计算机辅助几何设计
2021秋学期

课程介绍

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Introduction: Geometric Modeling

- Motivation
- Overview: Topics
- Basic modeling techniques

Motivation

Motivation

This lecture covers two related areas:

- Classical geometric modeling (CAGD)
- Geometry processing

Common techniques (math, models, terminology), but different problems

Geometric Modeling

- Start with a blank screen, design a geometric model
- Challenge: mathematical description of shape information
  - Computer friendly
  - User friendly
- Typical techniques:
  - Spline curves & surfaces
  - Constructive solid geometry (CSG)
  - Subdivision surfaces

Geometric Modeling

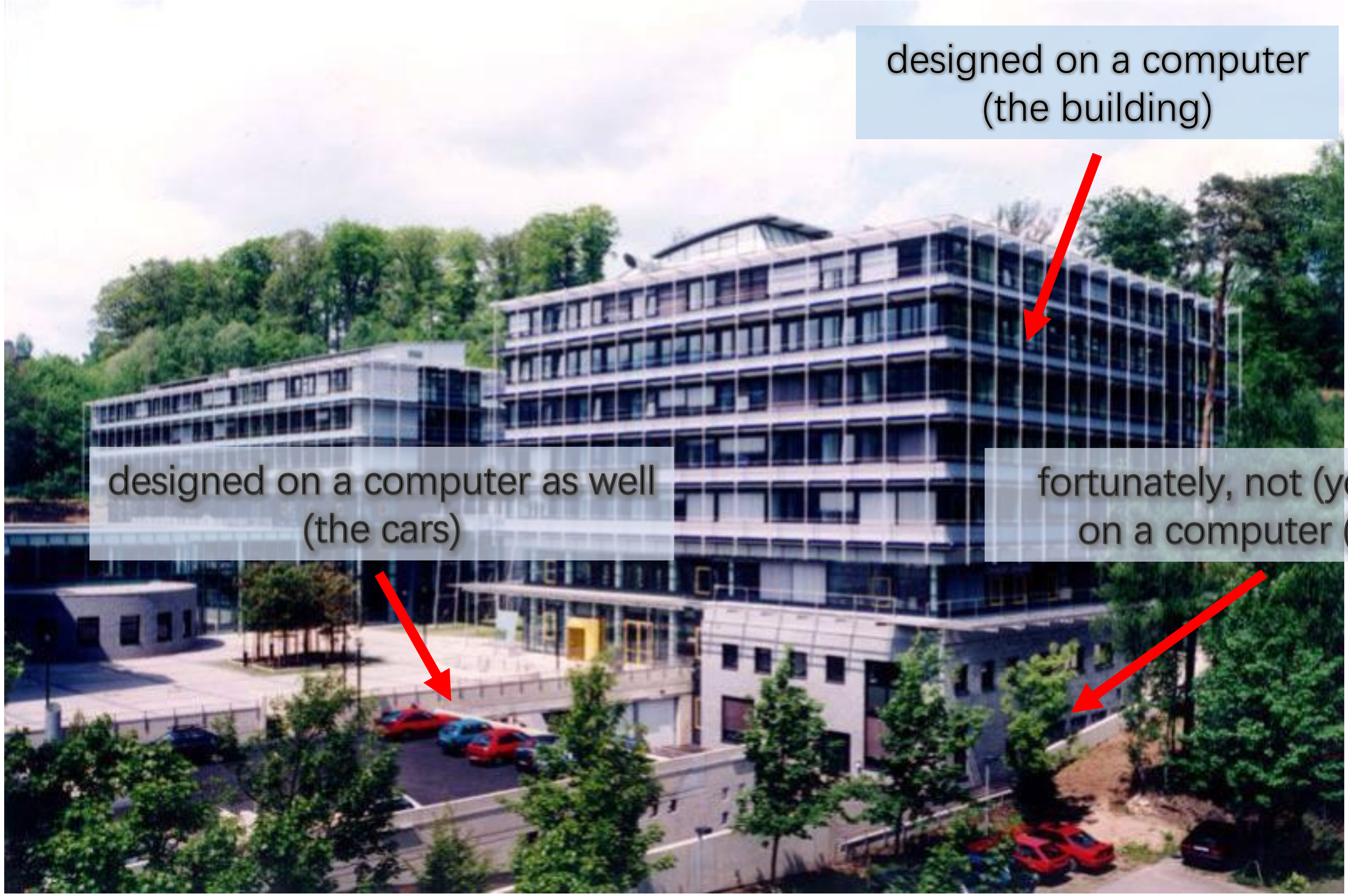
Geometric Processing

- A (discrete) sampling of the model is readily available
