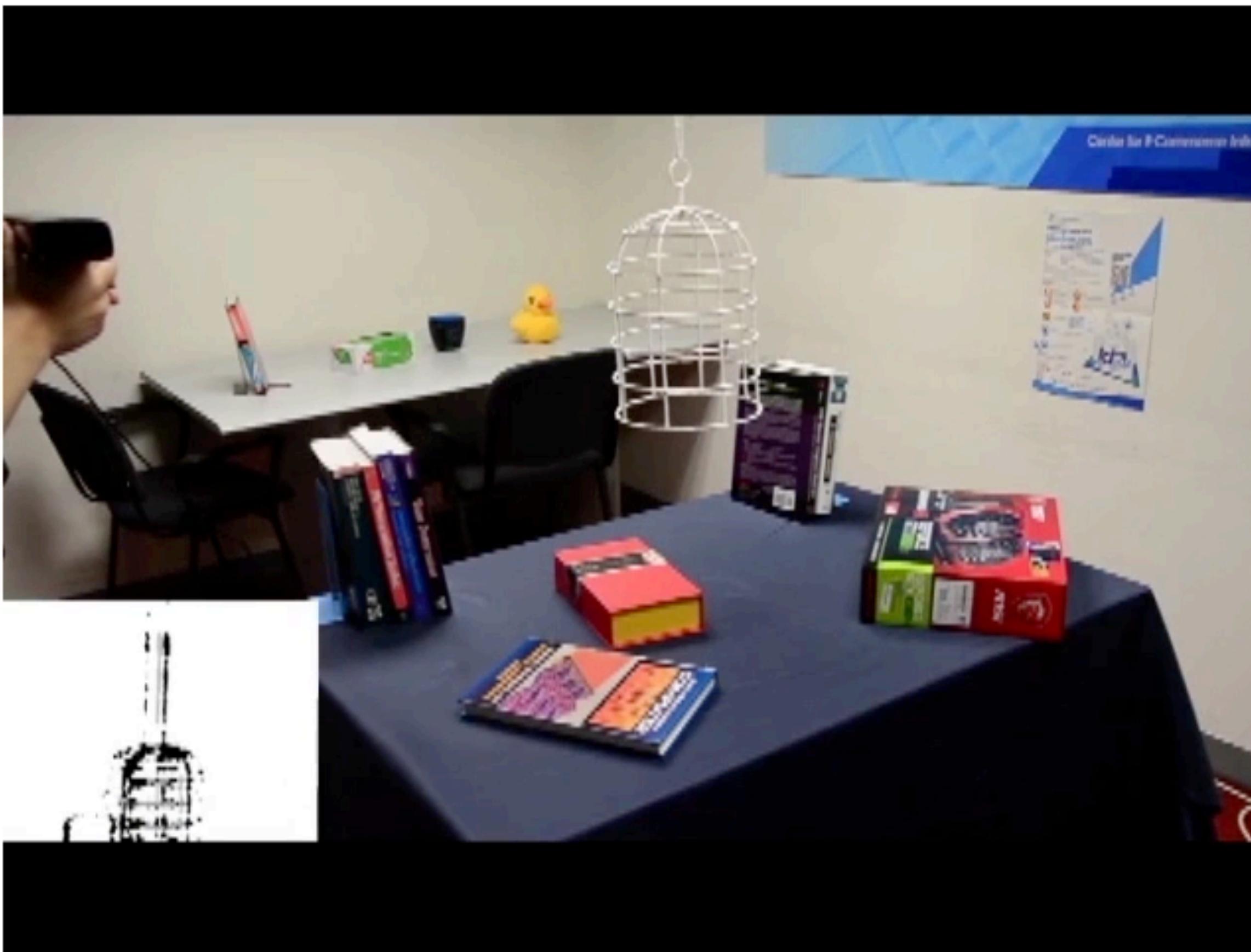
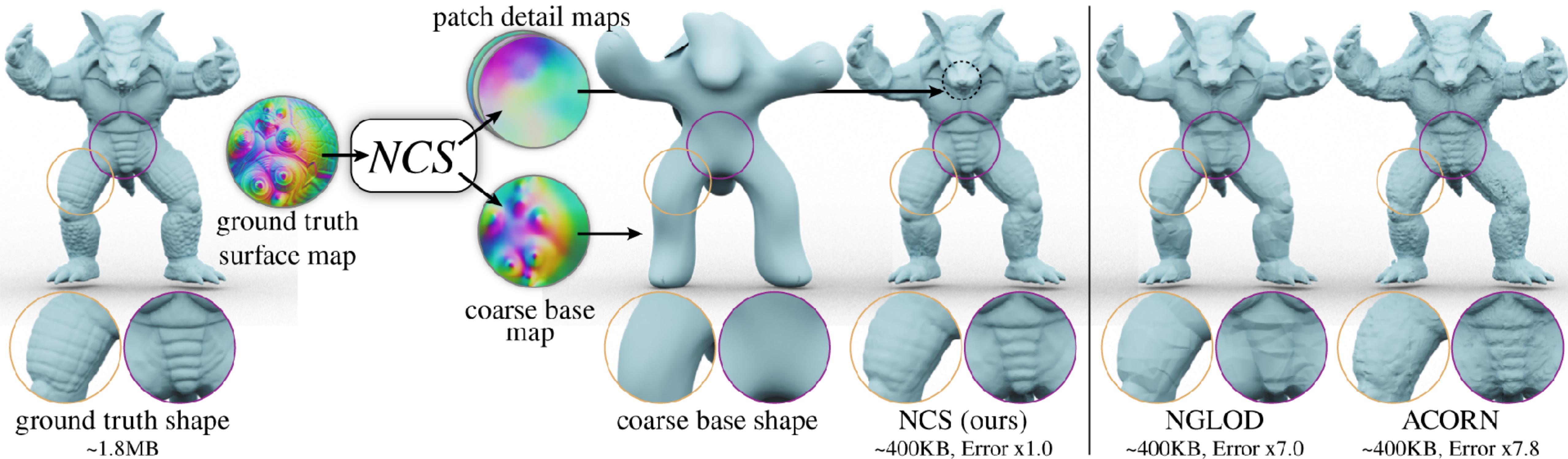
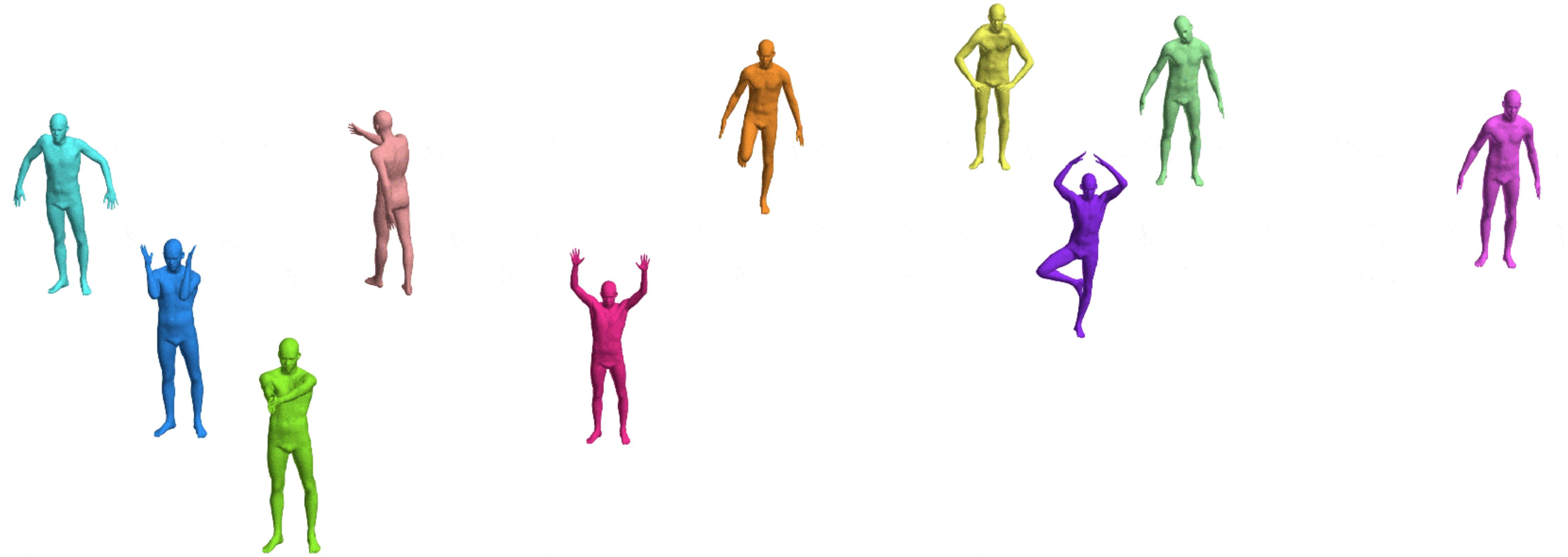


image difference set

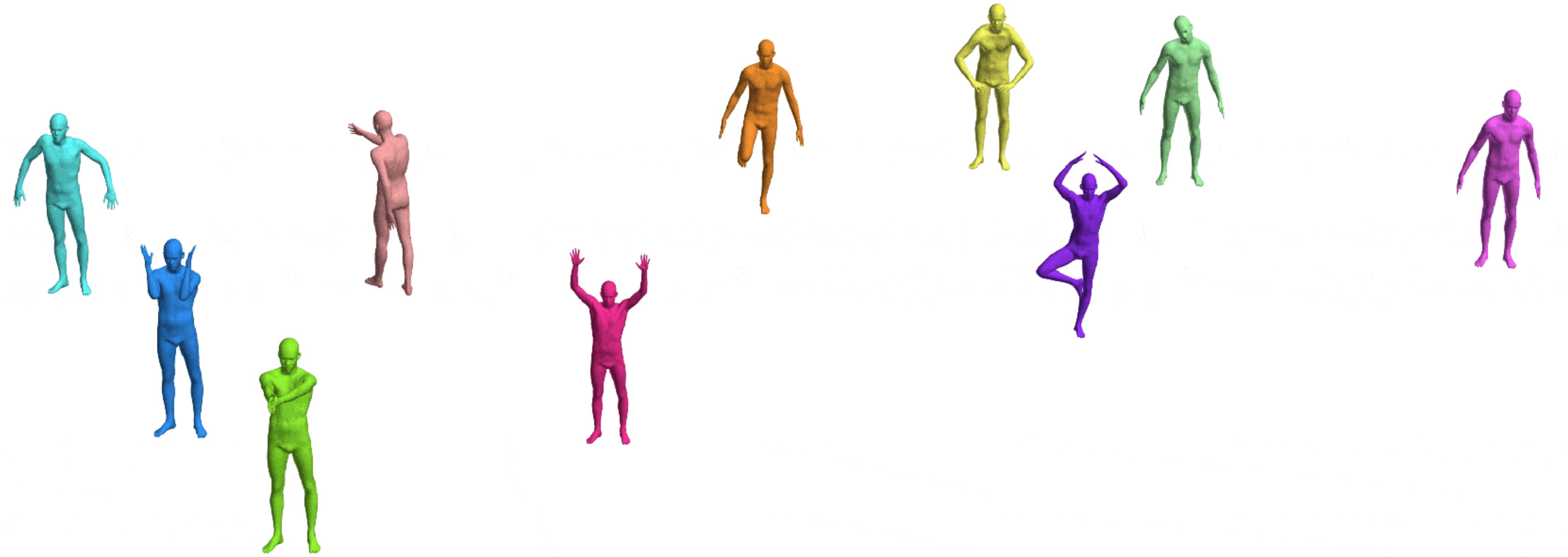
# Neural Representation [Luca M.]



# Neural Shape Spaces [Sanjeev M.]



# Neural Shape Spaces [Sanjeev M.]



# Quiz



1. Compute the eigen values/vectors of the matrix  $A = \begin{bmatrix} 10 & 3 \\ 3 & 16 \end{bmatrix}$
2. Compute maximum/minimum of the following function  $f(x) = 10x^2 - 3x$
3. Write Python/C++ function for any sorting algorithm of your choice. What is your favorite sorting algorithm?
4. What is the complexity of this code?

```
def sparse_dot_product(list_A, list_B, indices_A, indices_B):  
    pos_B = 0  
    len_A = len(list_A)  
    len_B = len(list_B)  
    result = 0  
    for i in range(len_A):  
        if pos_B < len_B - 1:  
            while indices_B[pos_B] < indices_A[i]:  
                pos_B += 1  
            if indices_B[pos_B] == indices_A[i]:  
                result += list_A[i] * list_B[pos_B]  
    return result
```

# Background



- A. Rate your Linear Algebra background — scale of 0-5
- B. Rate your Calculus background — scale of 0-5
- C. Rate your Coding background — scale of 0-5
- D. Rate your Data structure/algorithms background — scale of 0-5
- E. What is the most complex piece of code you wrote?  
Why was it challenging?

