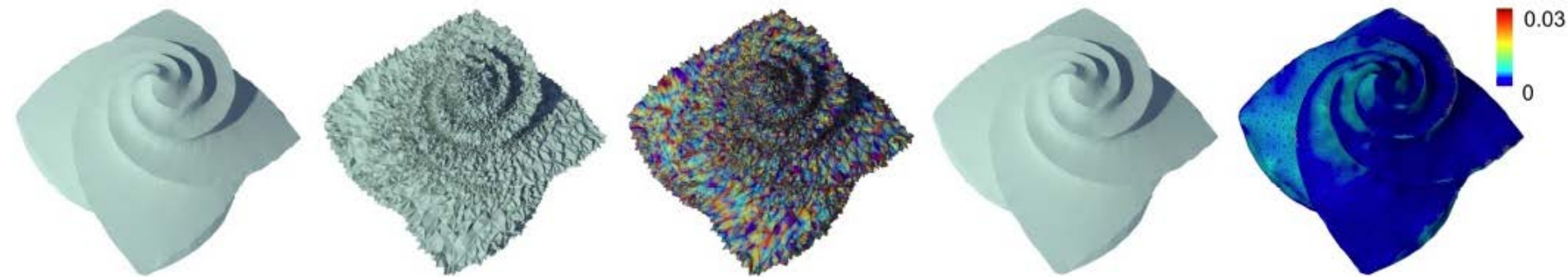


Digital Geometry Processing



Instructor: Ligang Liu

lgliu@ustc.edu.cn

<http://staff.ustc.edu.cn/~lgliu>

About This Course

- Prerequisite
 - Computer Graphics
 - CAGD
 - C/C++, Matlab
- State-of-the-art geometry modeling and processing
 - Hot topics
 - Future trend

My Research Speciality



My Researches

3D modeling

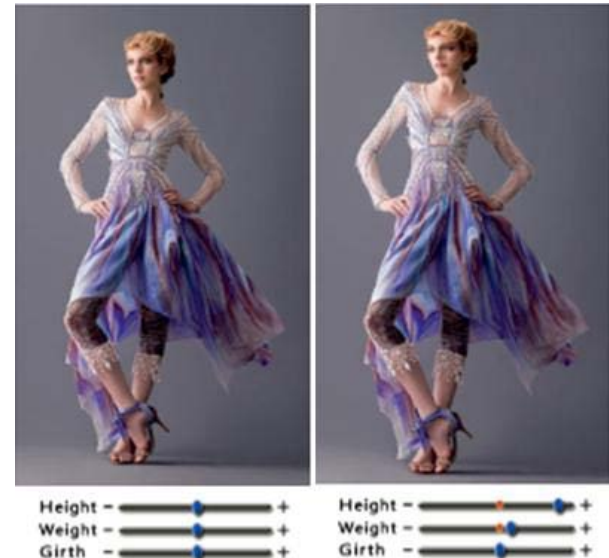
3D processing



3D printing

Research Interests

- 3D computer graphics
- Image and video processing
- 3D printing oriented graphics



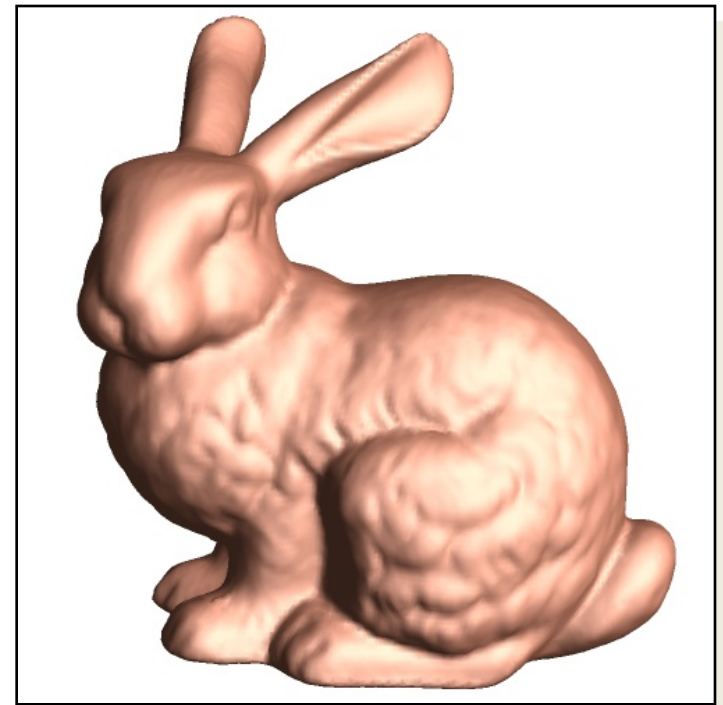
什么是3D几何？

Geometry Representation for 3D Objects

- Representing 3D object digitally

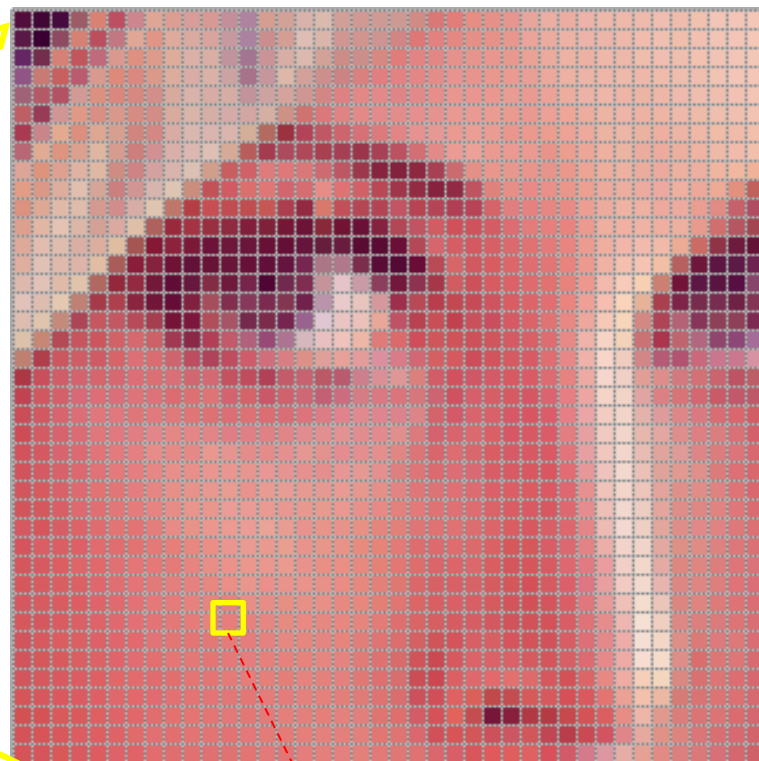
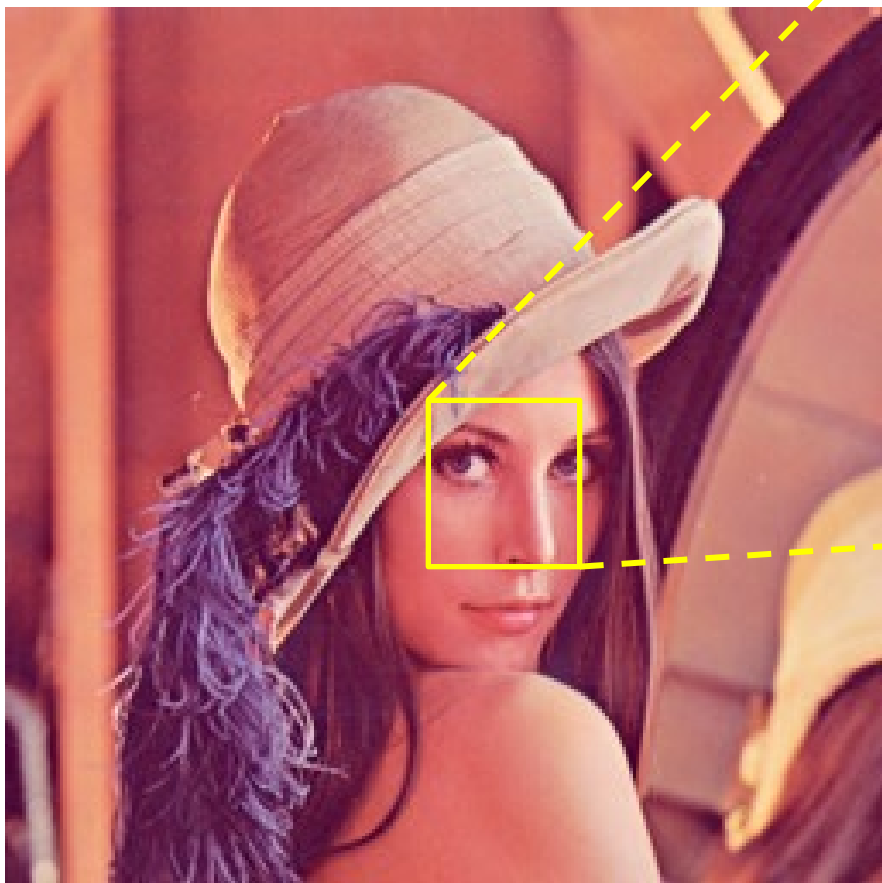


Real 3D object



Digital representation

2D Digital Image



$$0.6 R + 0.3 G + 0.1 B$$



Polygon Mesh

- Set of polygons representing a 2D surface embedded in 3D



Dodecahedron



Icosahedron



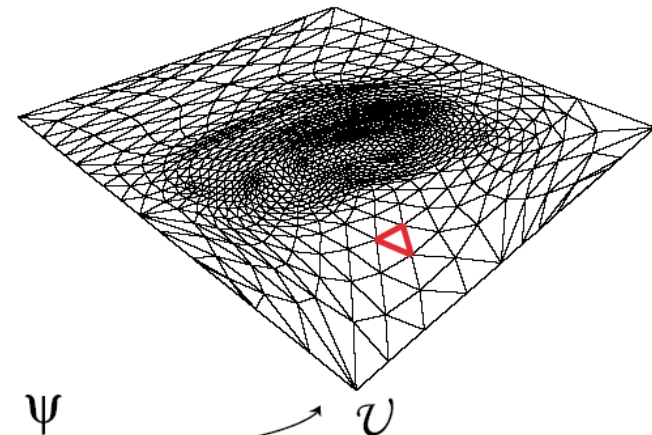
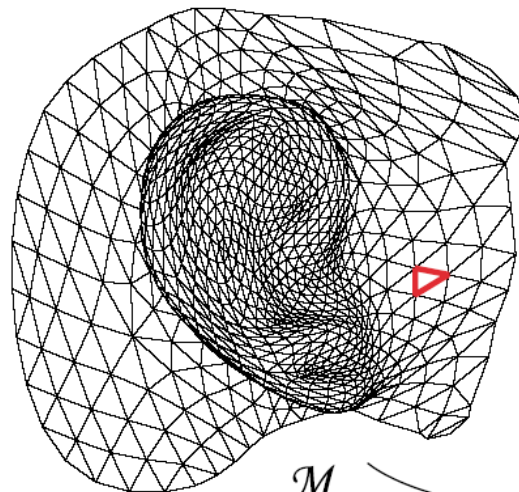
Tetrahedron