  - Typically: 3D scanner (point cloud)
- Challenge: make sense of large complex, unstructured data
  - Analyze and edit the geometry
- Typical issues
  - Noise removal, filtering
  - Surface reconstruction
  - Analysis (features, symmetry, hole-filling, etc…)
  - Parameterization (mapping textures)
  - Editing, deforming

Examples

Geometric Modeling

The Modern World···



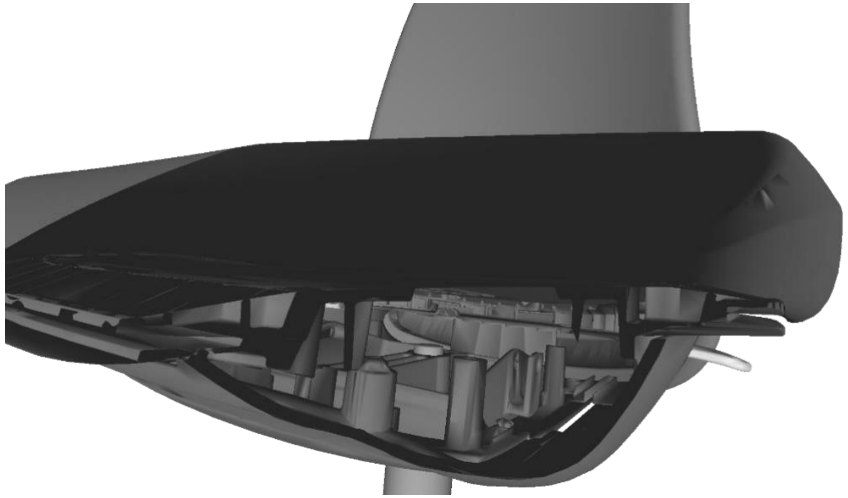
Impact of Geometric Modeling

We live in a world designed using CAD

- Almost any man-made structure designed with computers
  - Architecture
  - Commodities
  - Bike, car
  - Spline curves invented in automotive industry
  - Fonts
- Our abilities in geometric modeling shape the world we live in each day

Different Modeling Tasks

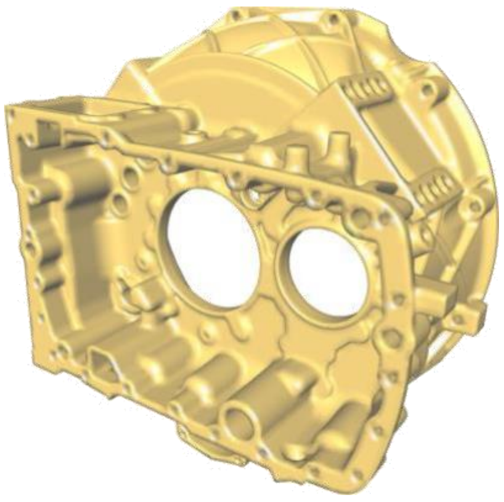
Different requirement for different setups