Geometry  
*γεωμετρία*

# Geometry

*γεωμετρία*

geo = earth

# Geometry

*γεωμετρία*

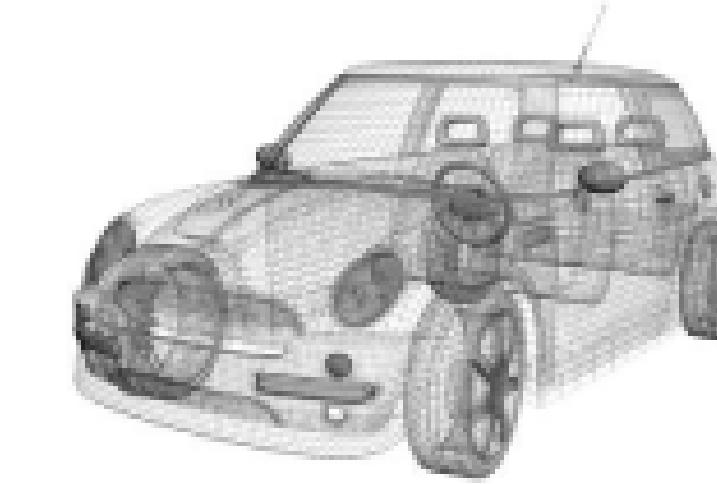
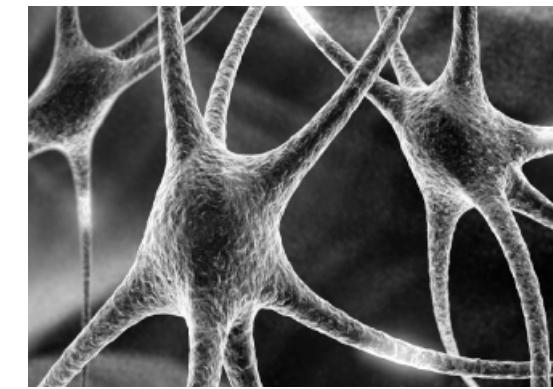
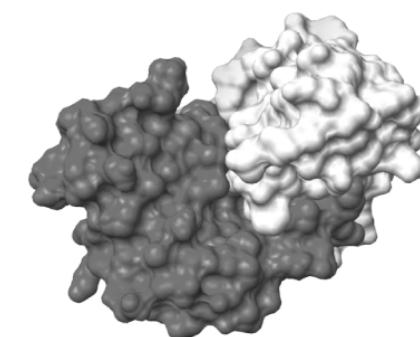
geo = earth      metria = measure

# Geometry

*γεωμετρία*

**geo = earth**      metria = measure



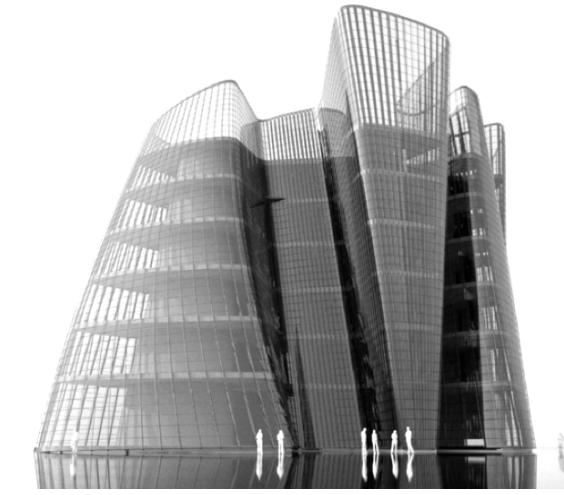


# Geometry

*γεωμετρία*

**geo = earth**

metria = measure



# Geometry

*γεωμετρία*

geo = earth    **metria = measure**



microscope



ultrasound



MRI scanner



x-ray diffractometer

# Geometry *γεωμετρία*

geo = earth

**metria = measure**



stereo camera



radio telescope



laser scanner



time-of-flight scanner

# Digital Geometry



## Entertainment



structured light scanner

Acquisition



2D depth maps

# Digital Geometry



## Entertainment

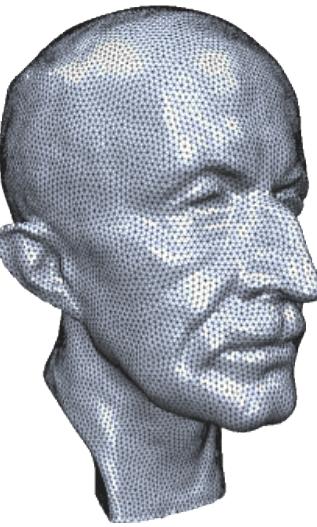


structured light scanner

Acquisition



2D depth maps



3D model

Reconstruction

# Digital Geometry



## Entertainment

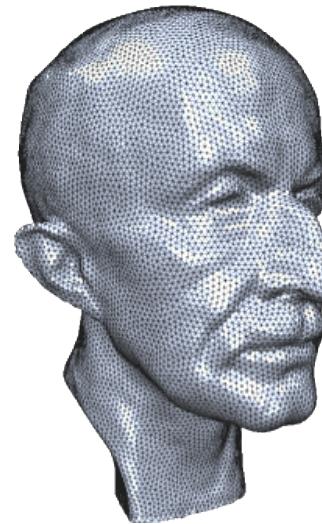


structured light scanner

Acquisition



2D depth maps



3D model

Reconstruction

- **Modeling** → digital character and set design
- **Simulation** → computer games, movies, special effects

# Digital Geometry

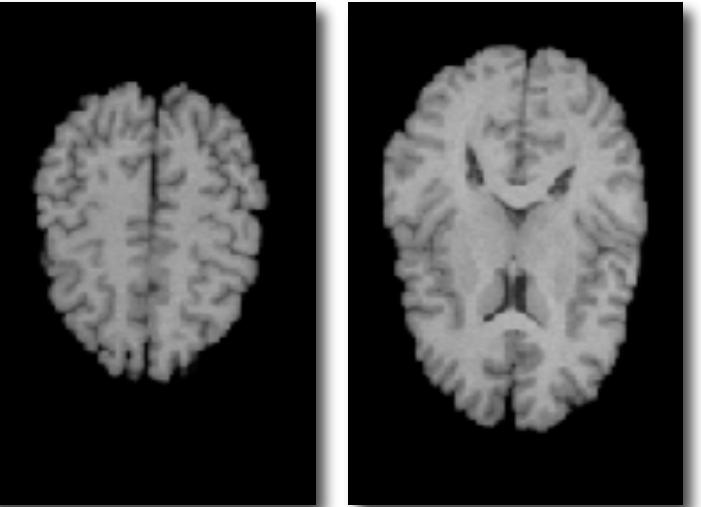


## Medical Applications



MRI scanner

Acquisition



2D slices

# Digital Geometry

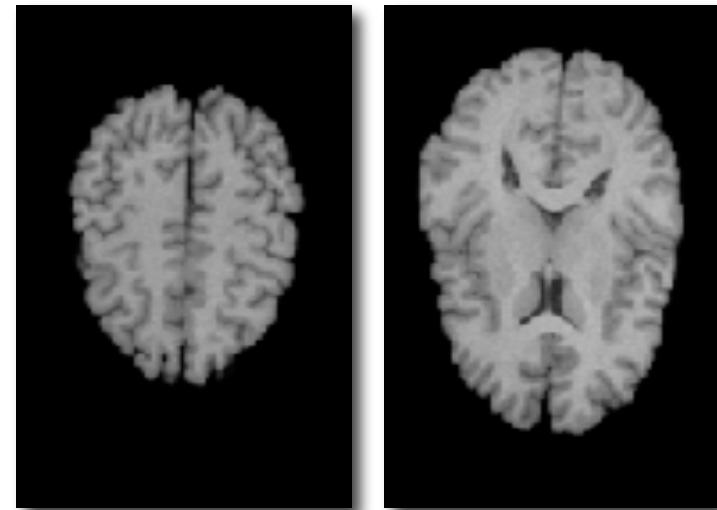


## Medical Applications



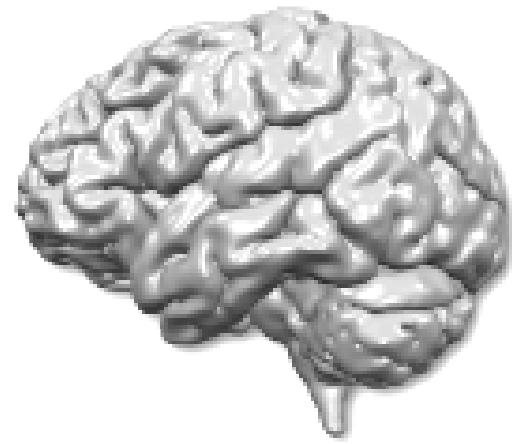
MRI scanner

Acquisition



2D slices

Reconstruction



3D model

# Digital Geometry

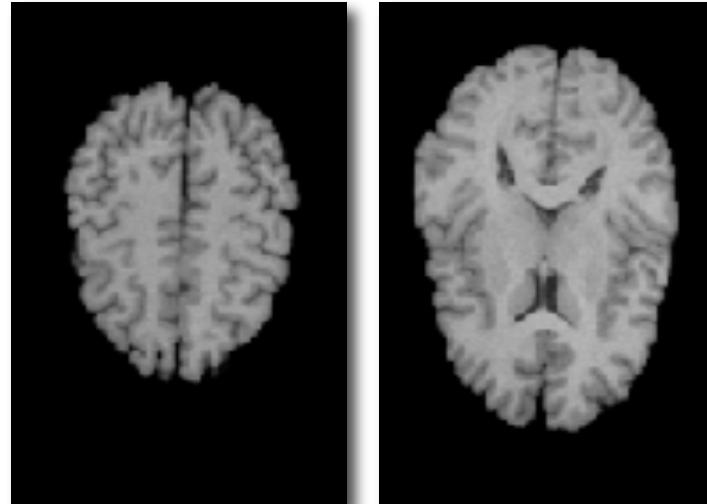


## Medical Applications



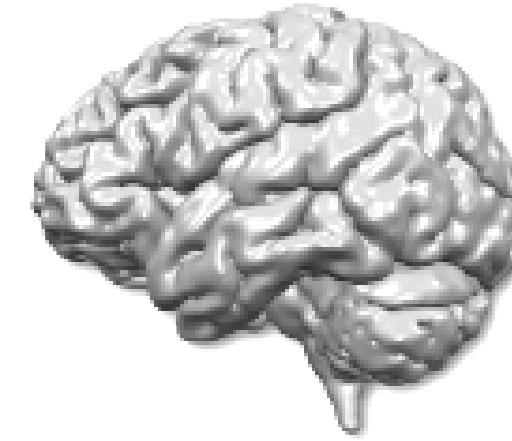
MRI scanner

Acquisition



2D slices

Reconstruction



3D model

- **Analysis** → diagnosis, operation planning
- **Modeling** → design of prosthetics
- **Simulation** → surgery training

# Digital Geometry

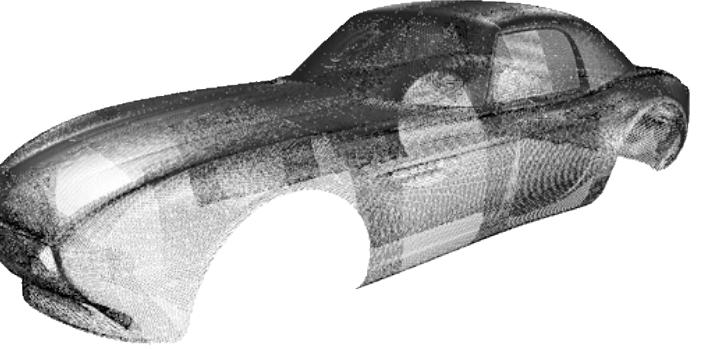


## Engineering Applications



laser scanner

Acquisition



3D point cloud

# Digital Geometry

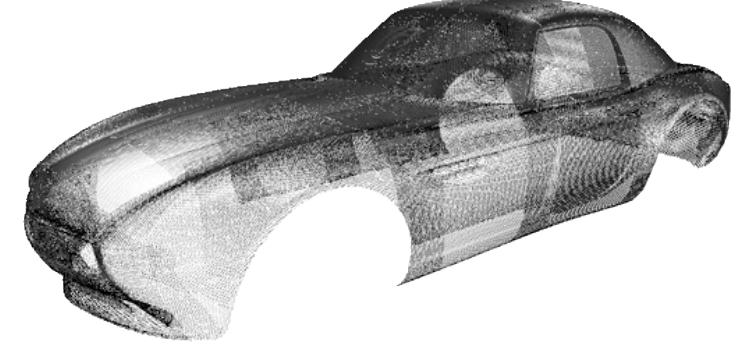


## Engineering Applications



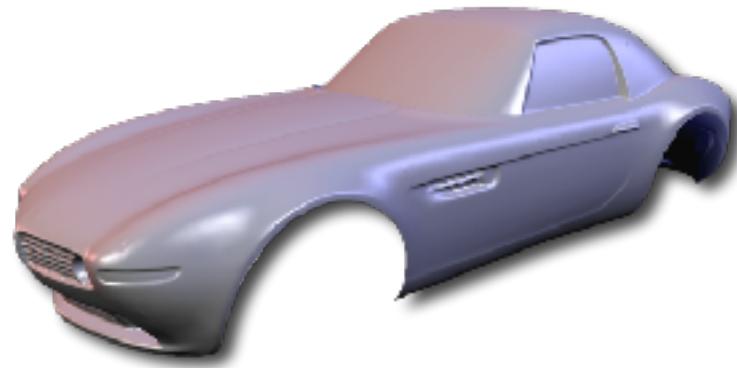
laser scanner

Acquisition



3D point cloud

Reconstruction



3D model

# Digital Geometry

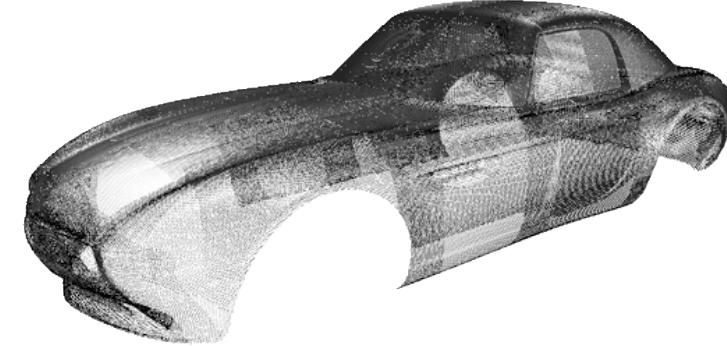


## Engineering Applications

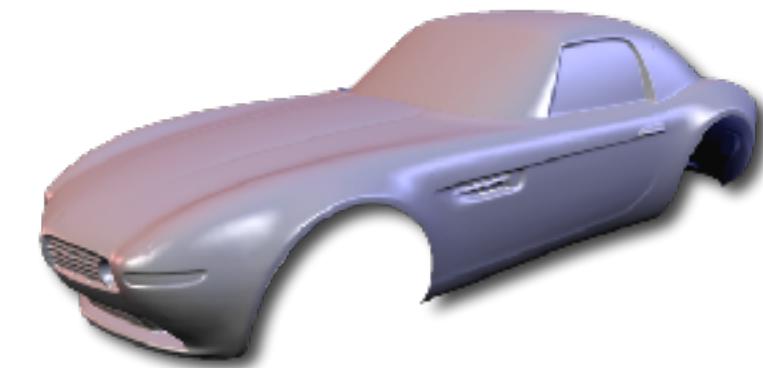


laser scanner

Acquisition



3D point cloud



3D model

Reconstruction

- **Analysis** → quality control
- **Modeling** → product design, rapid prototyping
- **Simulation** → aerodynamics, crash tests

# Digital Geometry

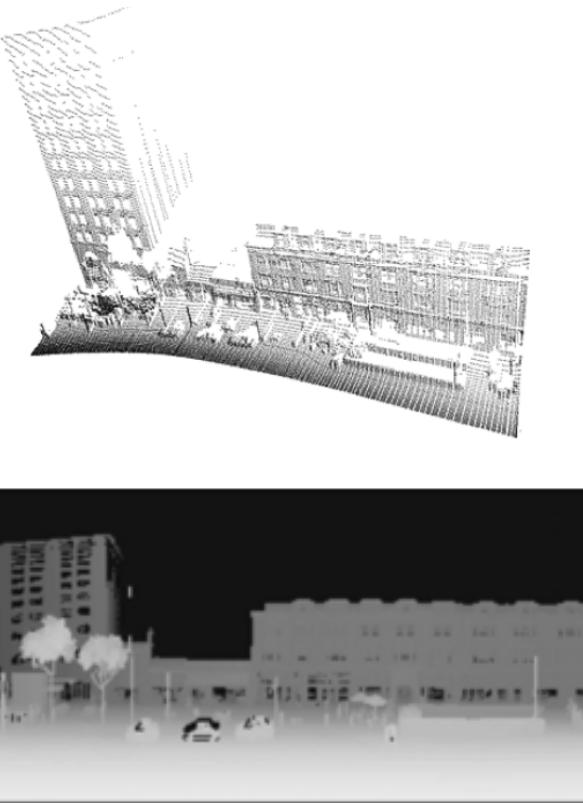


## Urban Planning and Modeling



multi-sensor scanning

Acquisition



range-data, images, etc.