Cube

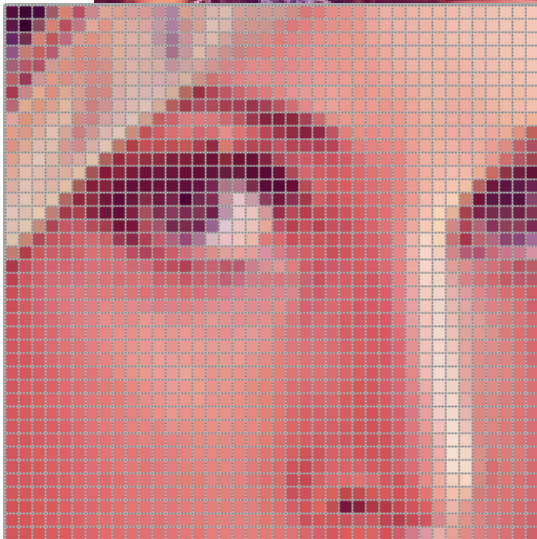
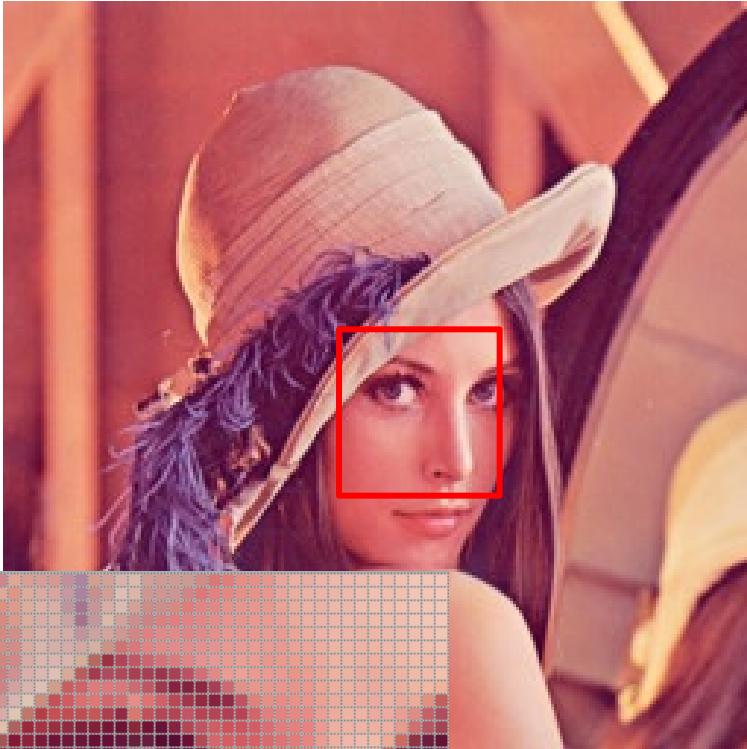


Octahedron

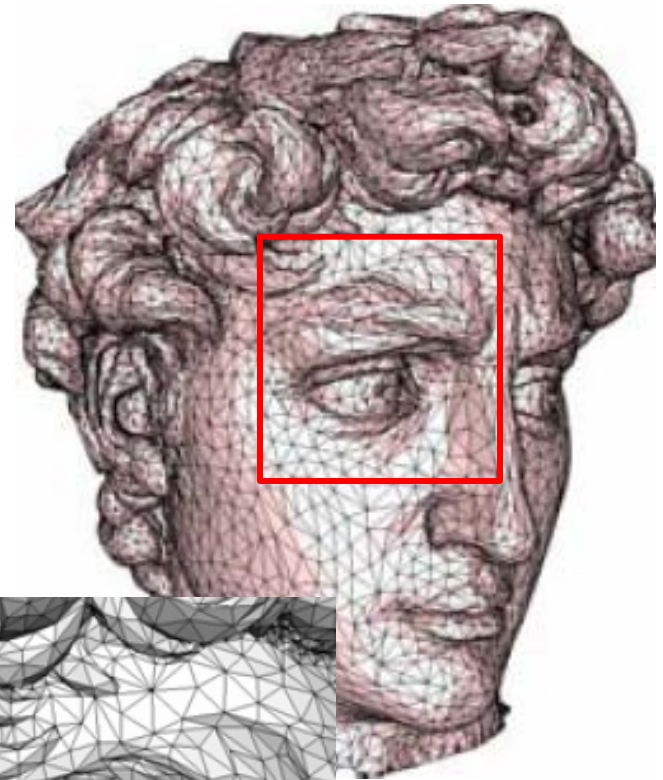


\mathcal{M} $\xrightarrow{\Psi}$ \mathcal{U}

Image vs. Geometry



Pixels
-regular

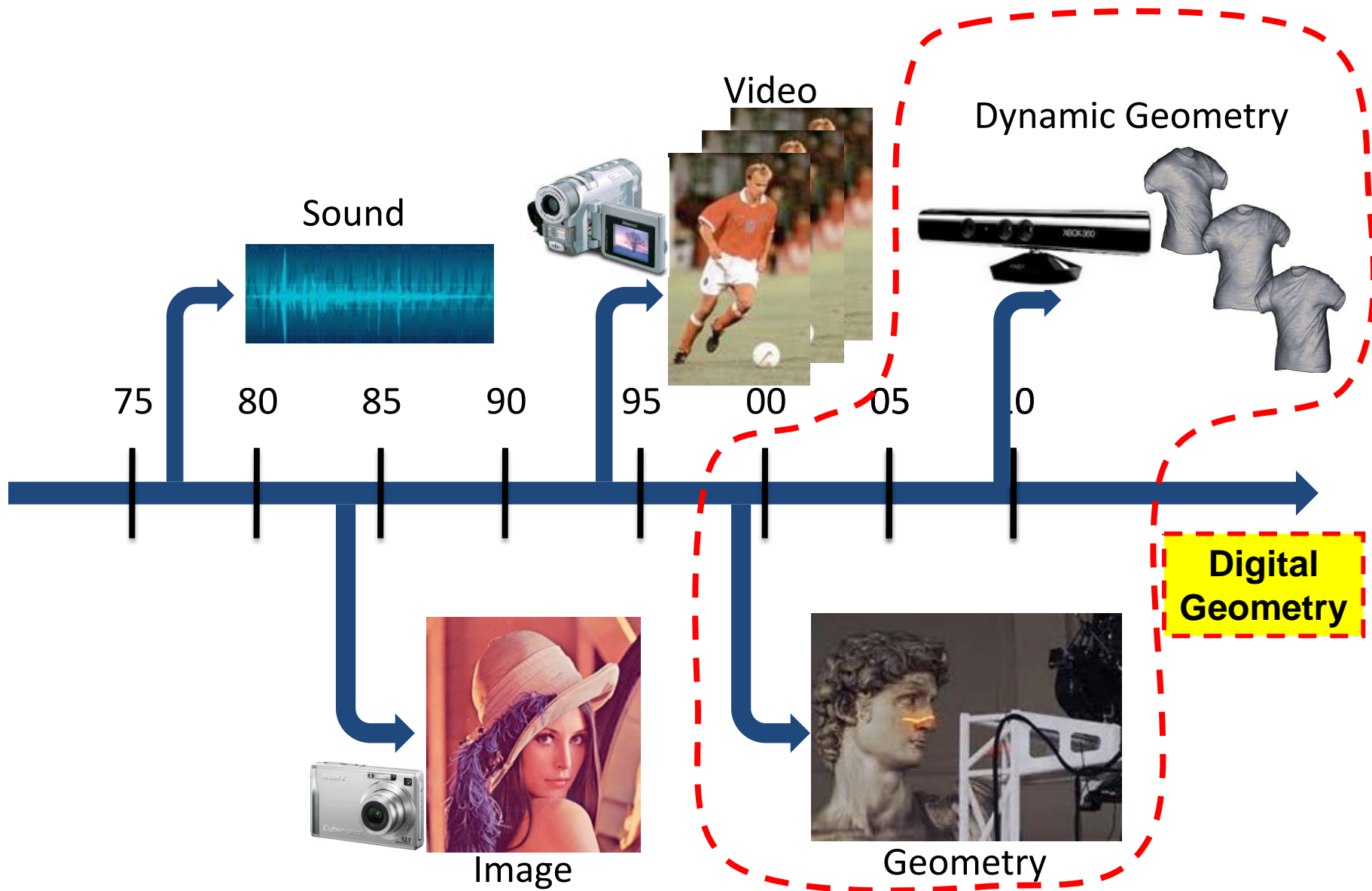


Vertices
-irregular

Image vs. Geometry

- Dimension
- Domain
- Function or parametric (manifold)
- Regularity

3D几何：第四代数字媒体



Digital Media

- Sound
- Image
- Video
- Geometry
 - Computer animation
 - Visualization
 - Computer game
 - Entertainment

Visual Computing

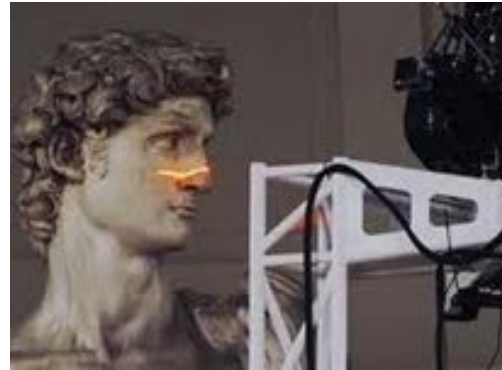
- Processing visual media
 - 2D vision
 - 3D graphics
 - 3D vision