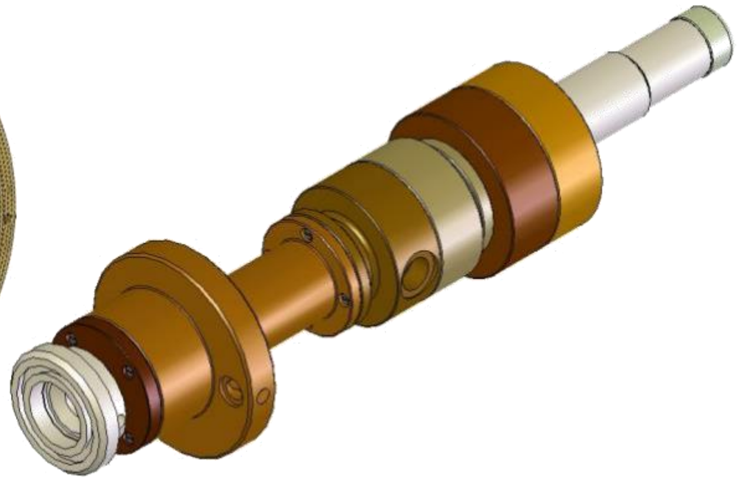
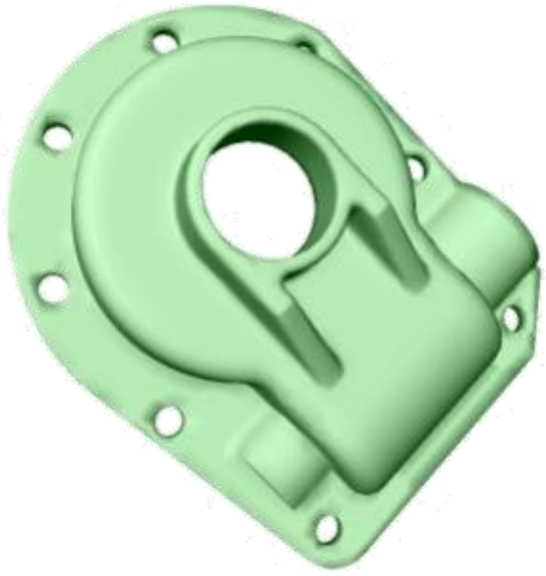


Different Modeling Needs

CAD / CAM

- Precision Guarantees
- Handle geometric constraints exactly (e.g. exact circles)
- Modeling guided by rules and constraints



Different Modeling Tasks

Photorealistic Rendering

- Has to “look” good
- Ad-hoc techniques are ok
- Using textures & shaders to “fake” details
- More complexity, but less rigorous

[Deussen et al: Realistic modeling and rendering of plant ecosystems, SIGGRAPH 1998]