Reconstruction



3D city model

# Digital Geometry

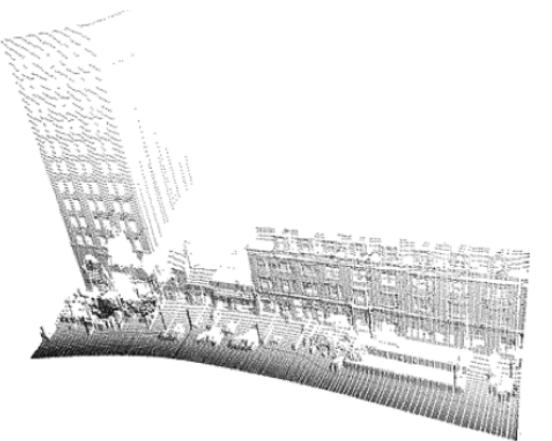


## Urban Planning and Modeling



Acquisition

multi-sensor scanning



Reconstruction

range-data, images, etc.



3D city model

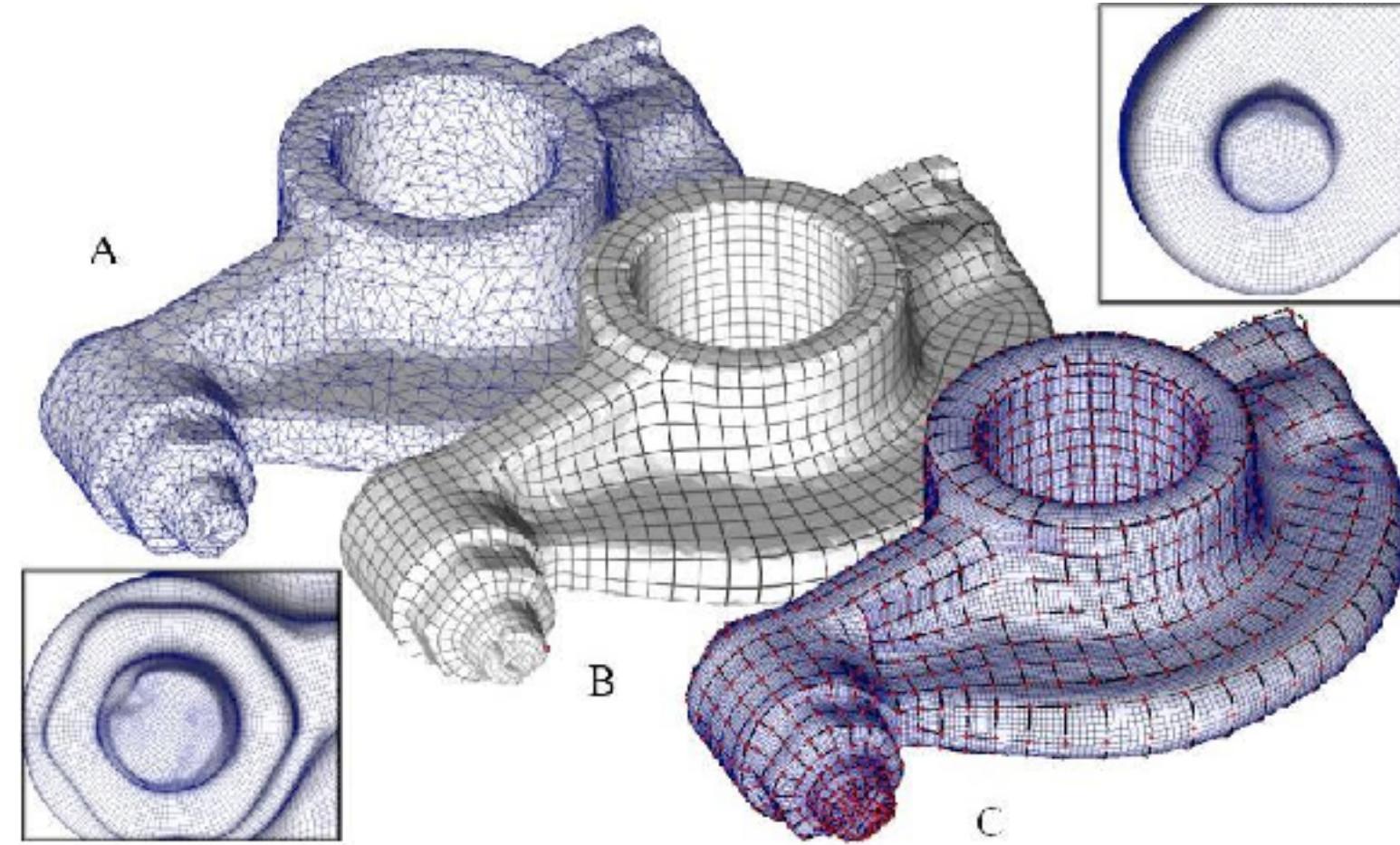
- **Analysis** → navigation, map design, traffic engineering
- **Modeling** → urban planning, virtual worlds
- **Simulation** → traffic, pollution, evacuation, etc.

## CreativeAI: Deep Learning for Graphics



<http://geometry.cs.ucl.ac.uk/creativeai/>

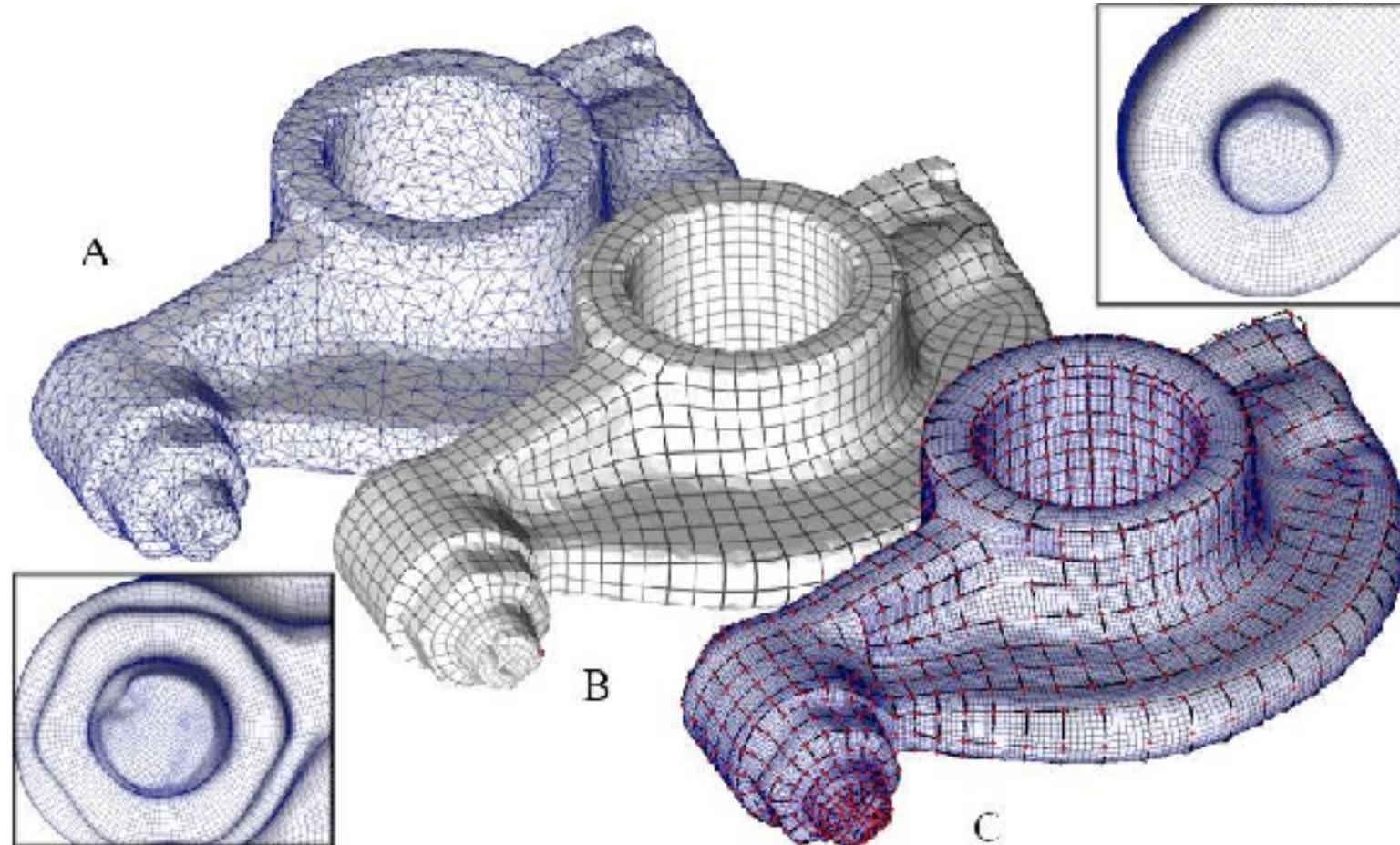
# Geometric Modeling and Processing



# Geometric Modeling and Processing



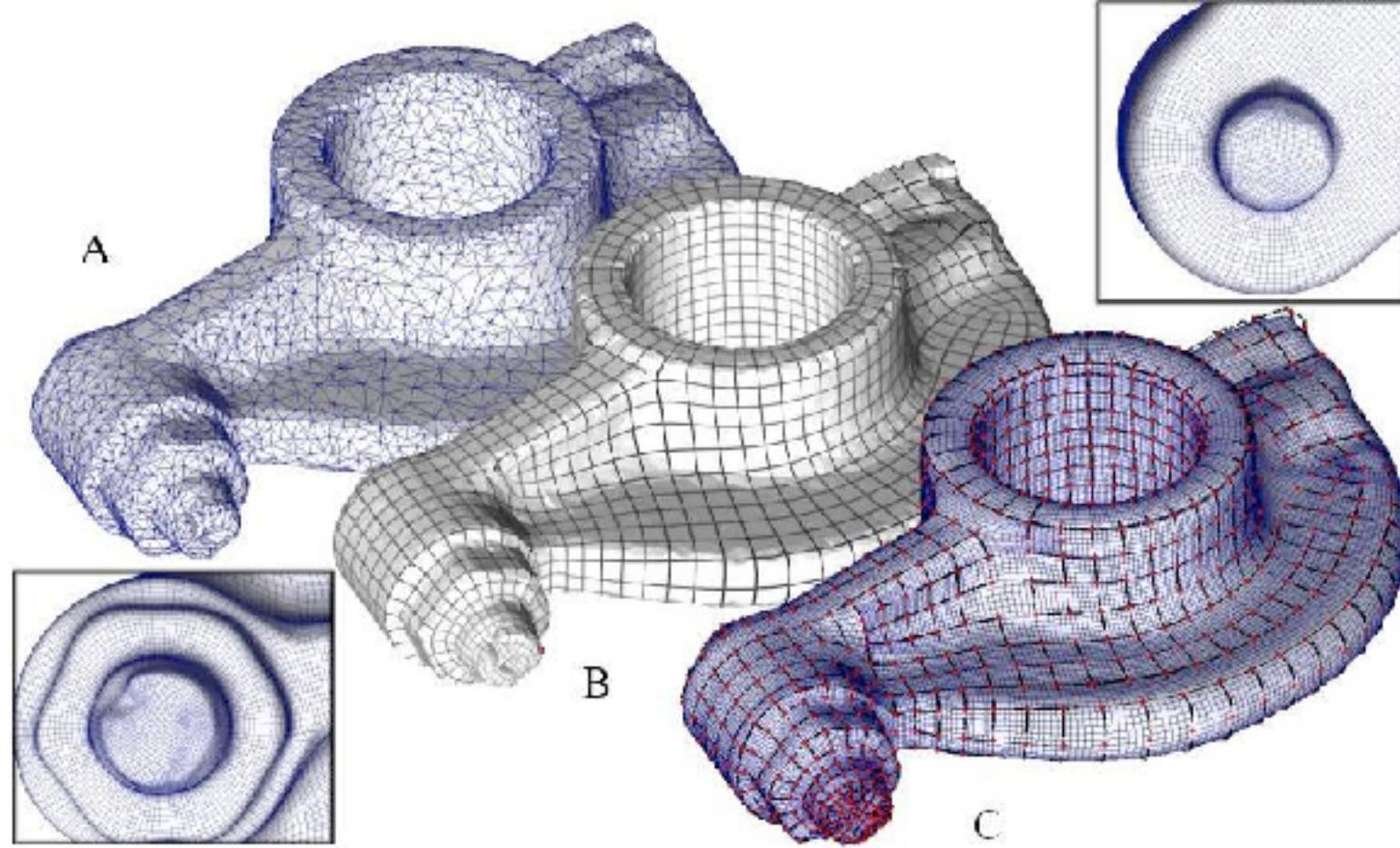
- To describe any real-life or imagined object on the computer: must start with shape (2D/3D)