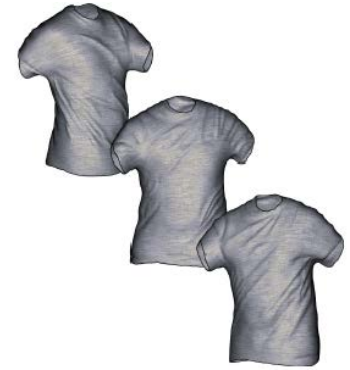
Image



Video



Geometry



Animated
geometry

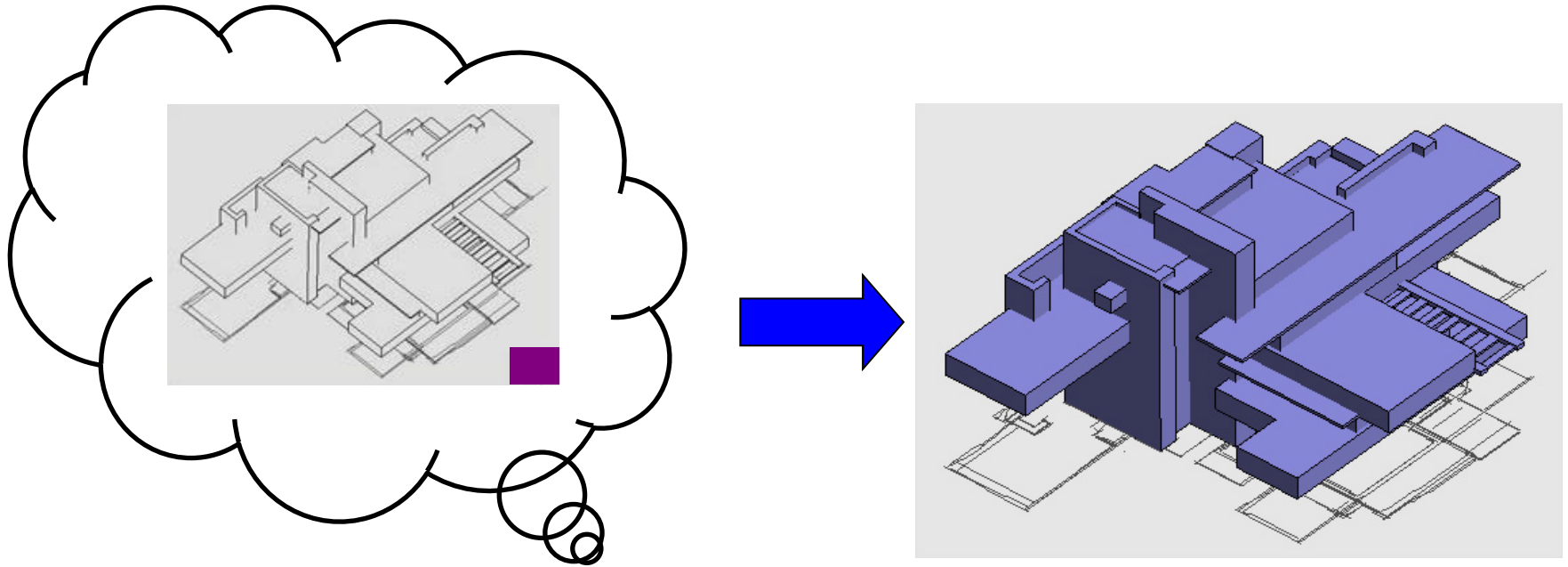
什么是计算机图形学？

计算机图形学的主要内容

1. 建模

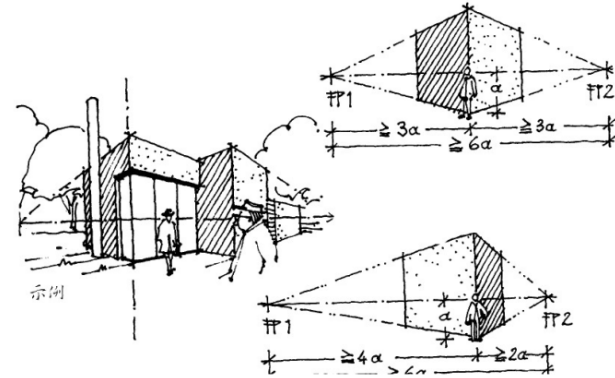
Modeling

3D content creation is hard



3D modeling: Hot topic!

3D Modeling

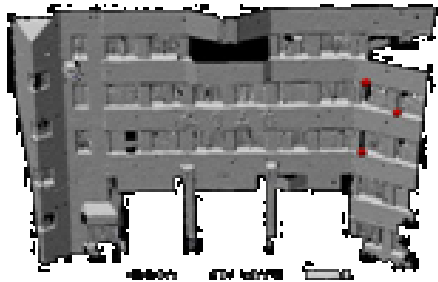


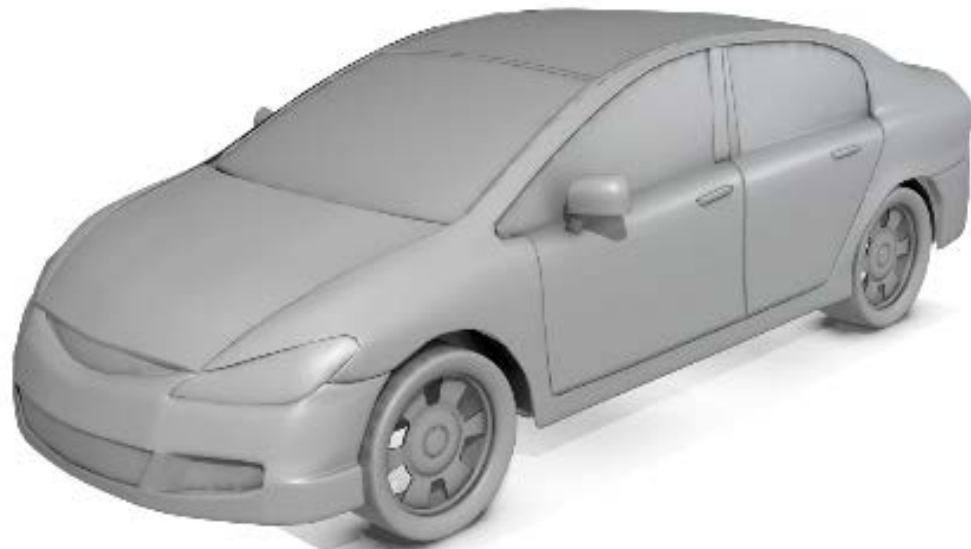
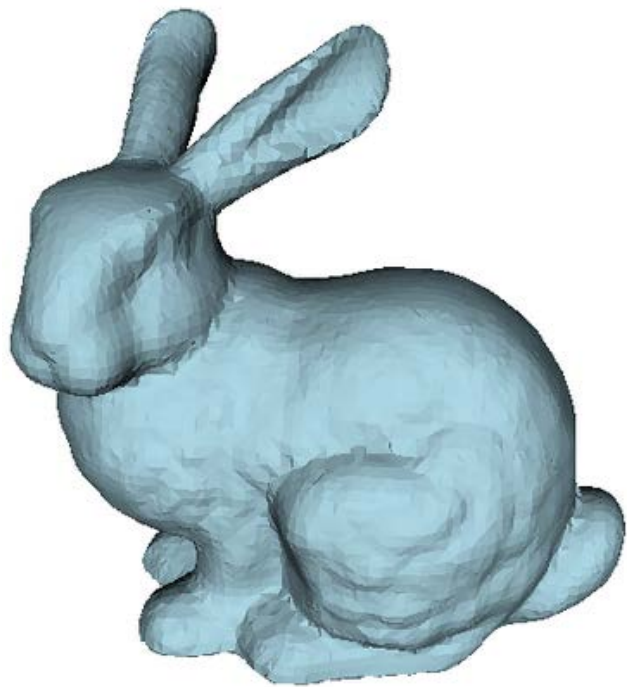
Sketches

3D
Model

Point
Clouds

Images










































Large and growing repositories of 3D Models

3D Warehouse Sign In desk

12,844 Results Relevance Go

 Office Desk <input type="button" value="↓"/>	 Executive Desk Plan <input type="button" value="↓"/>	 Cherrywood Office Desk w/ D... <input type="button" value="↓"/>	 Desk Light <input type="button" value="↓"/>
 desk with inbuilt keyboard EX... <input type="button" value="↓"/>	 Desk II <input type="button" value="↓"/>	 Modern Desk/ Home Office <input type="button" value="↓"/>	 Desk <input type="button" value="↓"/>
 Bagalight 2 Desk Lamp - Cont... <input type="button" value="↓"/>	 Chair & Desk <input type="button" value="↓"/>	 Computer desk with hutch. <input type="button" value="↓"/>	 Front Desk <input type="button" value="↓"/>
 Adelair's Desk (v2 of Cynth... <input type="button" value="↓"/>	 Wooden Desk <input type="button" value="↓"/>	 Desk with Computer <input type="button" value="↓"/>	 Herman Miller Airla Desk by S... <input type="button" value="↓"/>

Large and growing repositories of 3D Models

 \$149 max fbx obj 3ds	 \$49 max fbx obj 3ds	 \$149 max fbx obj 3ds	 \$79 max	 \$99 max fbx obj 3ds	 \$99 max	 \$99 max
 \$49.00 max fbx two obj blend ma	 \$39 max fbx obj	 \$59 max obj	 COLLECTION \$199.00 max two obj 3ds	 \$59 max fbx obj 3ds	 \$59 max obj	 \$59 ma max fbx obj 3ds
 \$49 max fbx obj 3ds	 \$59 ma max c4d fbx obj	 \$79 max	 \$39 max obj	 \$59 ma max c4d fbx obj	 \$599.00 max oth obj	 \$79 max fbx obj



2. 绘制

Rendering

绘制

- 光照
- 材质、BRDF
- 纹理、BTF
- 基于图像和视频的绘制







3. 动画

Animation



4. 交互

Interaction

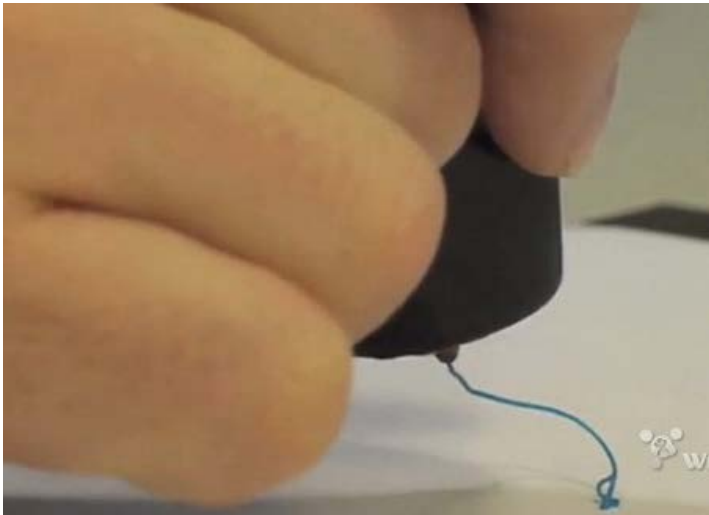
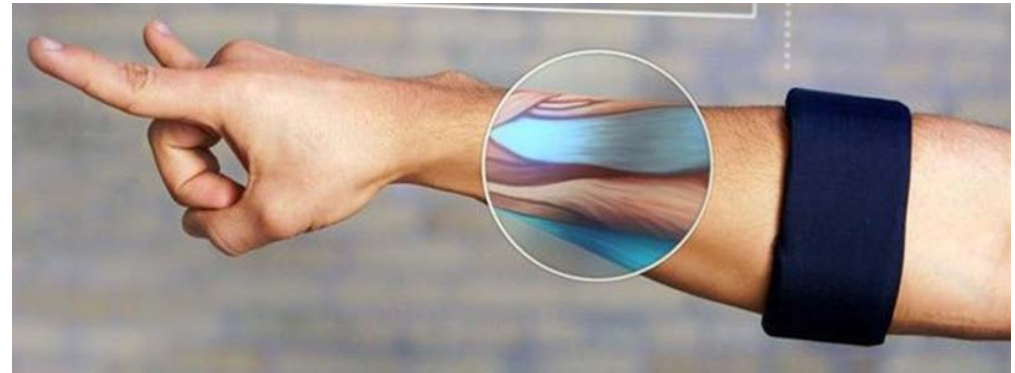
ACM SIGGRAPH