Geometric Modeling

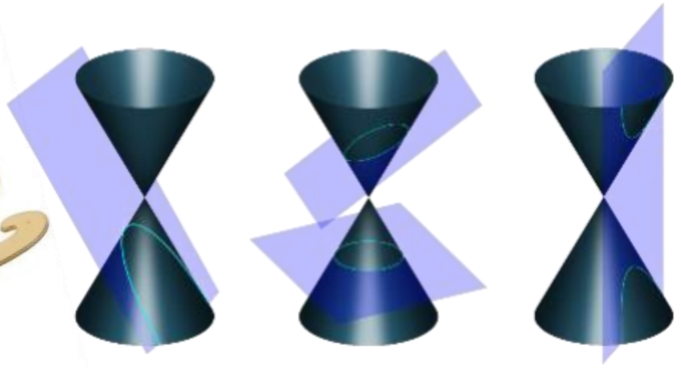
A look back

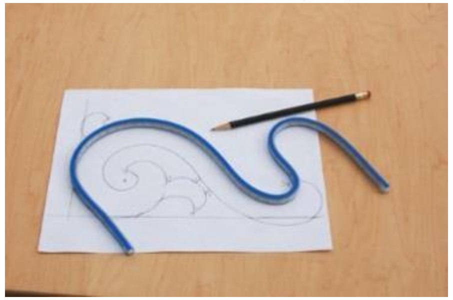
Modeling the old way

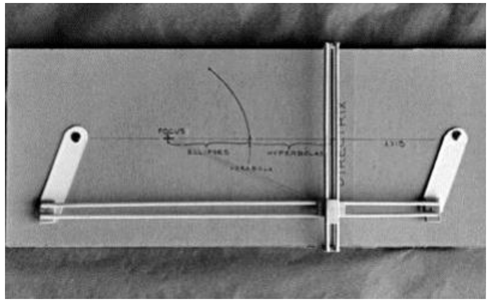
Basic tools

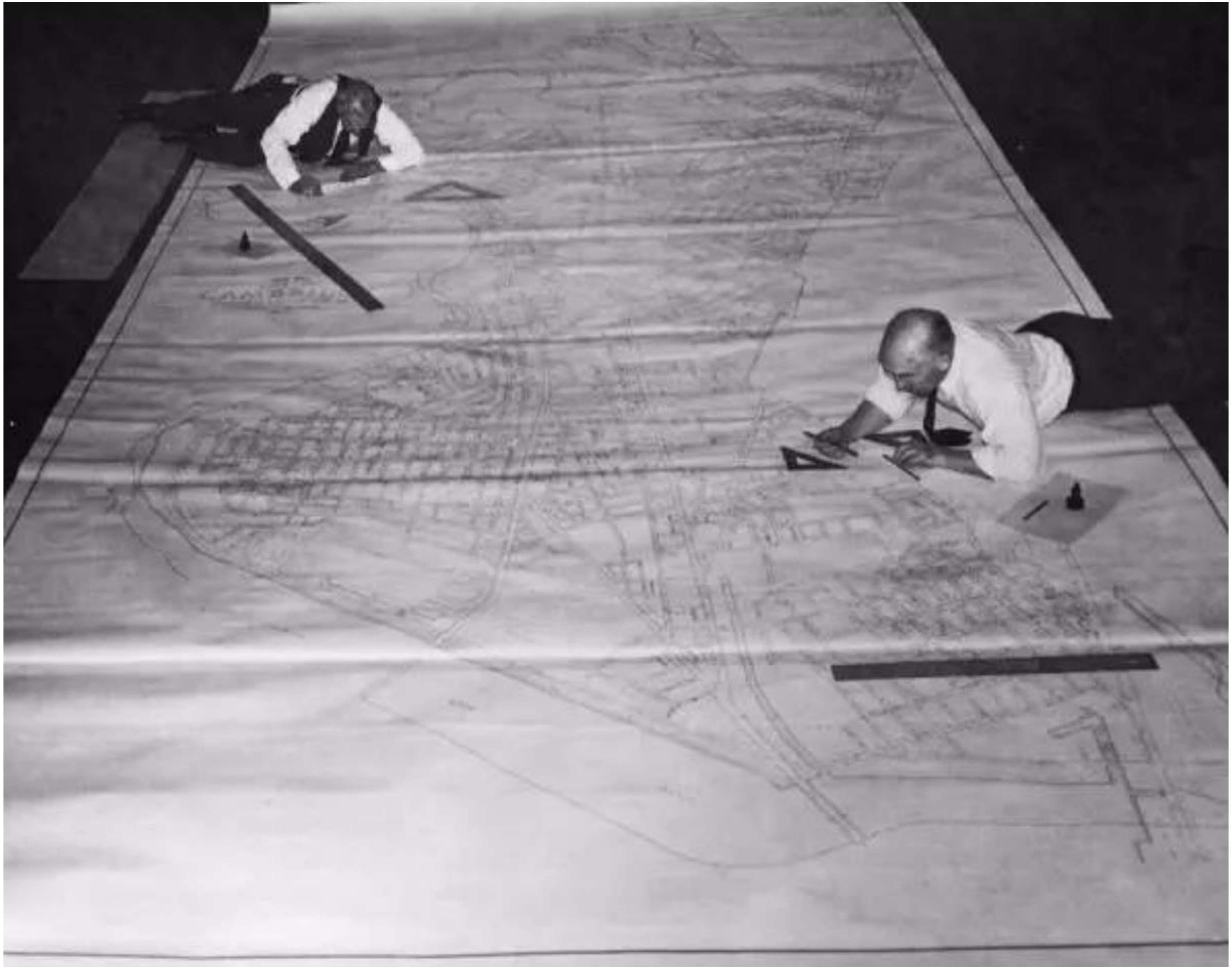
- Measuring and drafting tools



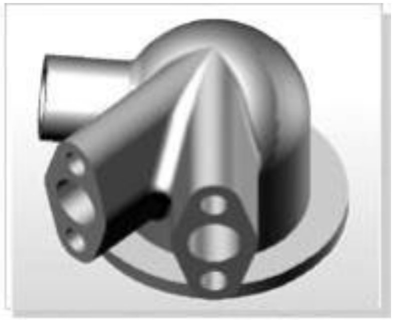







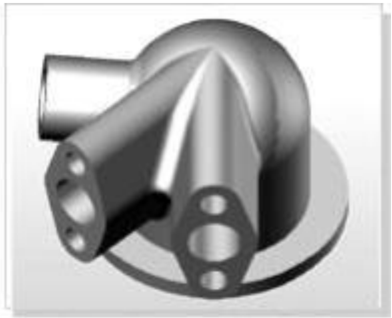
Industrial modeling developments

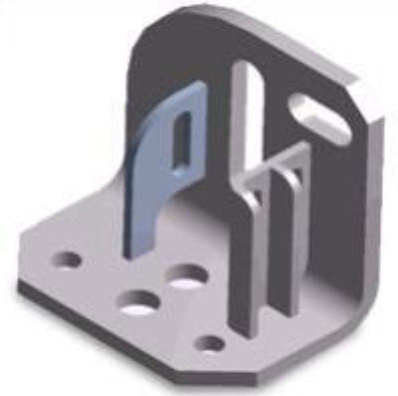


Industrial modeling: Two distinct shape classes

- Complex combination of elementary surfaces
  - Easy to model (blueprint)
  - Easy to produce
  - Easy technical evaluations (volume, moment of inertia)