# Geometric Modeling and Processing



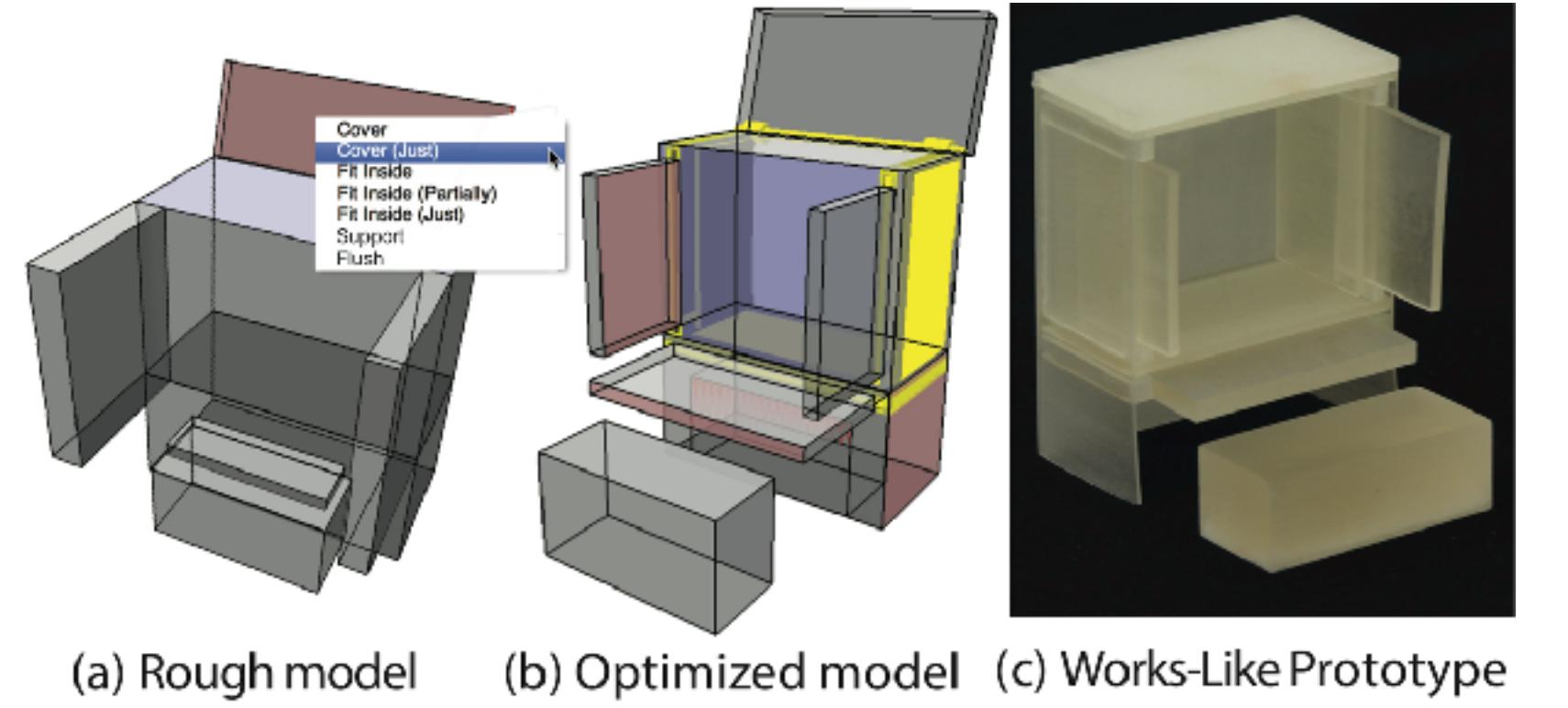
- To describe any real-life or imagined object on the computer: must start with shape (2D/3D)
- Geometry processing: computerized modeling of 2D/3D geometry + texture (appearance)



# Applications



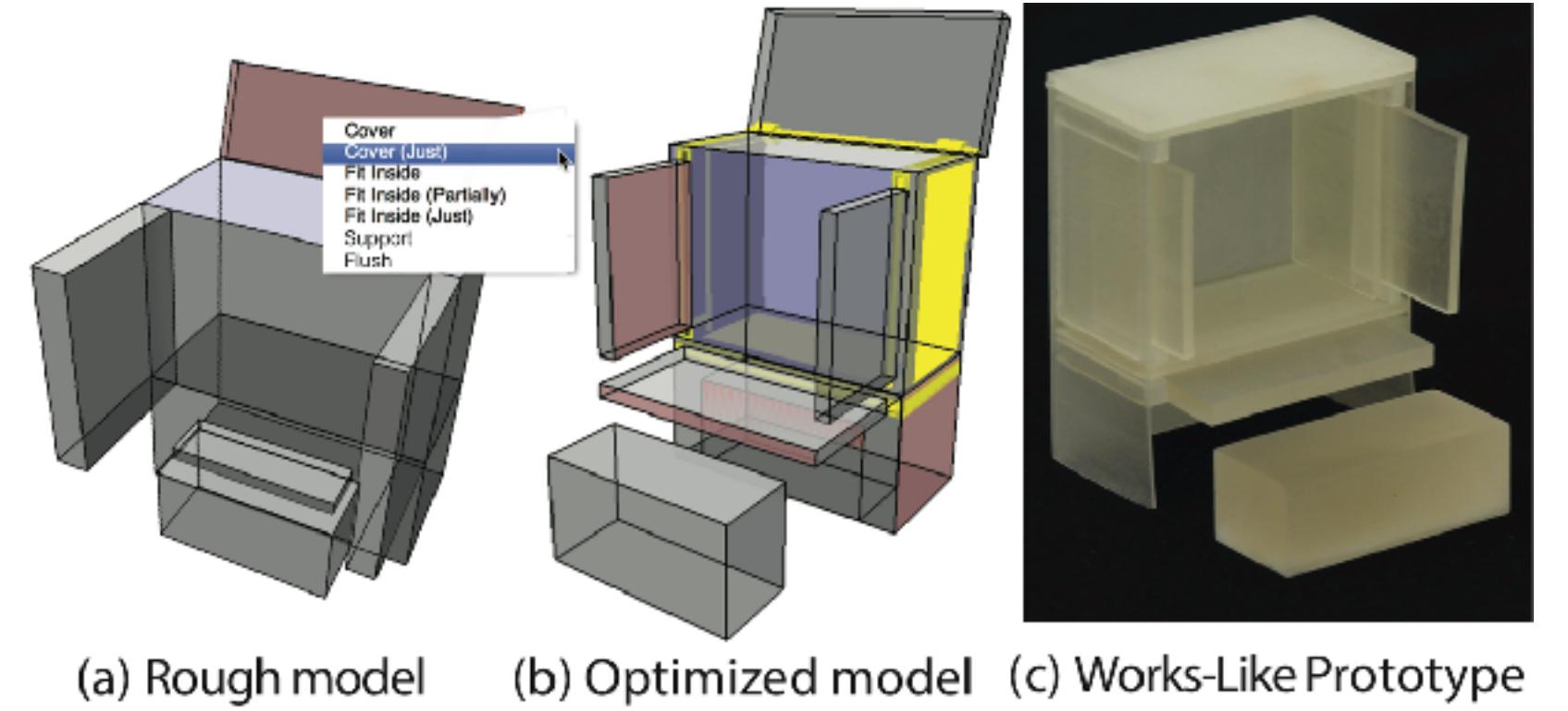
# Applications



(a) Rough model    (b) Optimized model    (c) Works-Like Prototype

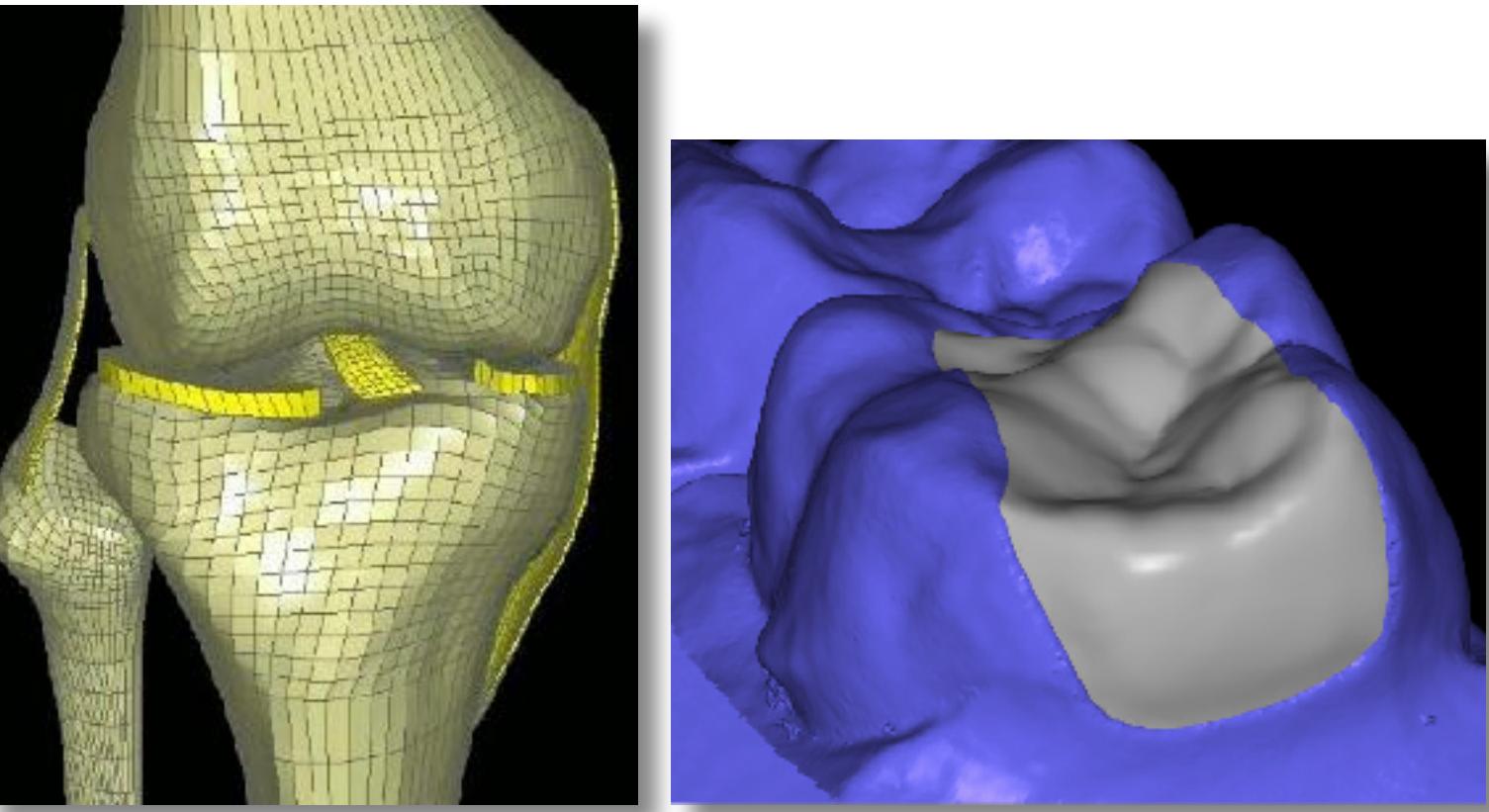
Product design and prototyping

# Applications



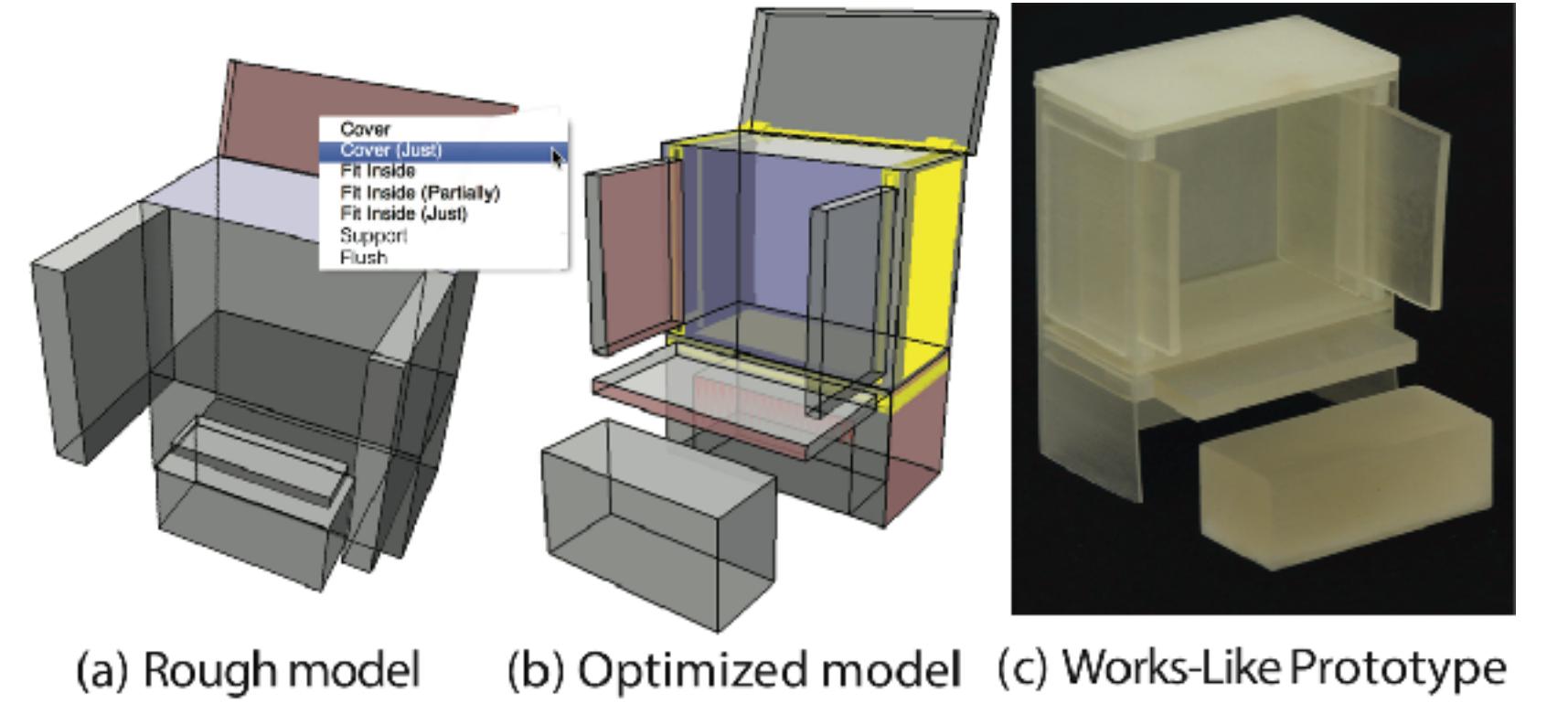
(a) Rough model (b) Optimized model (c) Works-Like Prototype