- Association for Computing Machinery
- Special Interest Group on Graphics and **Interactive Techniques**

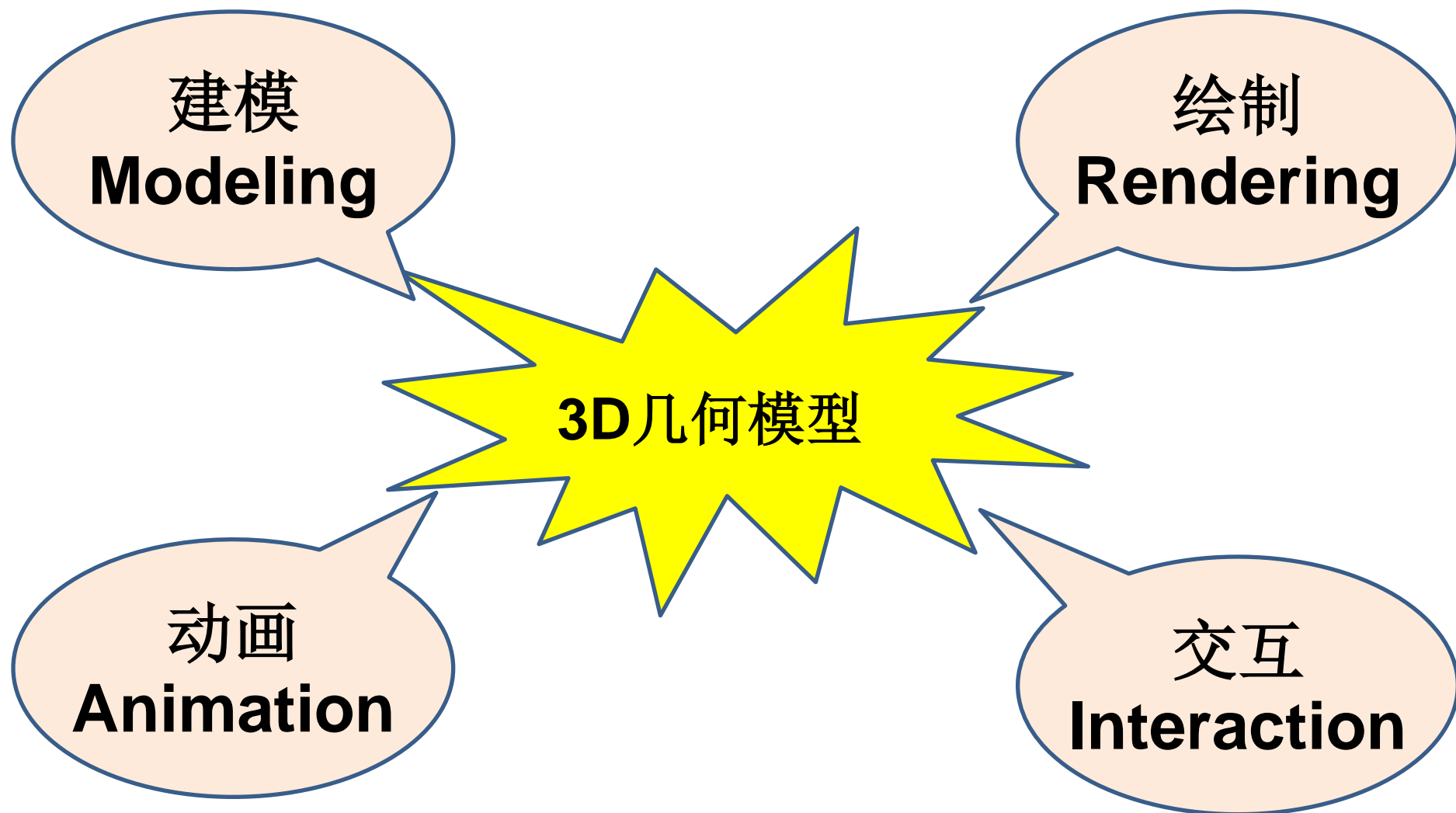




3D交互技术的新进展



计算机图形学的主要内容



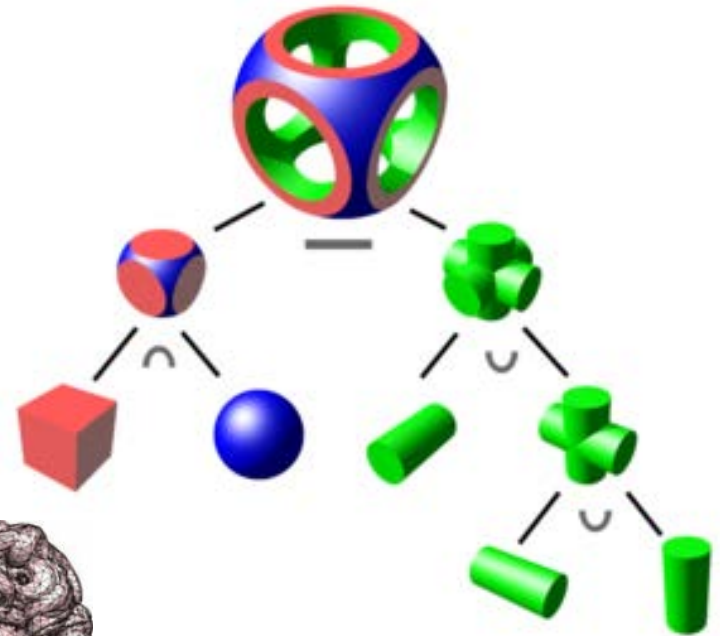
计算机图形学的主要内容

- 建模（Modeling）
 - 构建三维的几何模型
- 渲染（Rendering）
 - 将模型真实性的显示在屏幕上
- 动画（Animation）
 - 模拟真实世界的物理运动
- 人机交互（Human-computer interface）
 - 人与电脑的“对话”（意图表达）

3D几何的表达及处理

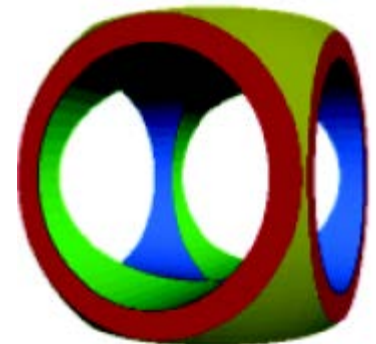
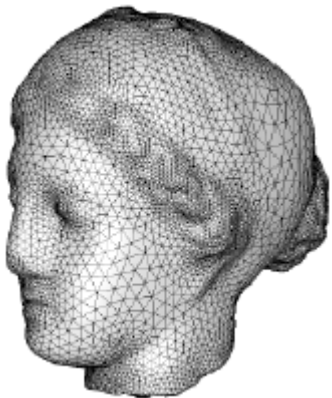
Geometry Representations

- Constructive Solid Geometry (CSG)
 - Cube, cylinder, cone...
 - Boolean operations
- Boundary Representation
 - B-spline, NURBS
 - **Triangular mesh**
 - Rendering engine



Geometry Examples

- Meshes
- Point clouds
- Implicit surfaces
- Volumetric data
- CSG



Geometry Processing

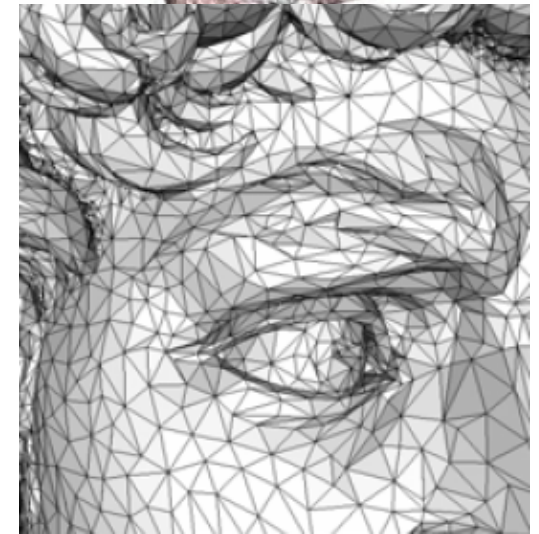
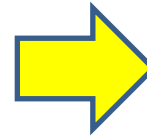
- 3D Geometry is based data for
 - CAD/CAM, Engineering
 - Visualization and simulation - medical, physics, etc...
 - Graphics, multimedia
- Geometry processing
 - Computerized modeling of 3D geometry
- Digital Geometry \approx Mesh Processing

Digital Geometry Processing (DGP)

- Easy acquisition of 3D models
- Process of discrete models

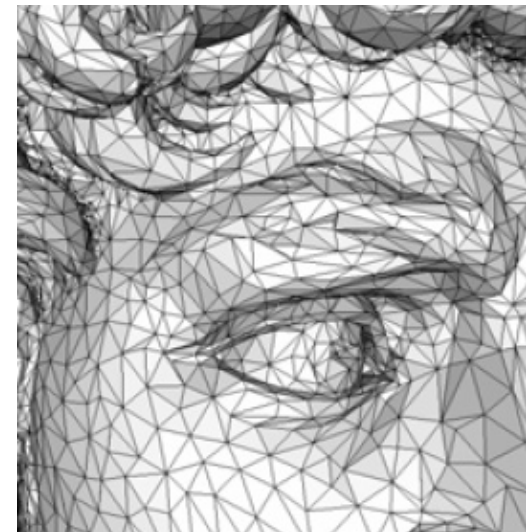


3D scanners



Digital Geometry Processing (DGP)

- Processing of discrete models
 - Polygonal mesh (Typically triangular)
- Why discrete?
 - Simplicity - ease of description
 - Based data for rendering software/hardware
 - Input to most simulation/analysis tools
 - Output of most acquisition tools
 - laser scanner, CT, MRI, etc...