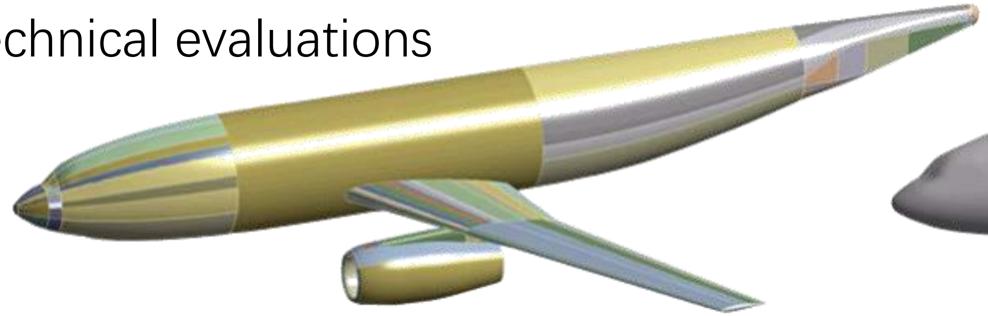
Industrial modeling developments





Industrial modeling: Two distinct shape classes

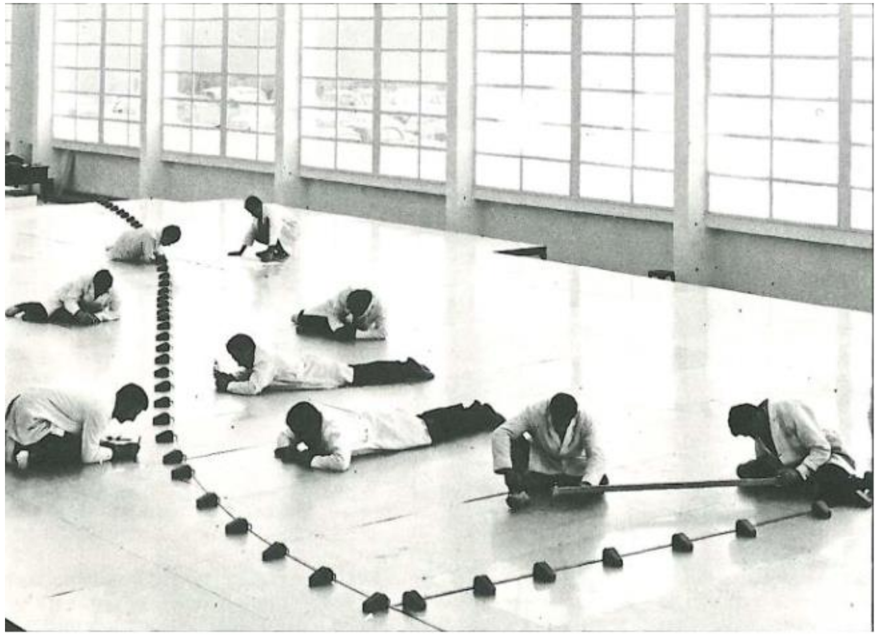
- Complex combination of elementary surfaces
  - Easy to model (blueprint)
  - Easy to produce
  - Easy technical evaluations (volume, moment of inertia)
- Free-form shapes
  - Required mainly by modern industries e.g. aeronautics, shipbuilding, auto industry
  - Not easy to describe mathematically
  - Harder technical evaluations



Early modeling of free-form curves and surfaces

Splines

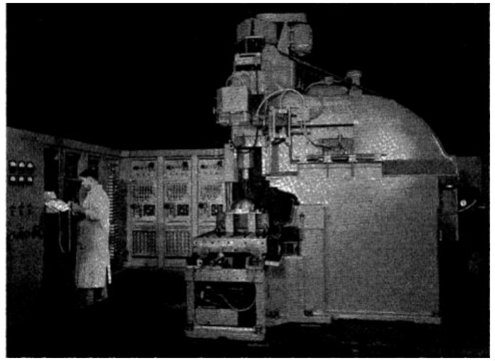
- Thin flexible band made out of wood, plastic or steel
- Can be held in shape using weights
- Smooth energy minimizing curves

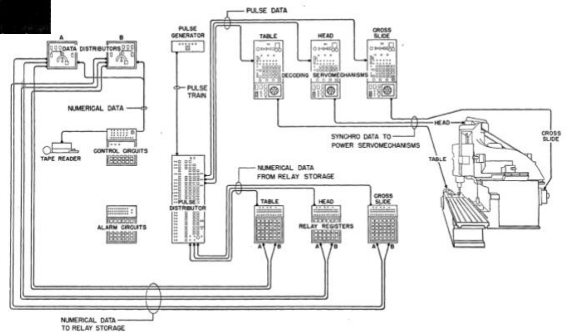


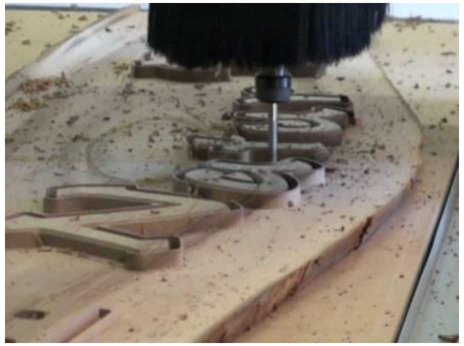
Birth of computer aided design (CAD)

Two major events

- The world's first NC 3D milling machine (MIT 1951)
  - Shapes can be described mathematically
  - Read shape information from drawing