Product design and prototyping



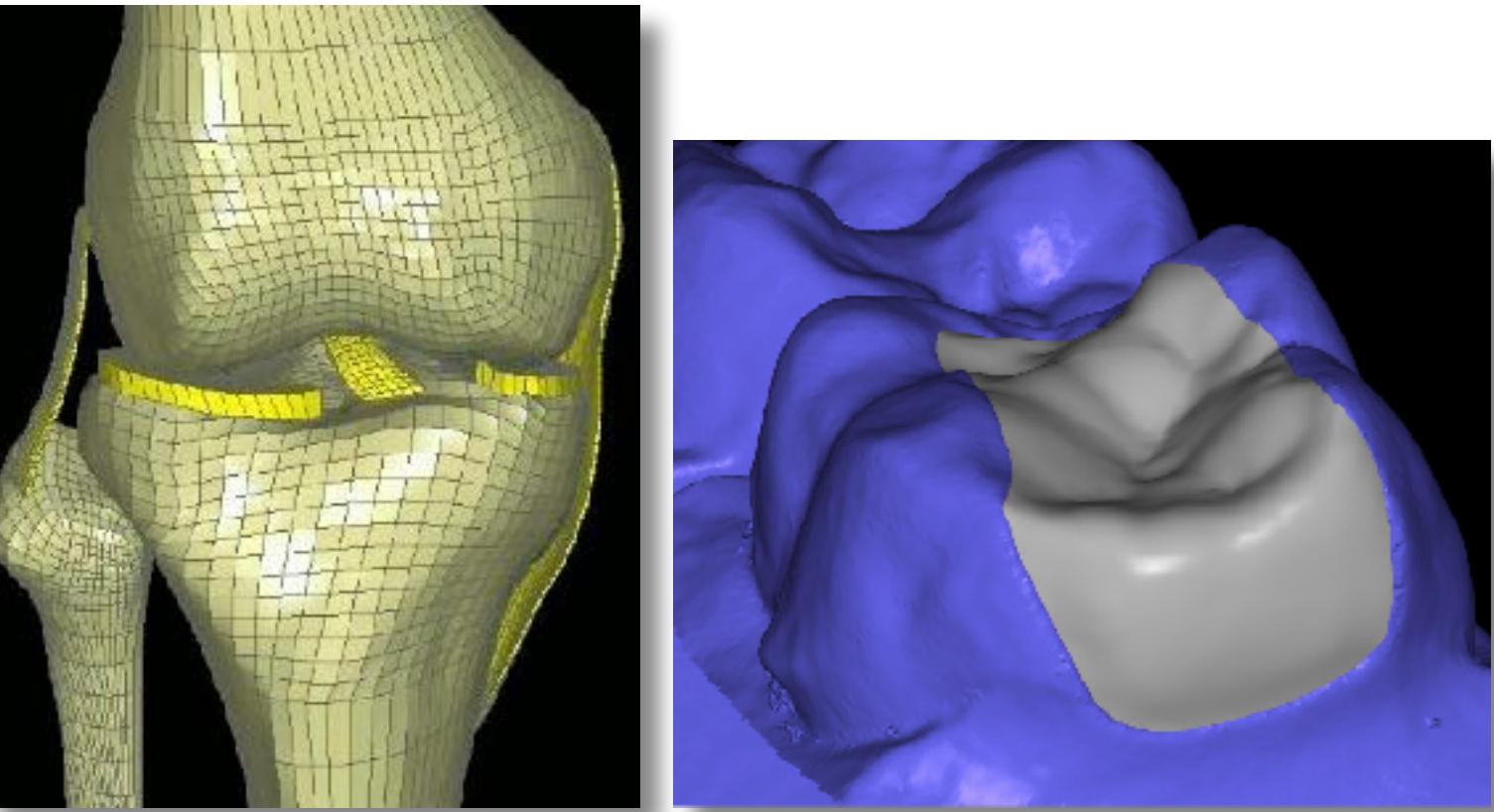
Medicine, prosthetics

# Applications



(a) Rough model (b) Optimized model (c) Works-Like Prototype

Product design and prototyping

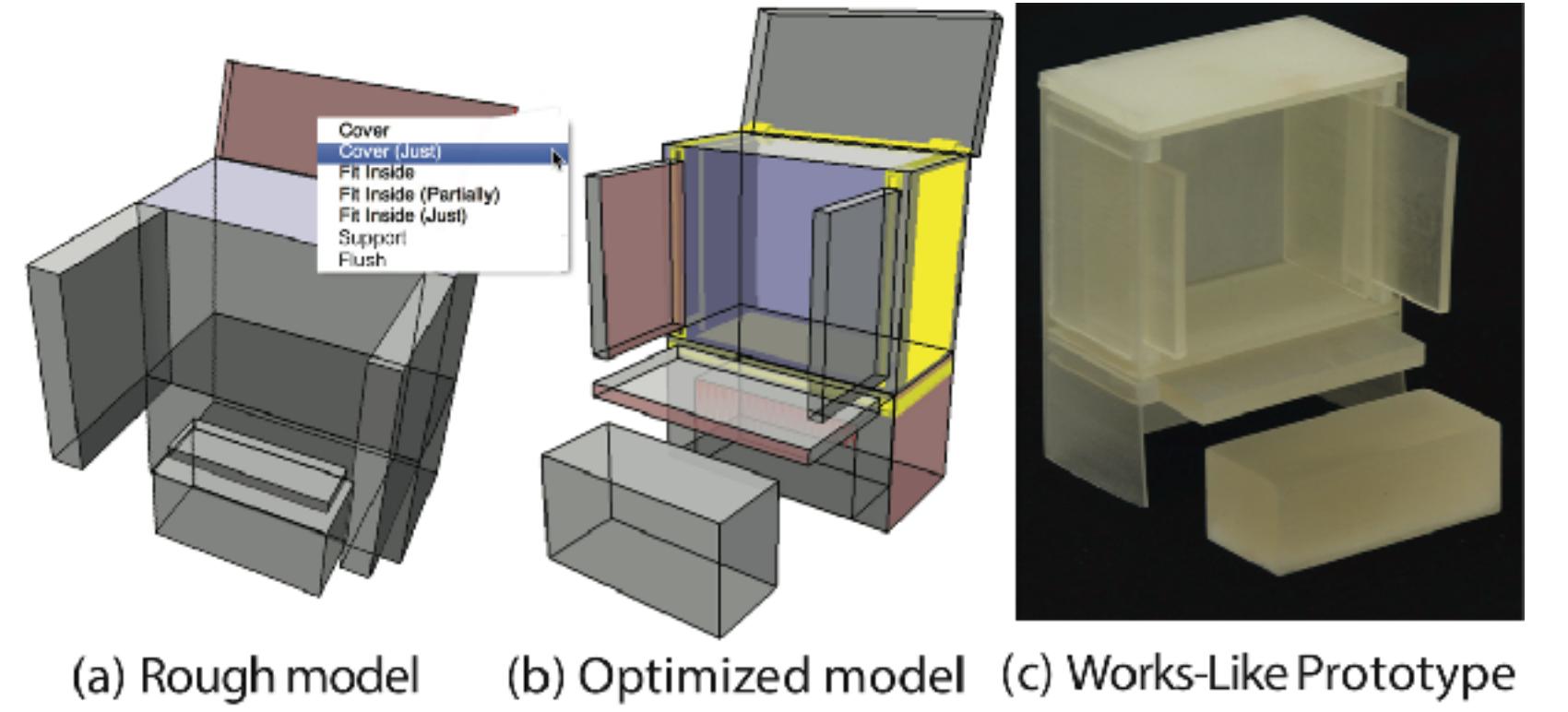


Medicine, prosthetics



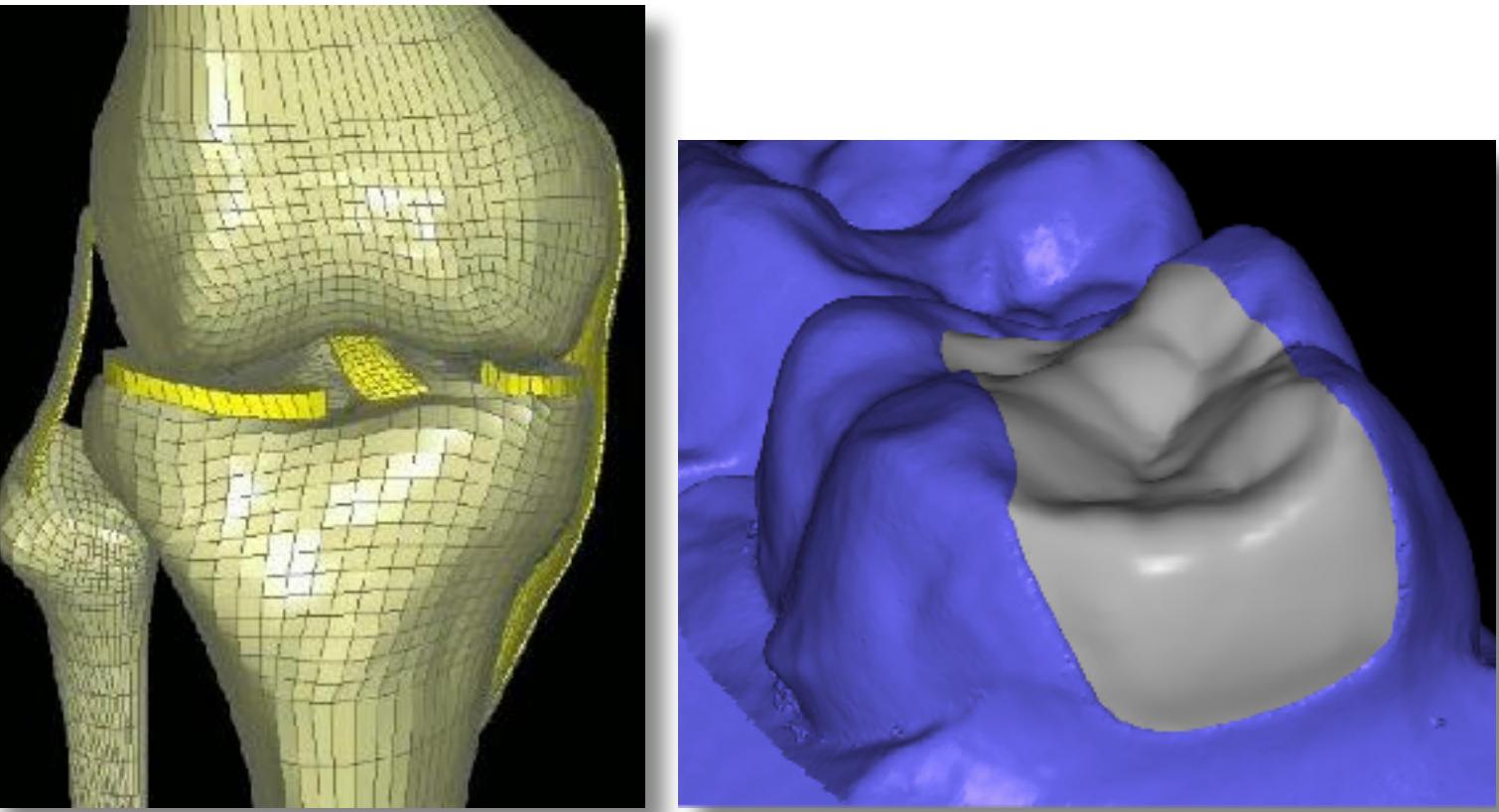
Architecture

# Applications



(a) Rough model (b) Optimized model (c) Works-Like Prototype