Course Syllabus

- Low-level geometry processing
 - Model acquisition
 - Surface reconstruction
 - Mesh simplification and Remeshing
 - Mesh parameterization
 - Mesh editing, deformation and morphing
 - Subdivision surfaces
- High-level geometry processing
 - Shape segmentation
 - Shape similarity
 - Shape understanding
 - Shape matching and retrieval

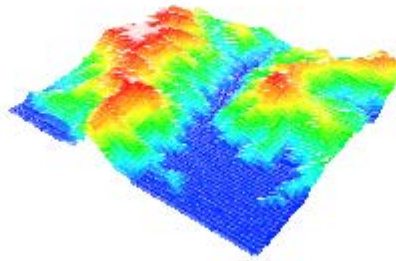
Applications



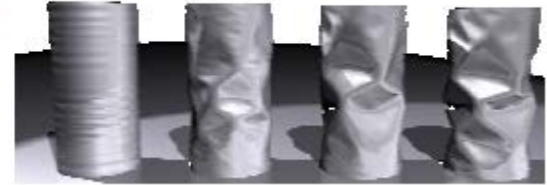
Medical



Engineering



Topography



Simulation



Game



Movies

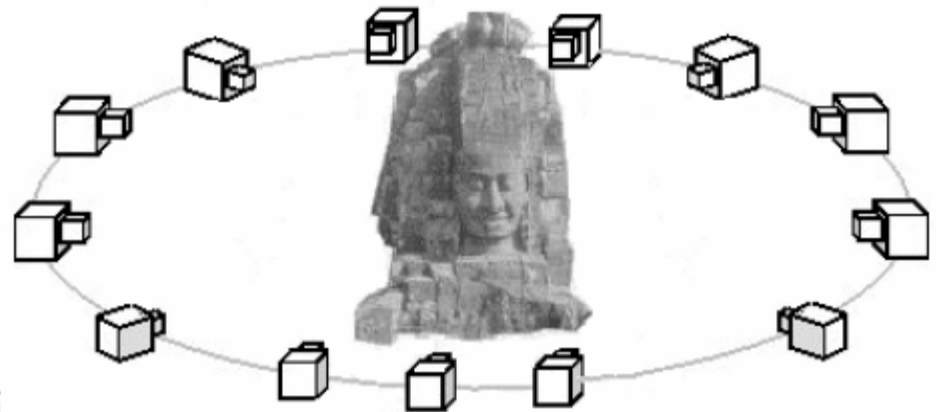
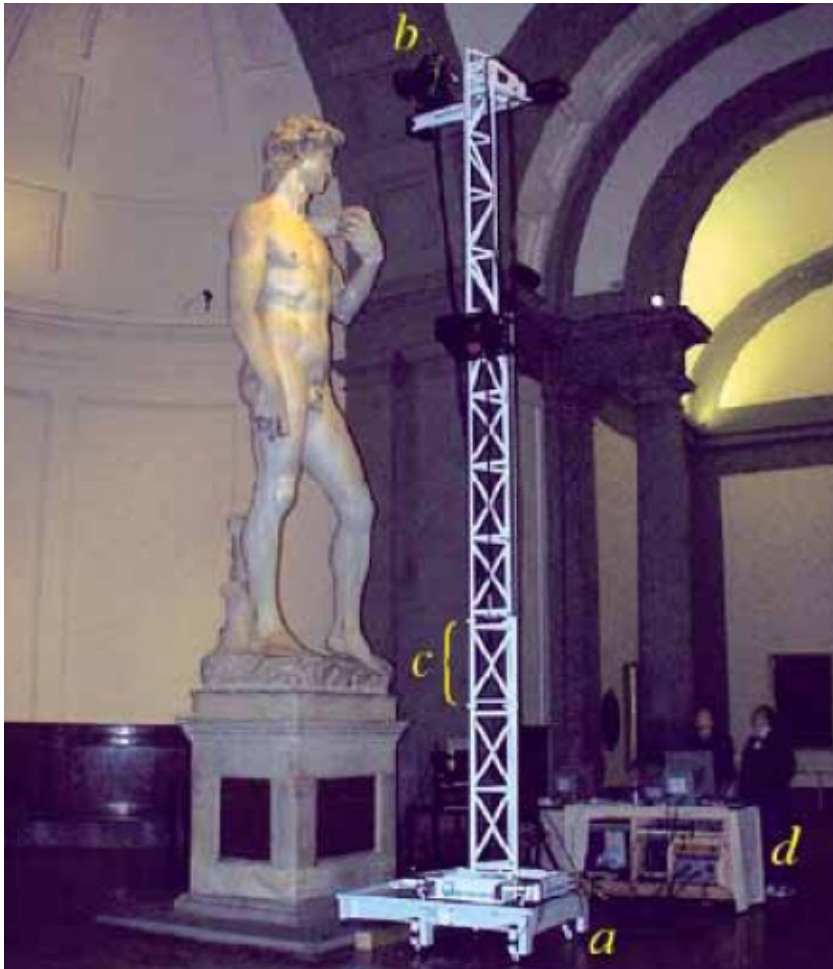


E-commerce

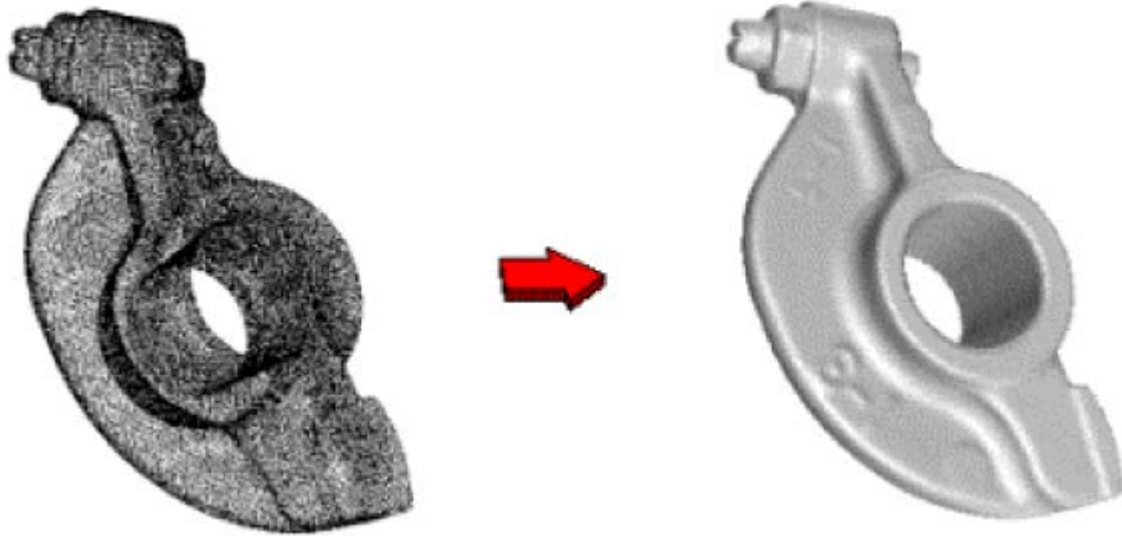


Art history

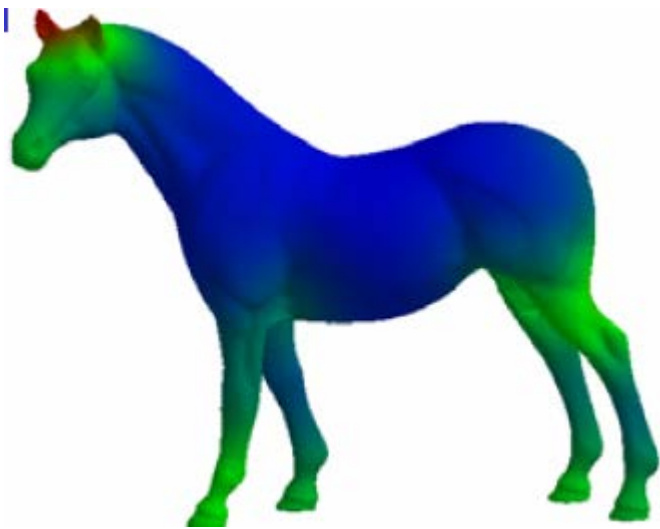
Data Acquisition



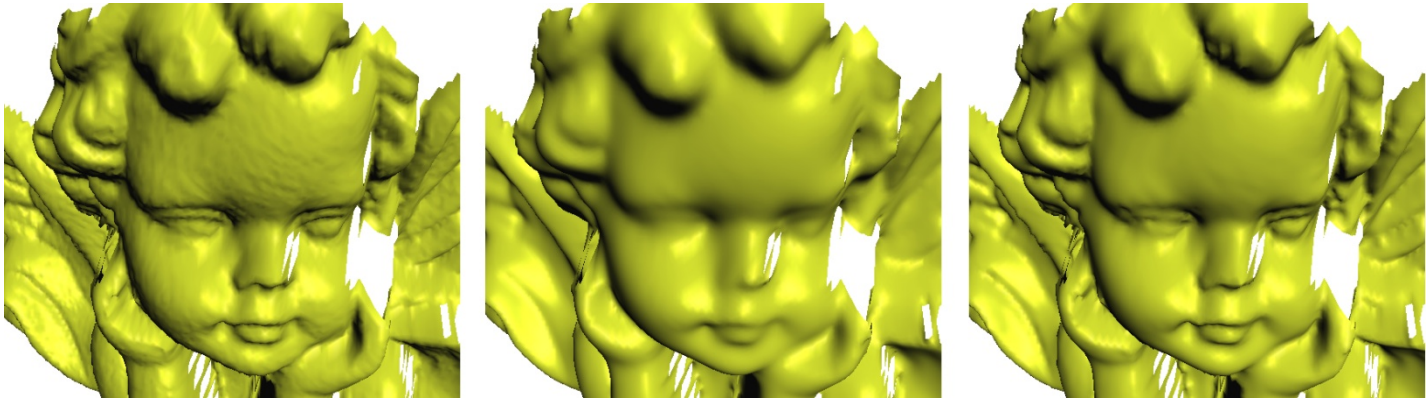
Surface Reconstruction



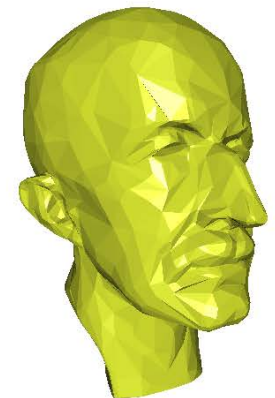
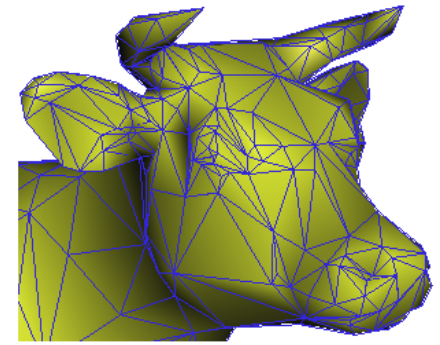
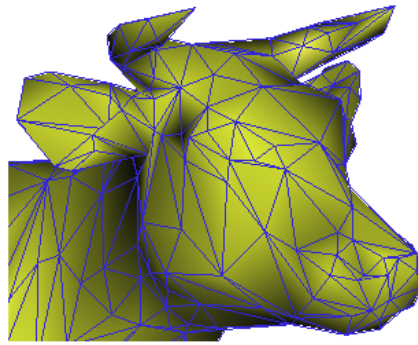
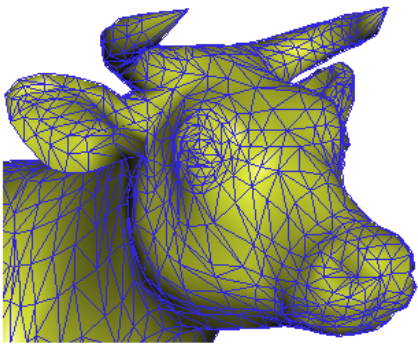
Differential Geometry