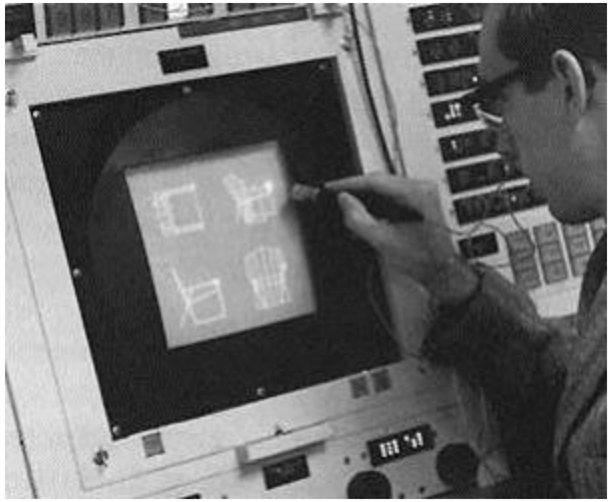


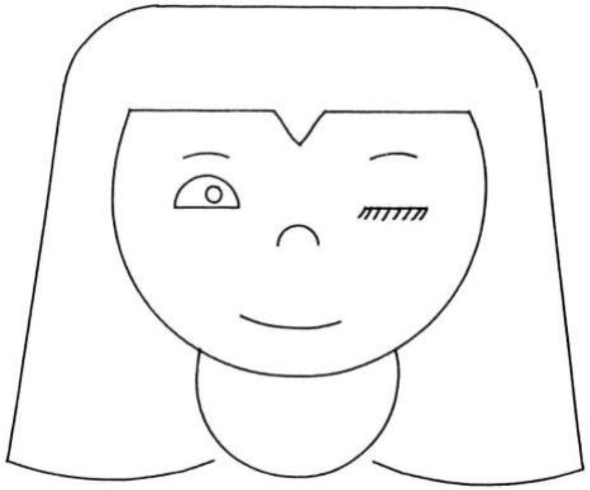


Birth of computer aided design (CAD)

Two major events

- I. Sutherland sketchpad: A man machine graphical communication system (MIT 1963)
  - Shape became visible (Not just a formula)
  - Direct interaction with shape



Birth of computer aided design (CAD)

Development of mathematical descriptions of Free form curves and surfaces

- Ferguson curves and surfaces (Boeing 1961)
  - Vector description and use of parameters
- Coon surface patches (MIT 1964)
  - Control through positions and tangents

- de Casteljau Algorithm (Citroën 1959)
- Bézier curves (Renault 1971, UNISURF system)
- B-splines, NURBS, T-splines, AST, S-splines…

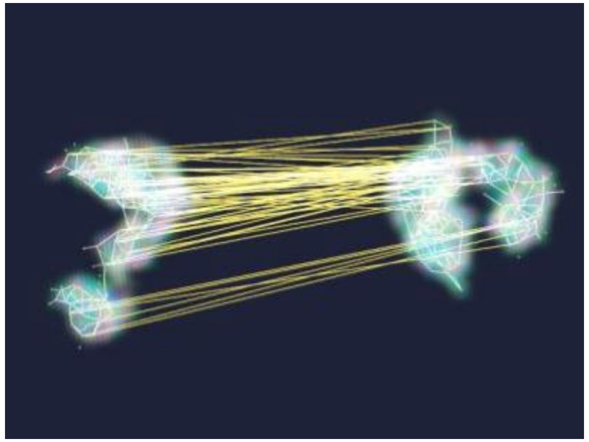
Geometry Processing

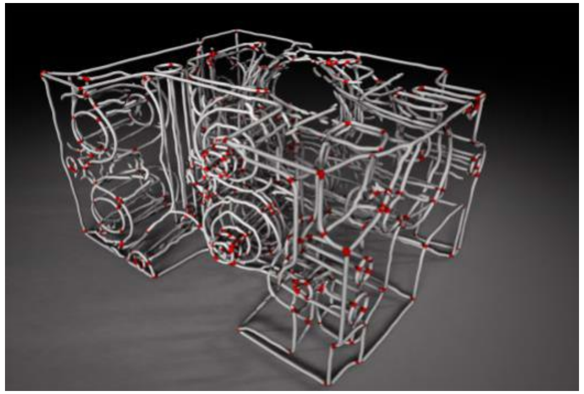
Examples

Geometry Processing

A rather new area

- Motivation: 3D scanning
  - 3D scanners
  - Clouds of millions of measurement points
- Sources of spatial data:
  - Science: CT, MRI,...
  - 3D movie making
  - Game / movie industry:
    Servers with GBs of "polygon soup"
  - Crawl the internet
- Need to process the geometry further