Product design and prototyping



Medicine, prosthetics



Architecture

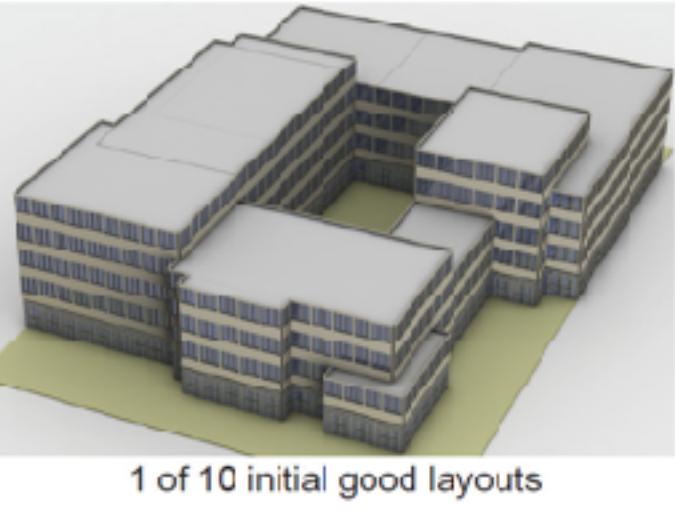


Cultural heritage

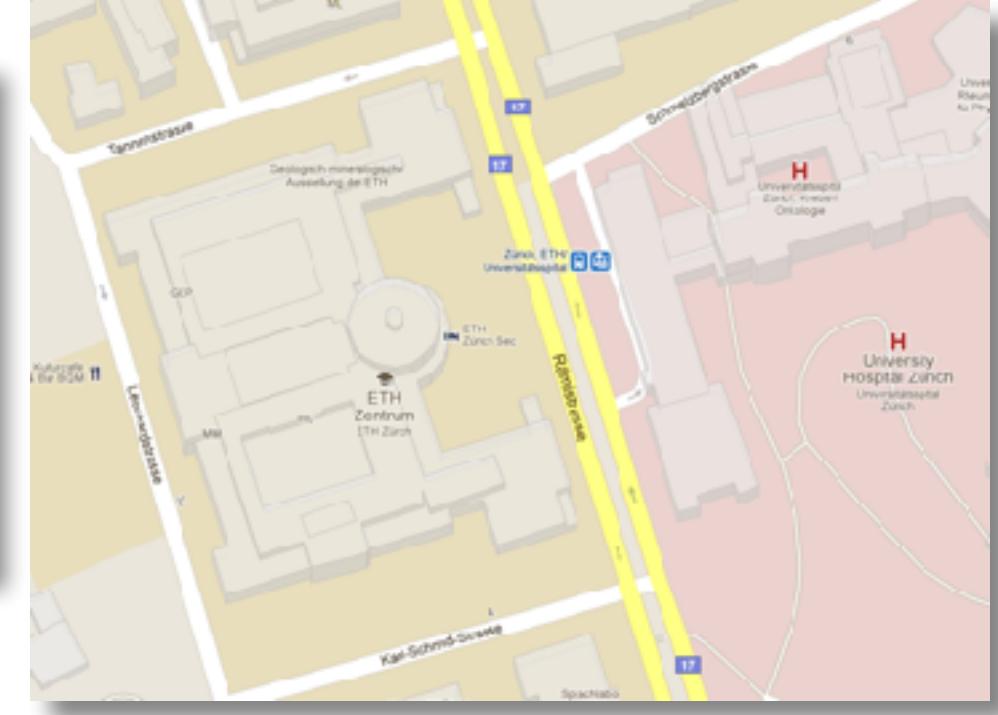
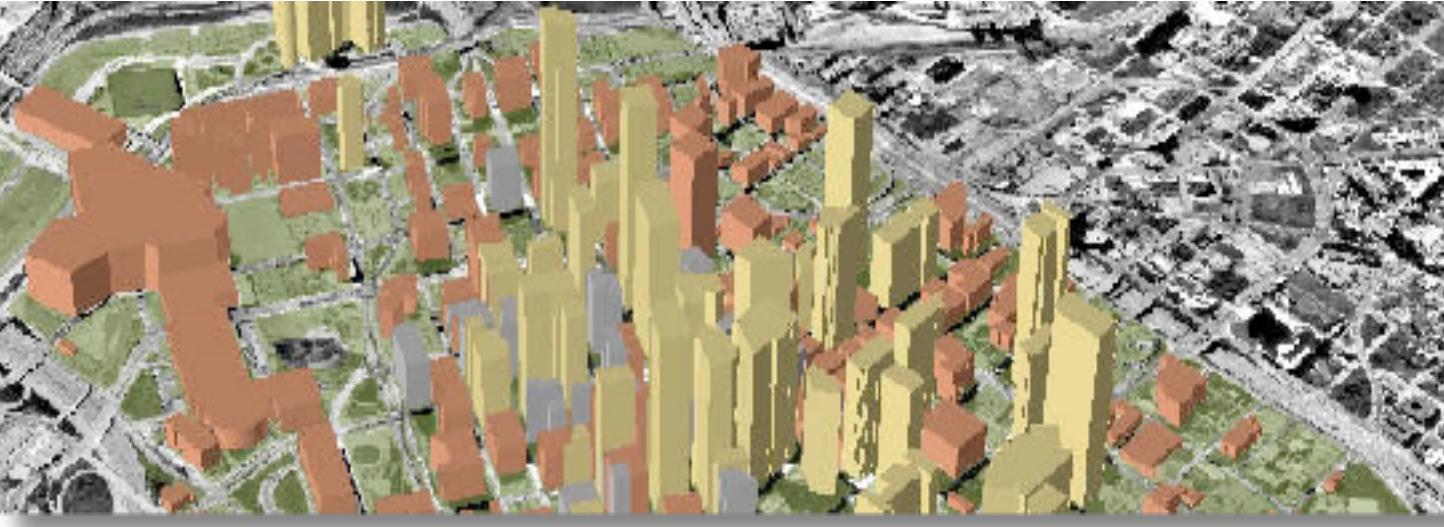
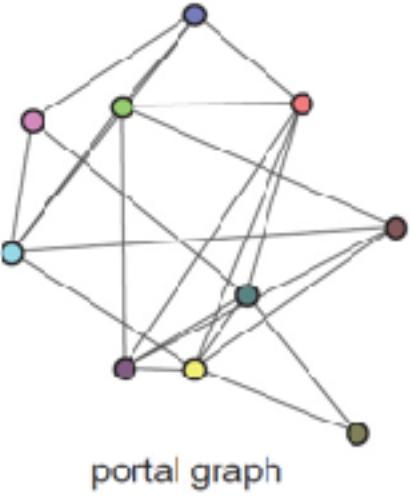
# Applications



# Applications

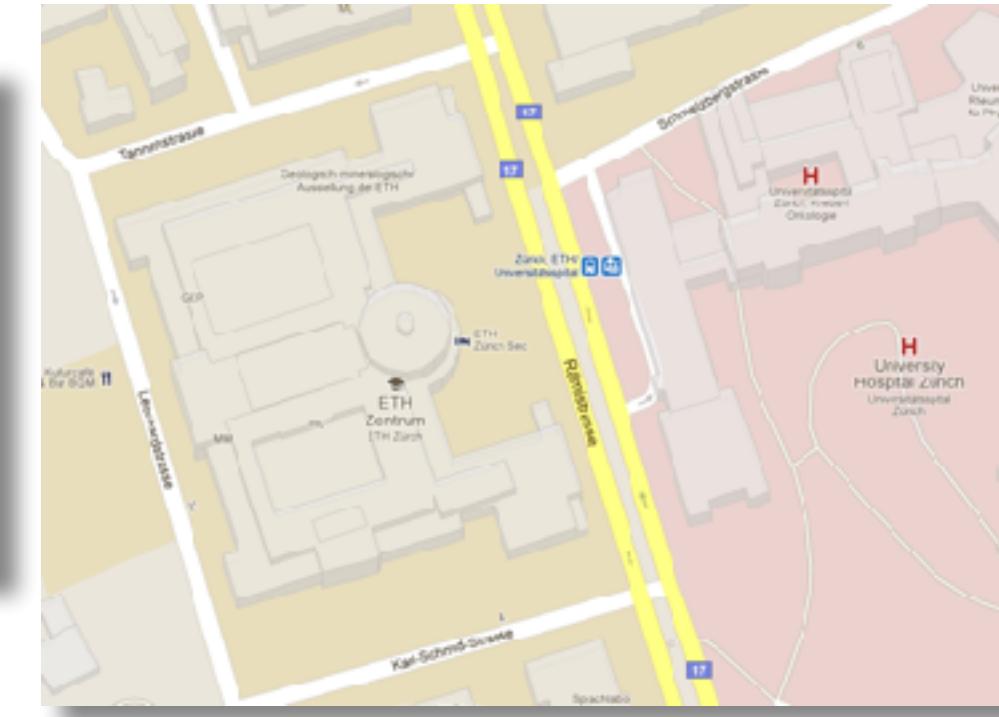
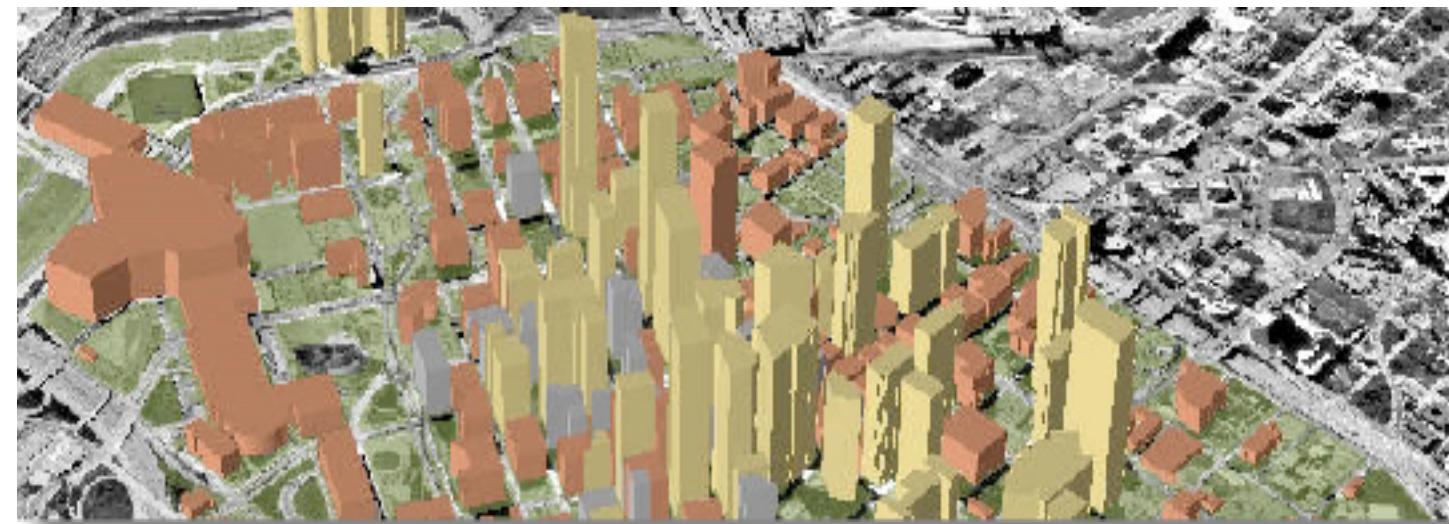
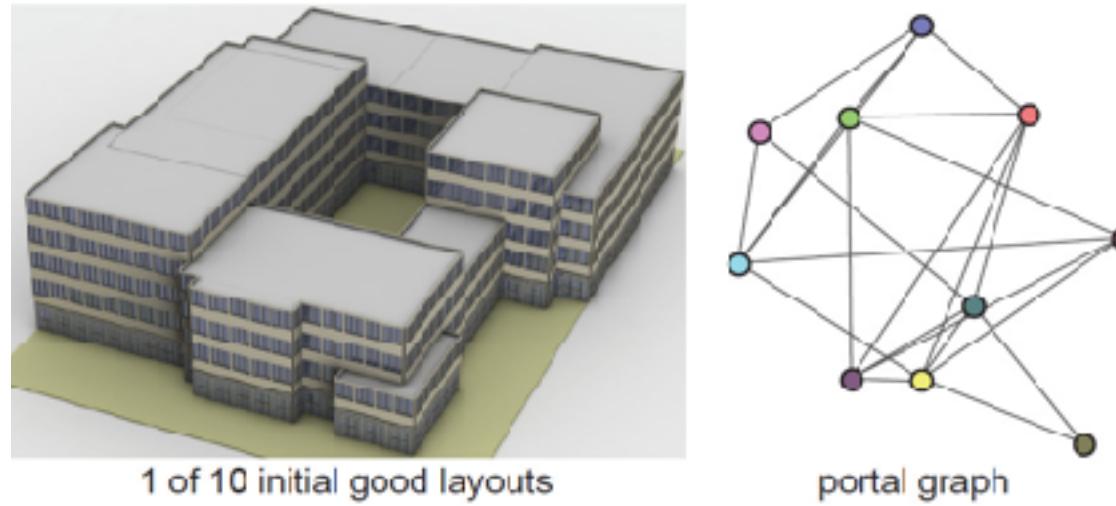