Smoothing/Fairing



Mesh Simplification

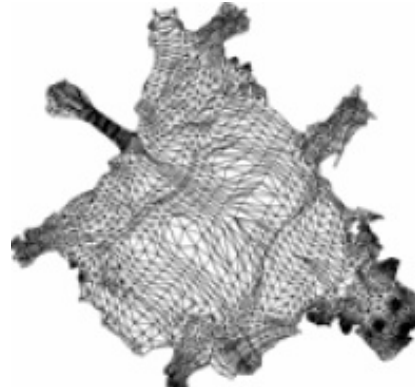
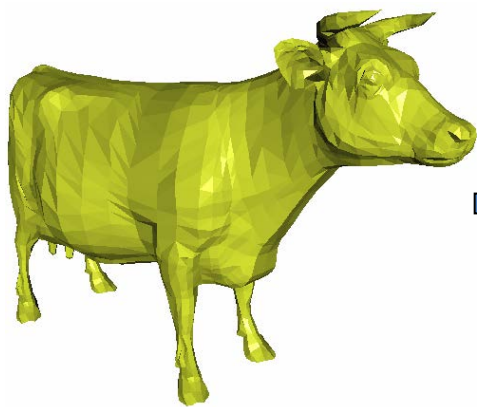
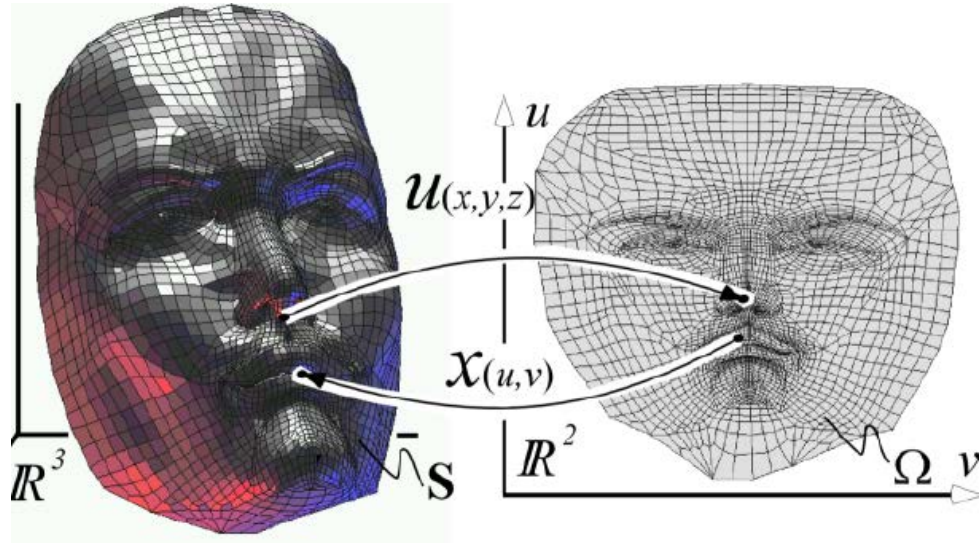


Geometry Coding

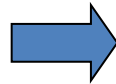
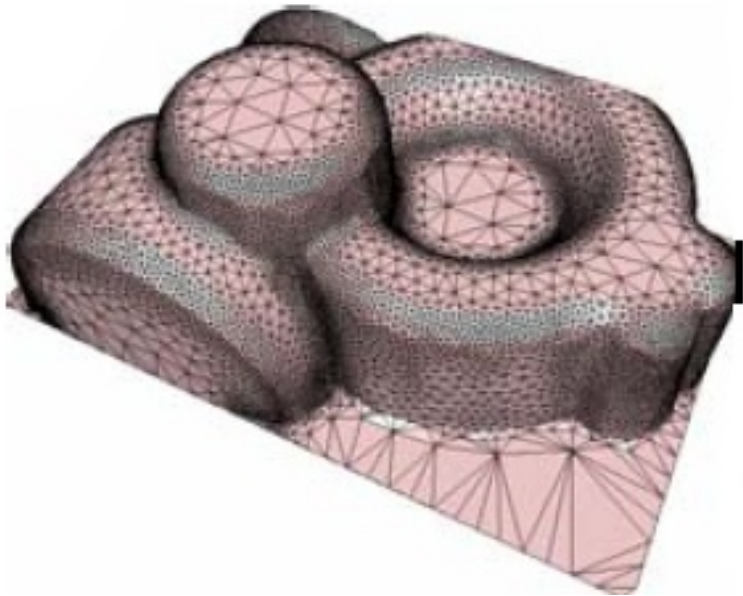


010011110010101100010101 ...

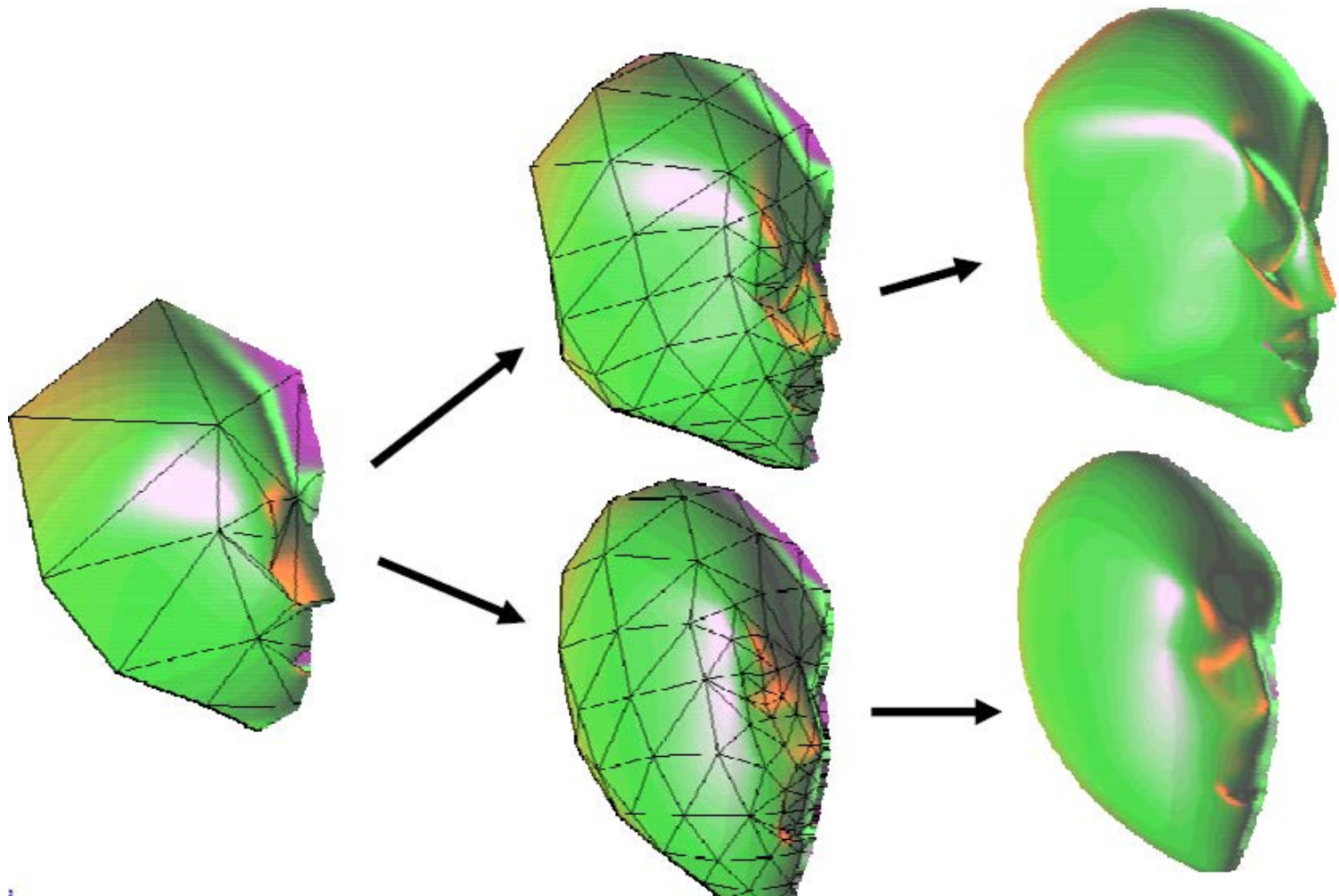
Parameterization



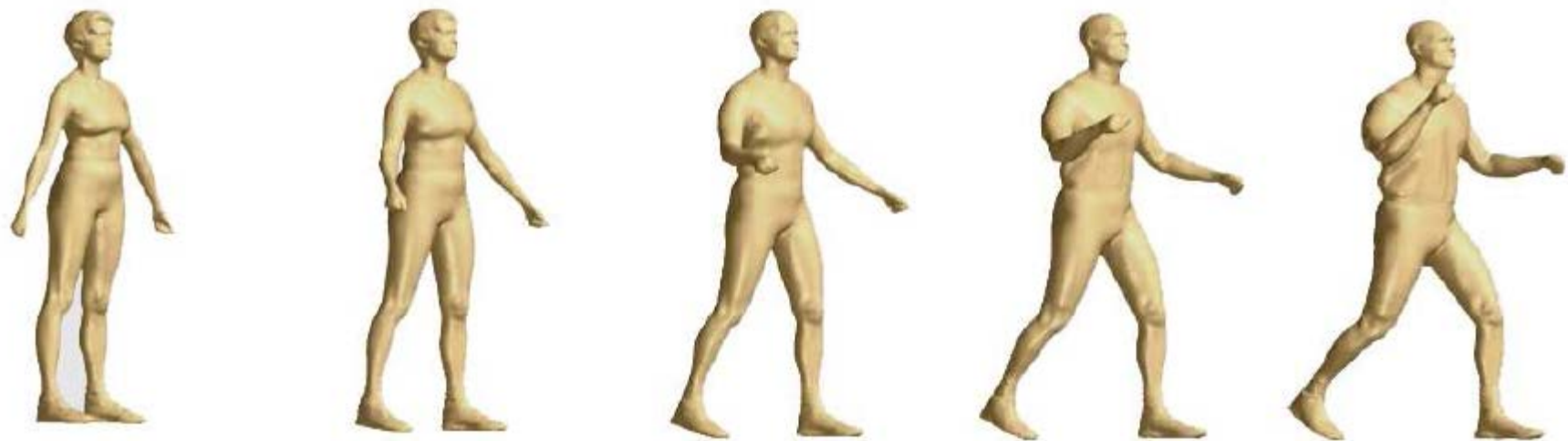
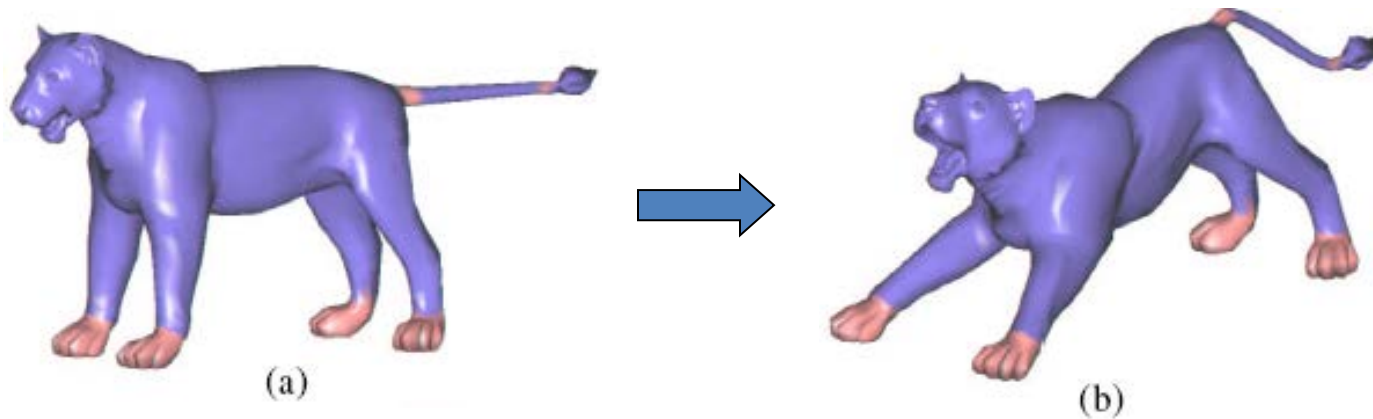
Remeshing



Subdivision Surfaces



Mesh Editing and Morphing

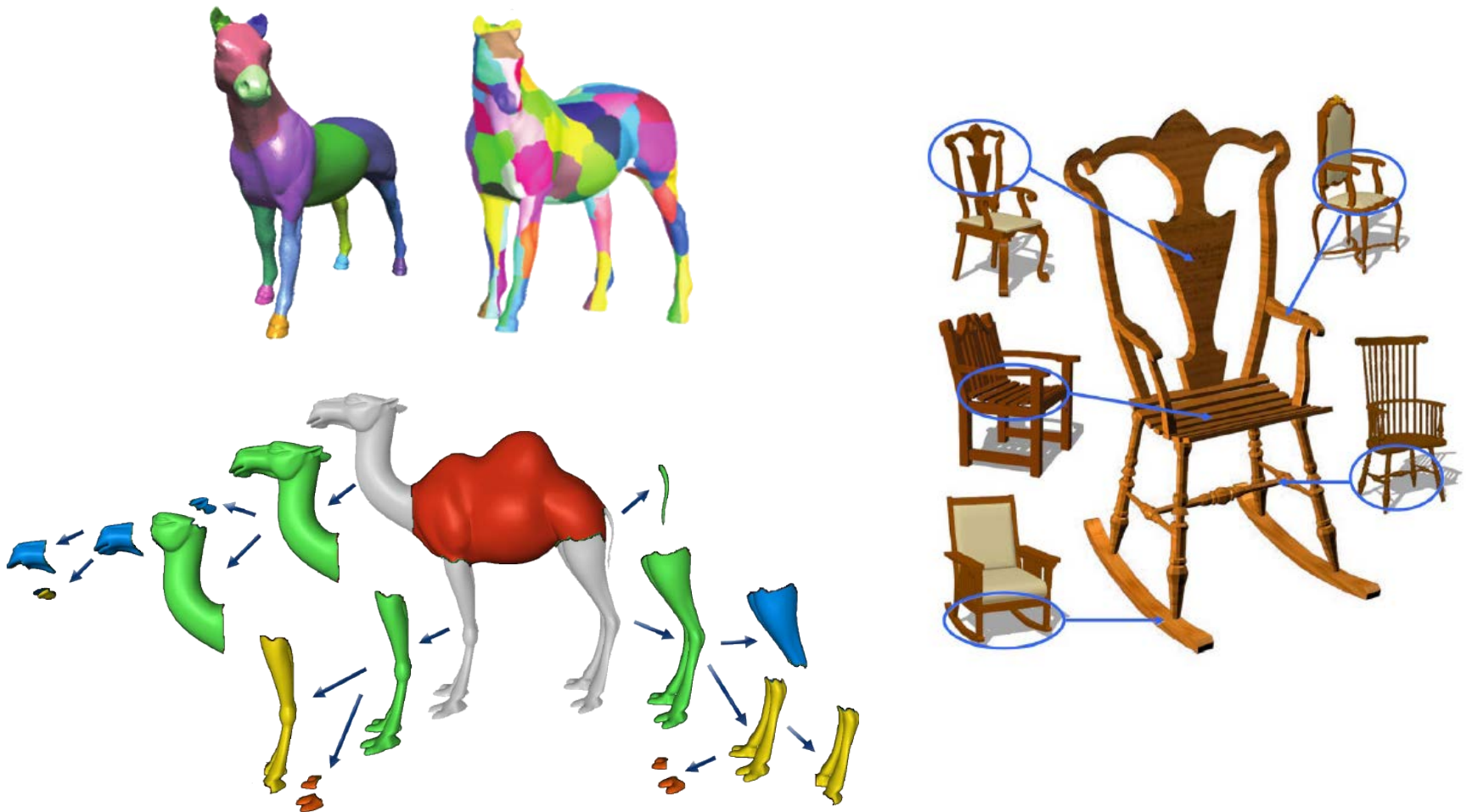


Point Based Surfaces



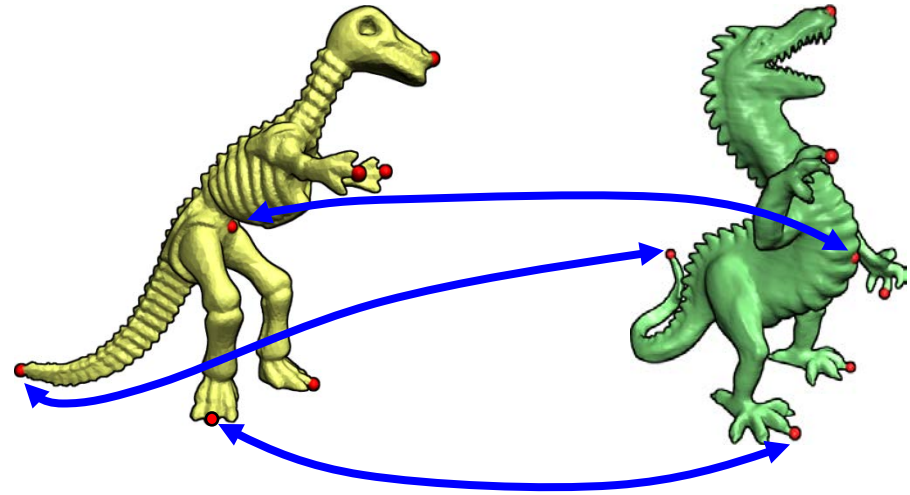
Understanding Shapes

- Shape components (semantics)