1 of 10 initial good layouts

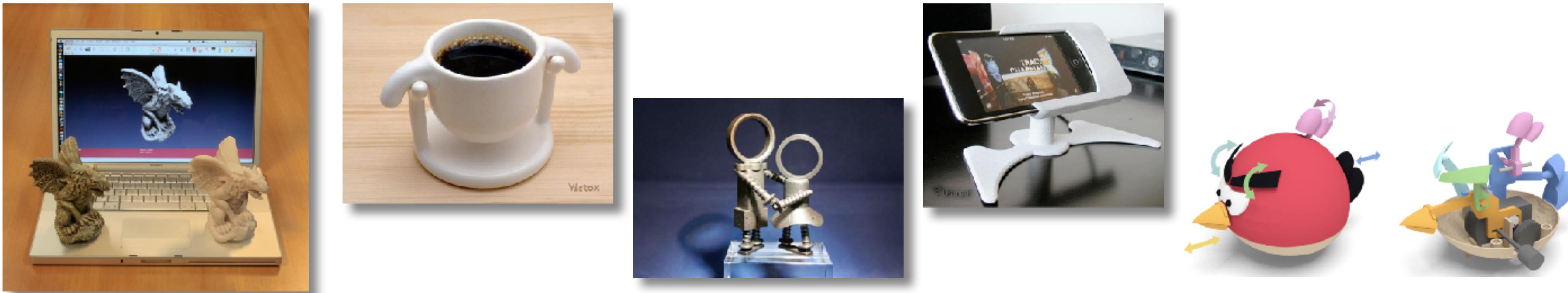


## Geographical systems

# Applications

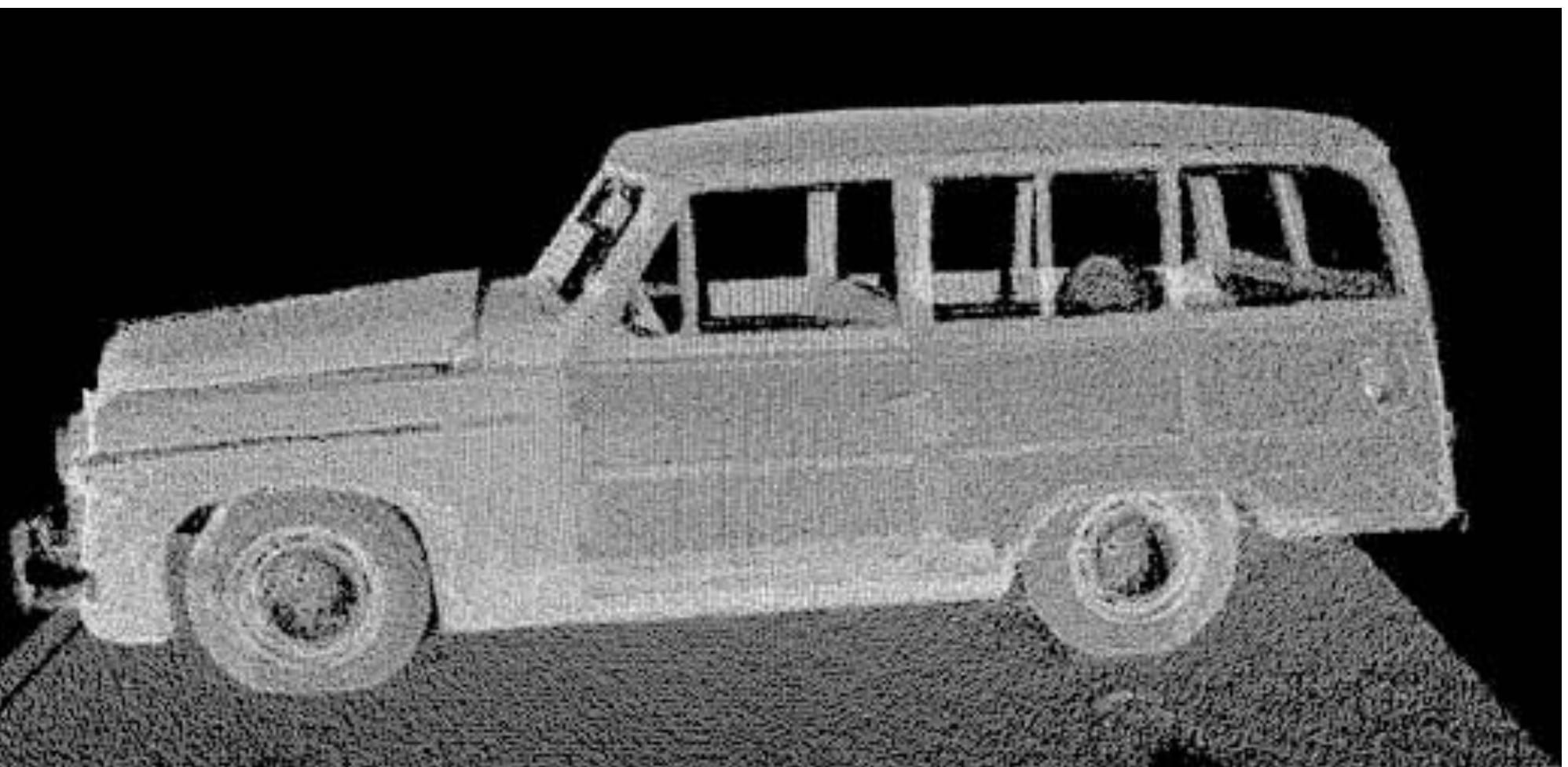
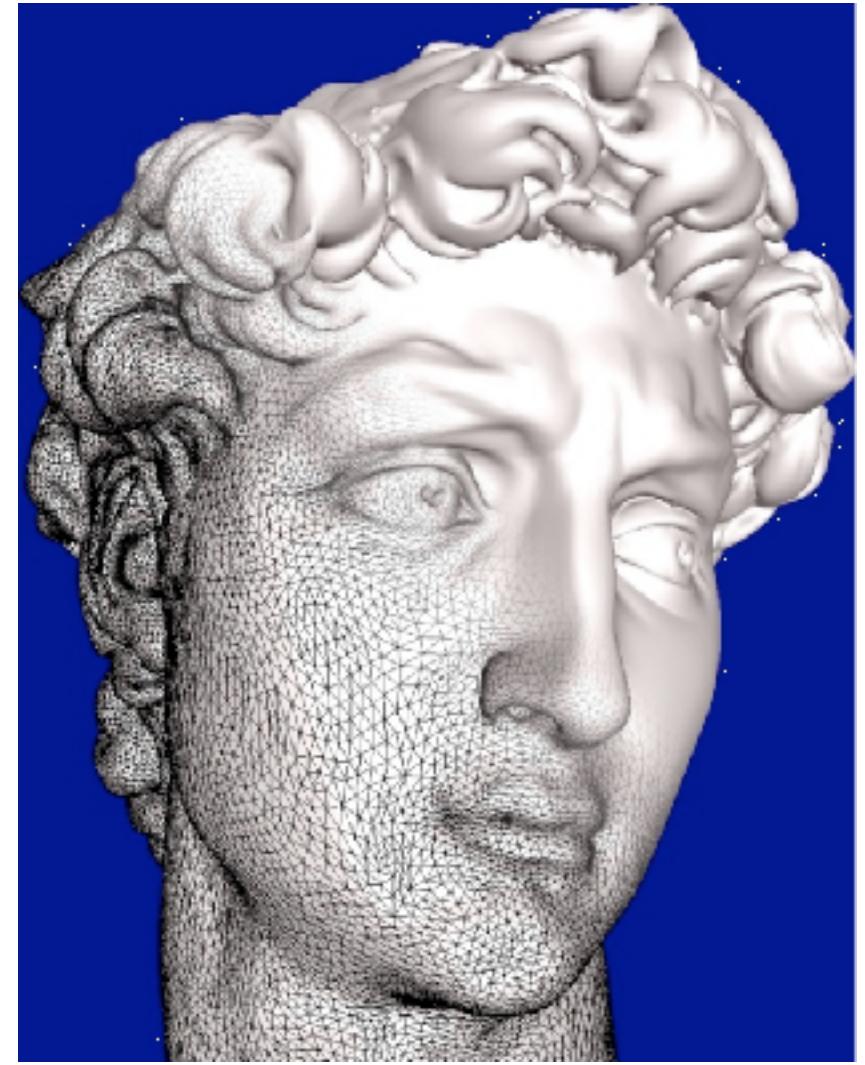


Geographical systems



Fabrication (e.g., 3D Printing, laser cutting)

# Digital Geometry Processing

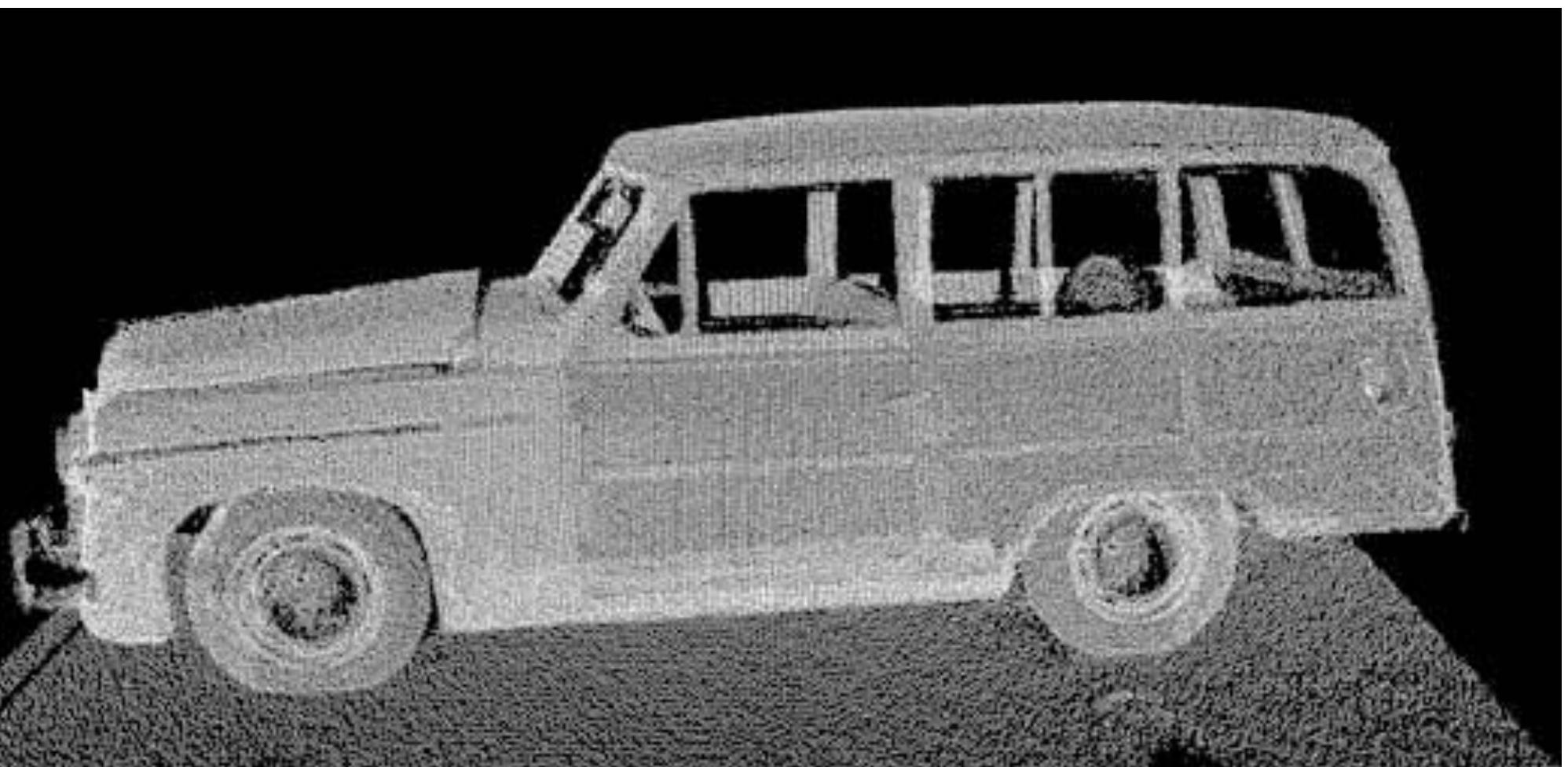
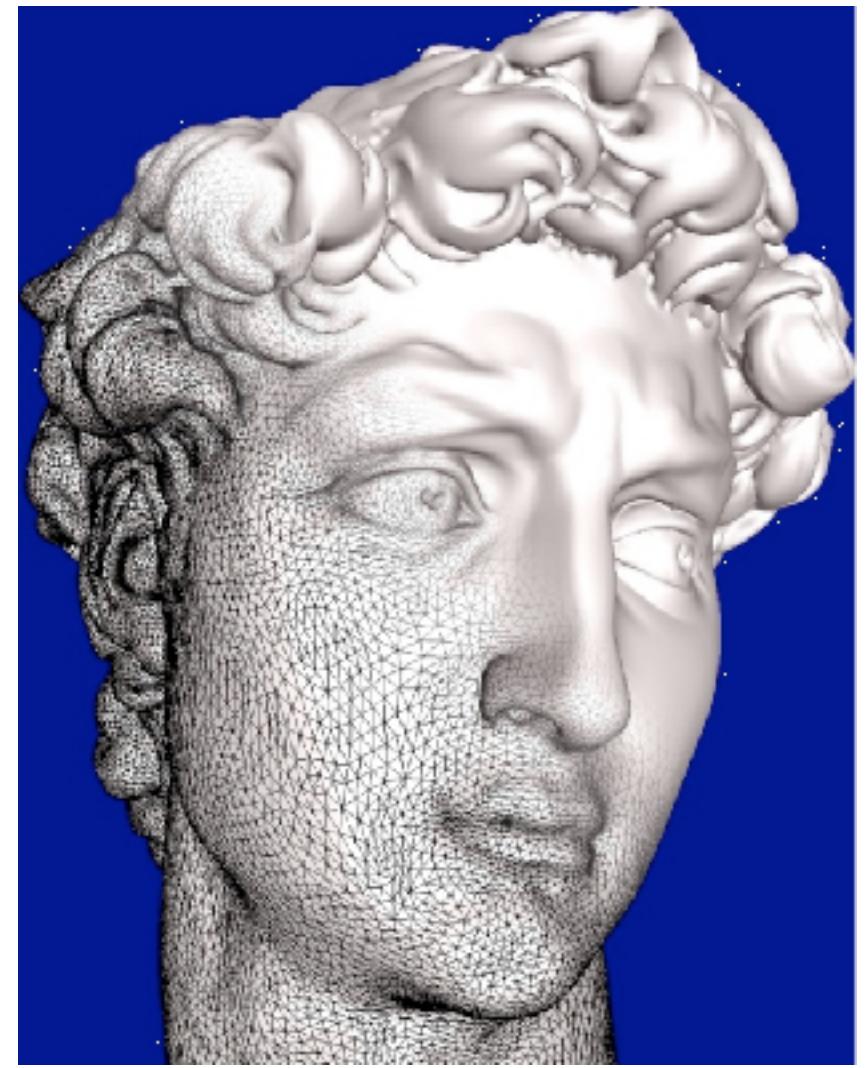


# Digital Geometry Processing



Processing of discrete (polygonal mesh) models

Typically triangular or quad



# Digital Geometry Processing

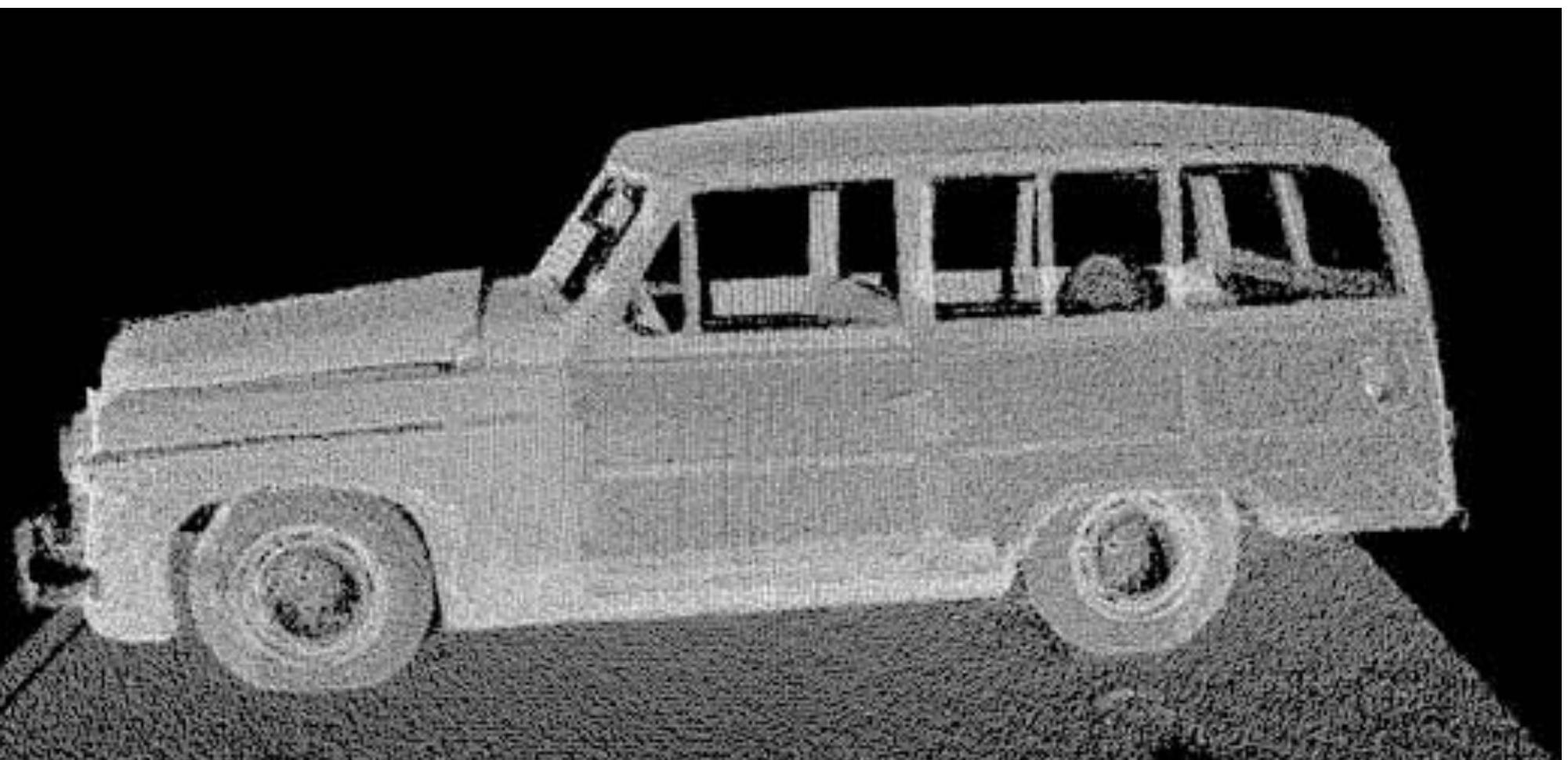
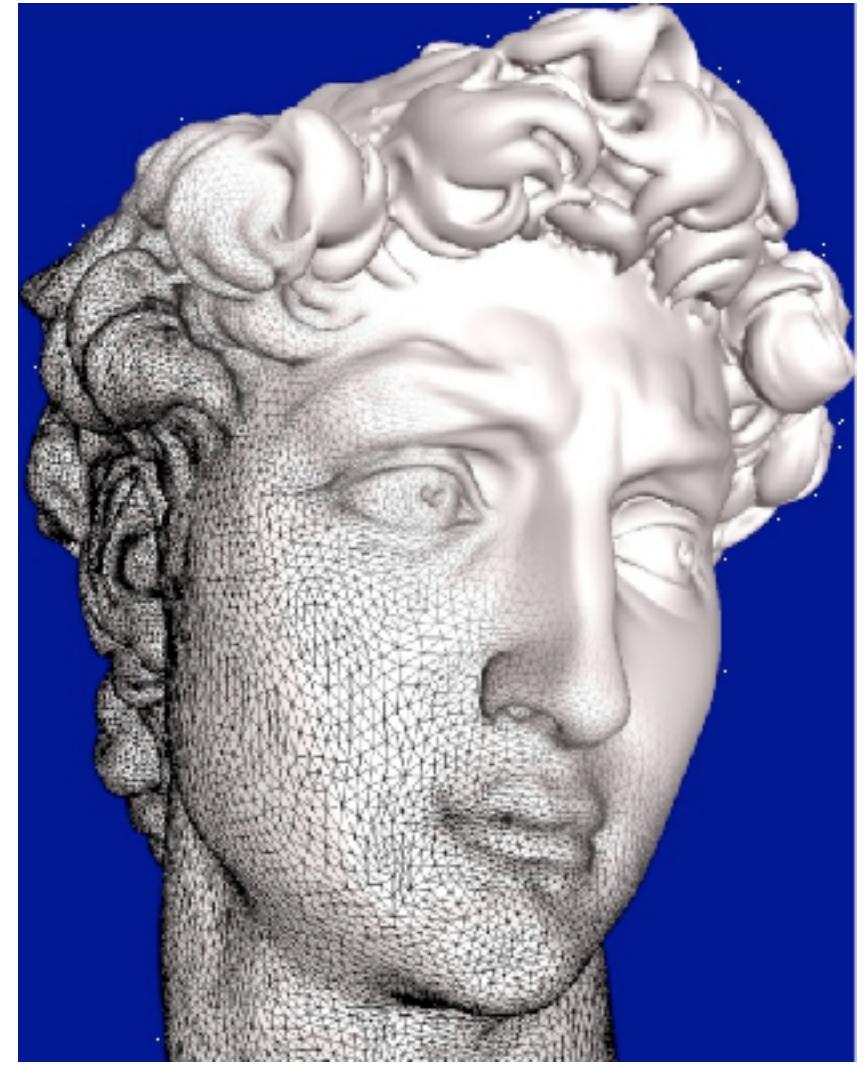
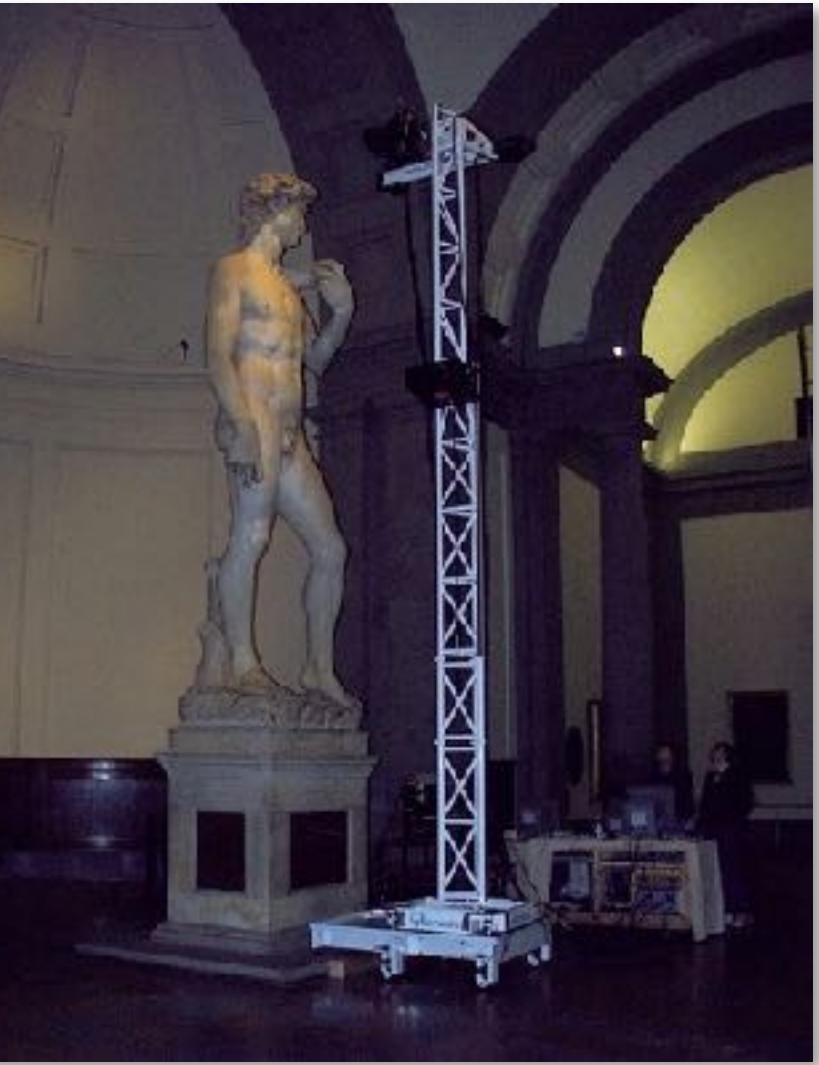


Processing of discrete (polygonal mesh) models

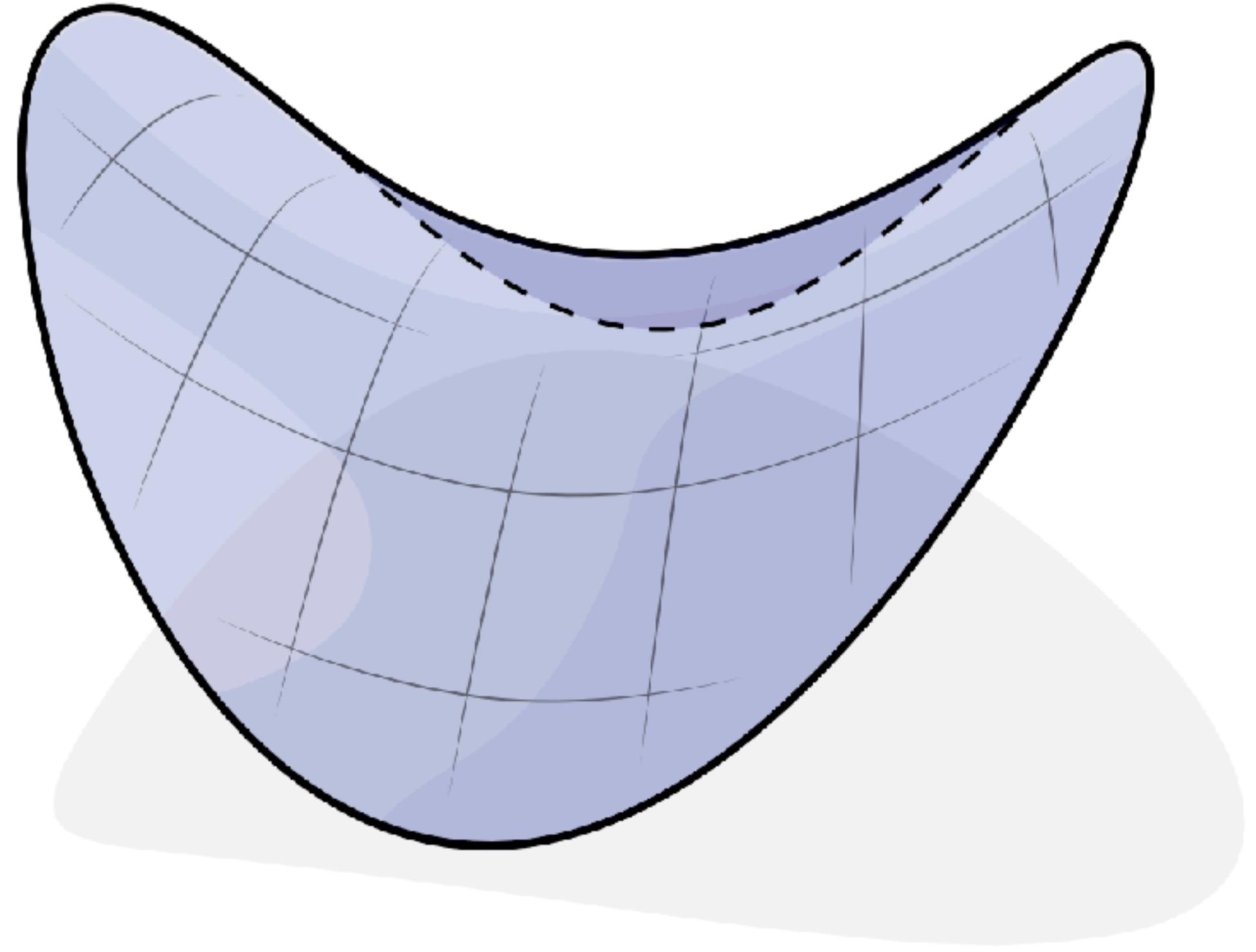
Typically triangular or quad

Why discrete?

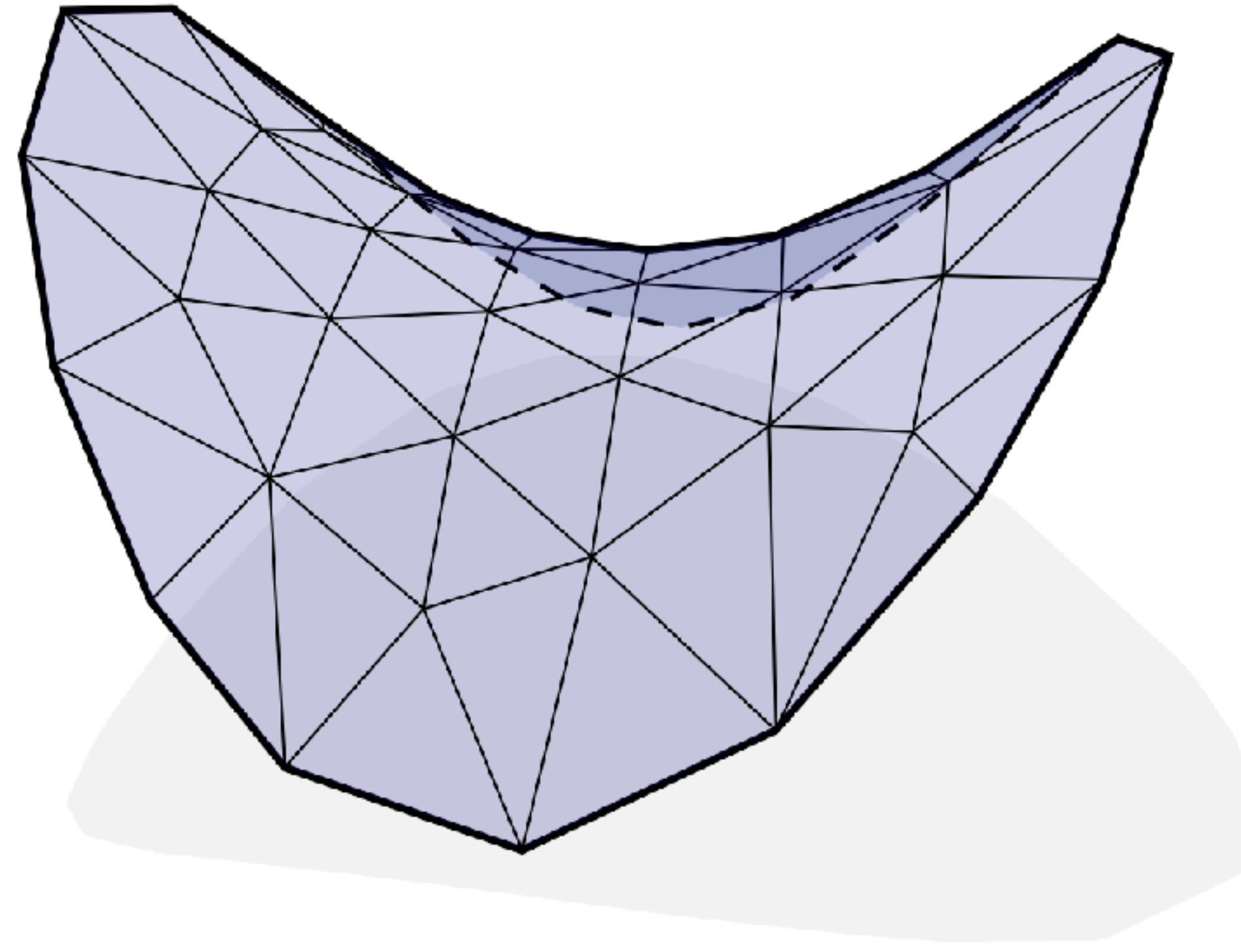
- **Simplicity** – ease of description
- **Efficiency** — supported by graphics hardware
- **Output** of most acquisition tools (CT, MRI, LIDAR, Kinect...)
- **Input** to most simulation/analysis tools (FE solvers)



# Continuous vs Discrete Representation



Continuous



Discrete

[Image from Keenan Crane]