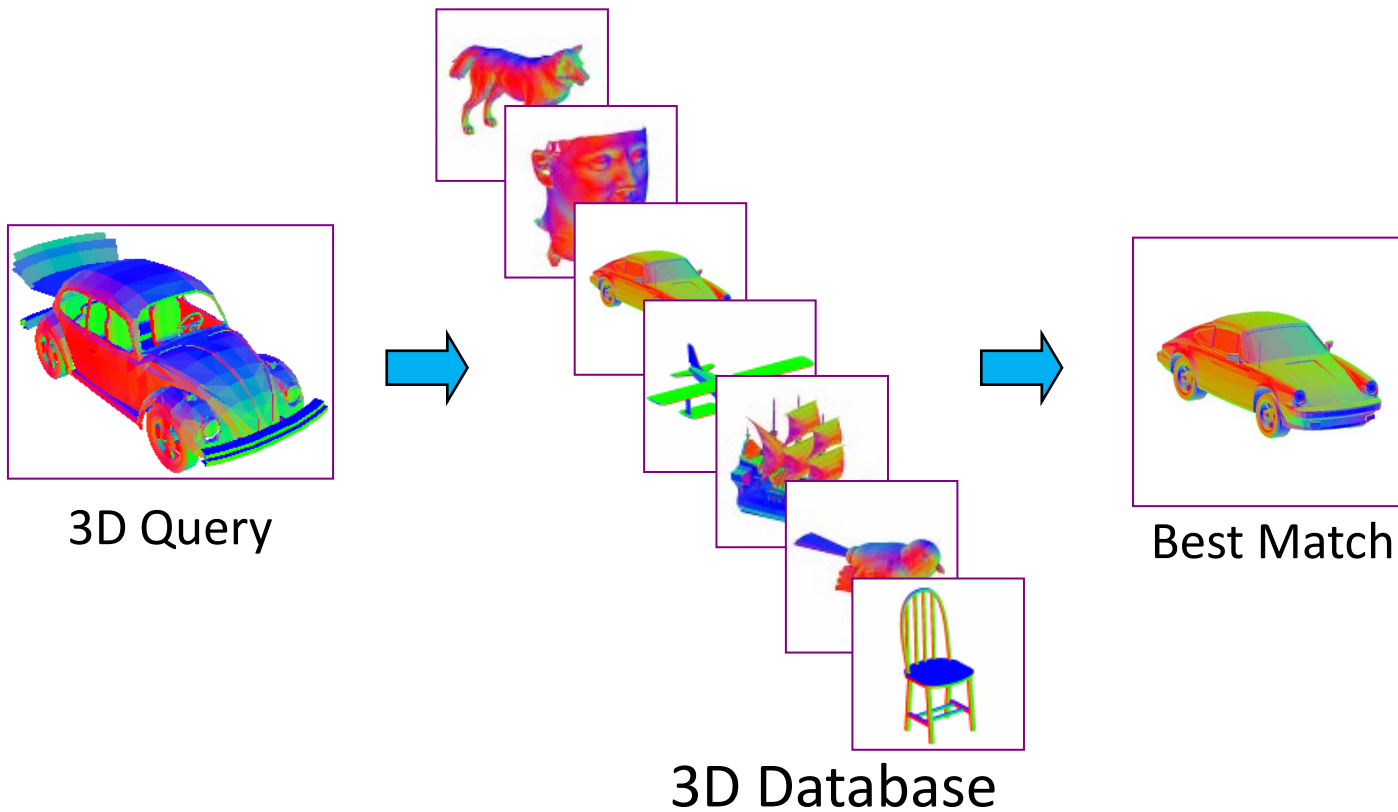
Understanding Shapes

- Shape matching
 - Similarity
 - Correspondences



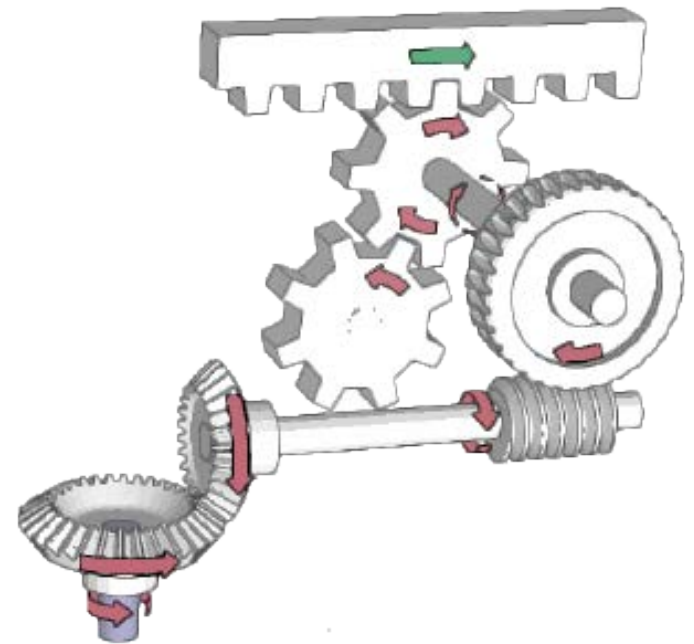
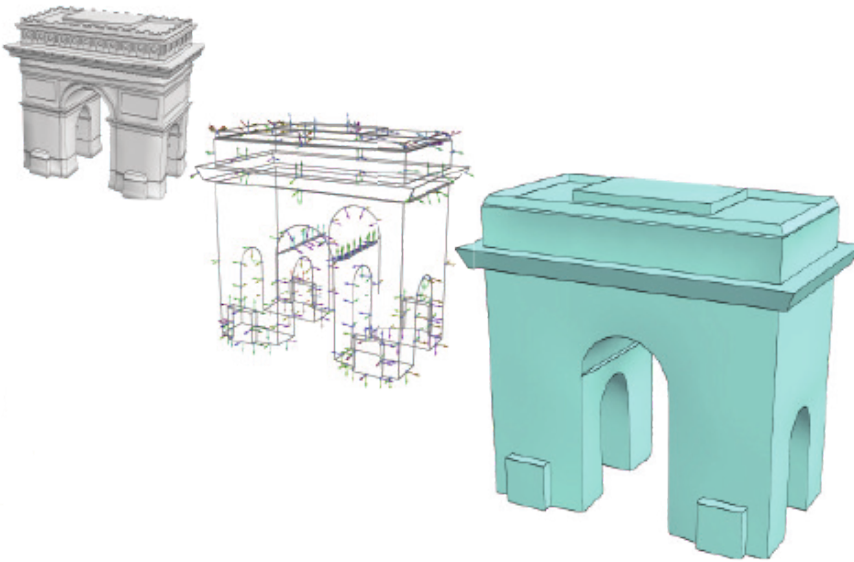
Understanding Shapes

- Shape retrieval



Understanding Shapes

- Abstraction of shapes
 - [Mehra et al. SIGAsia 2009]
- Understanding assemblies
 - [Mitra et al. SIG 2010]



**我们正处在3D技术
极速发展的浪尖...**

Microsoft Kinects (2011)

- 无接触体感交互

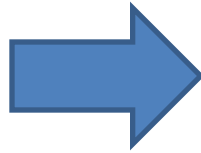
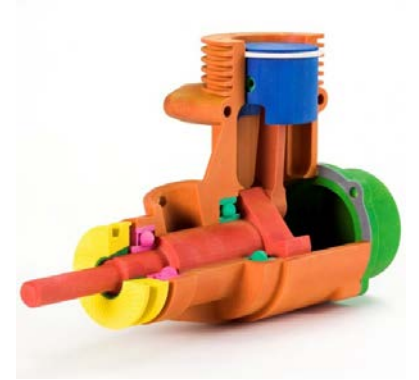


Microsoft Kinects 2.0 (2014)

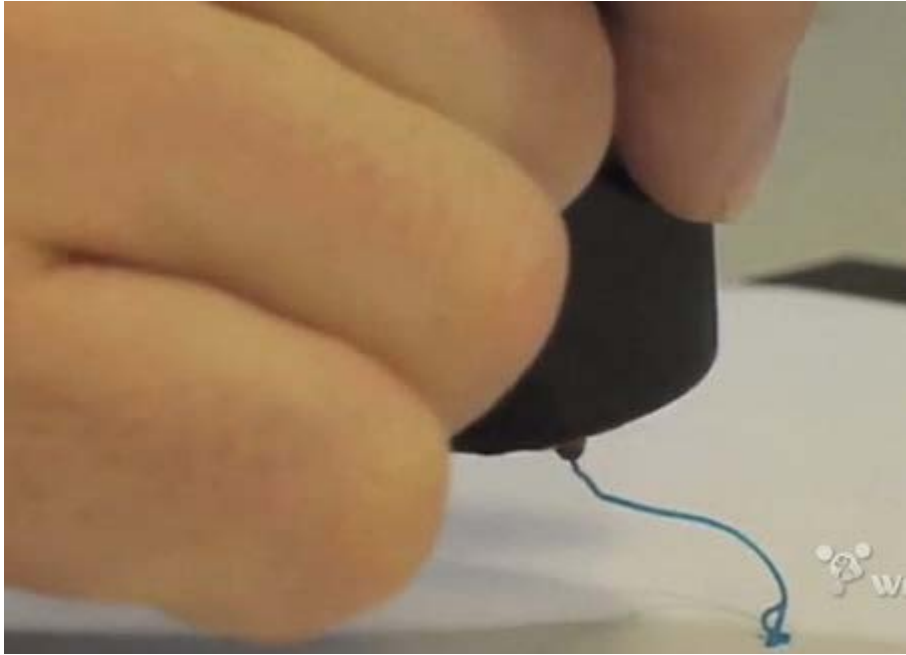
- 可以识别手的Kinects



三维打印 (2012)



三维打印笔 (2013, 2014)



3Doodler, 2013



CreoPop, 2014

Leap Motion (2013)

- 无接触手势交互



Google Glass (2013)



Big Dog (2013)



Apple iWatch (2019!)

- Apple iWatch 智能手表



本课程的内容

预备知识：数学

- 线性代数
- 几何：空间几何、微分几何
- 微积分
- 微分方程
- 数值方法与计算
- 最优化
- ...

还没有学没有关系：数学在使用的过程中学得更快，能更深刻地深刻理解和掌握

数学不是没有用，而是不够用

预备知识：编程

- 编程能将你脑中的想法得到实现并看到
 - 从C到C++（面向对象编程）
- 算法：严谨的逻辑思维
- Matlab
- 各种专业应用软件
 - Photoshop, 3D Max, Maya, AutoCAD, Adobe Products...

工欲善其事必先利其器

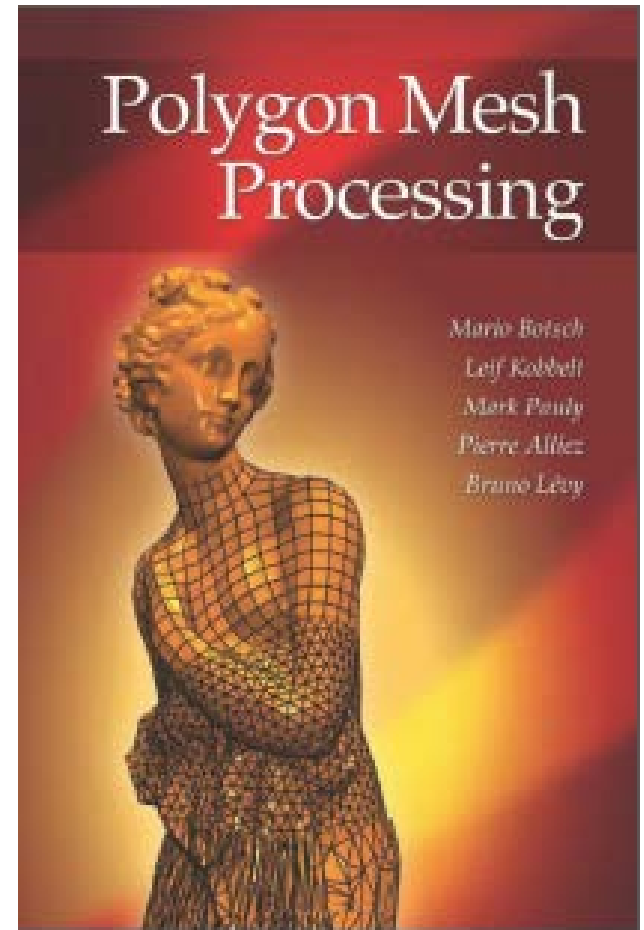
相关学科

- 图像处理
- 几何造型
- 计算机辅助几何设计
- 计算几何
- 计算机视觉
- 人工智能
- 计算机硬件
- ...

数学与其他学科的交叉

参考资料

- Book
 - Polygon mesh processing
- Siggraph courses
- Papers
- Online resources
 - Course website



Course Requirements

- Basic knowledge
- Self learning (40%)
 - Reading papers
 - Presentations
 - Discussions
- Programming project (20%)
- Final survey report (40%)
 - Literature survey on an interesting topic

课程寄语

3D时代的来临...

Expectations

- DGP
 - Many interesting topics
 - Wide applications
- Do something interesting
- Learn something
 - Coding, writing, [demo](#), presentation
- Hard work!

Have fun! 😊

计算机图形学的挑战

- 计算机图形学在美国已经形成一个完整的产业链：科研，游戏，电影，娱乐，教育，艺术，工业界....
- 在中国，正在逐渐形成
 - 中国急需计算机图形学的人才！！！！

广阔天地, 大有可为!

Have fun!

“每天早晨醒来，一想到所从事的工作和所开发的技术将会给人类生活带来的巨大影响和变化，我就会无比兴奋和激动！”

– *Bill Gates*

Q&A