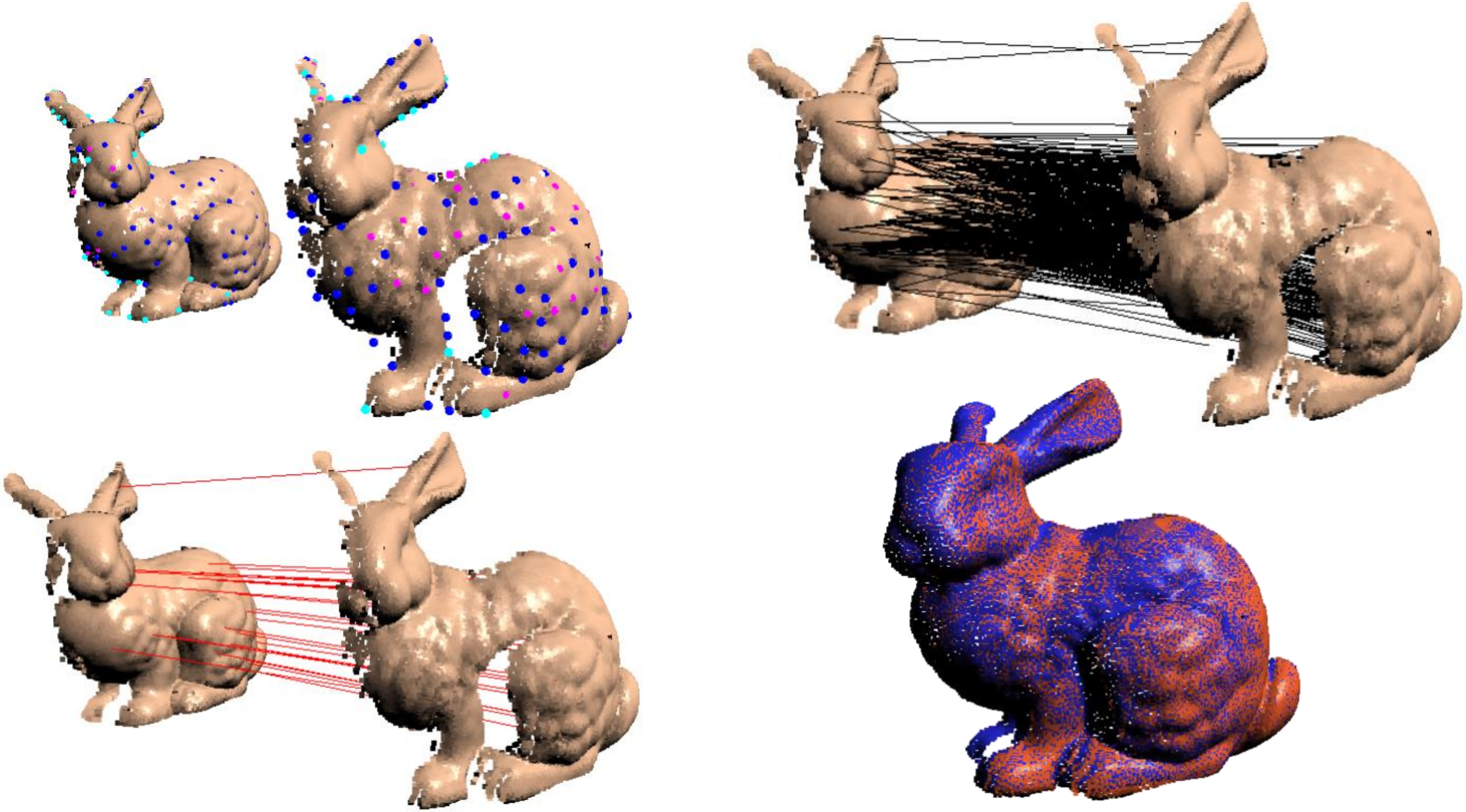


Photoshopping Geometry

Geometry Processing:

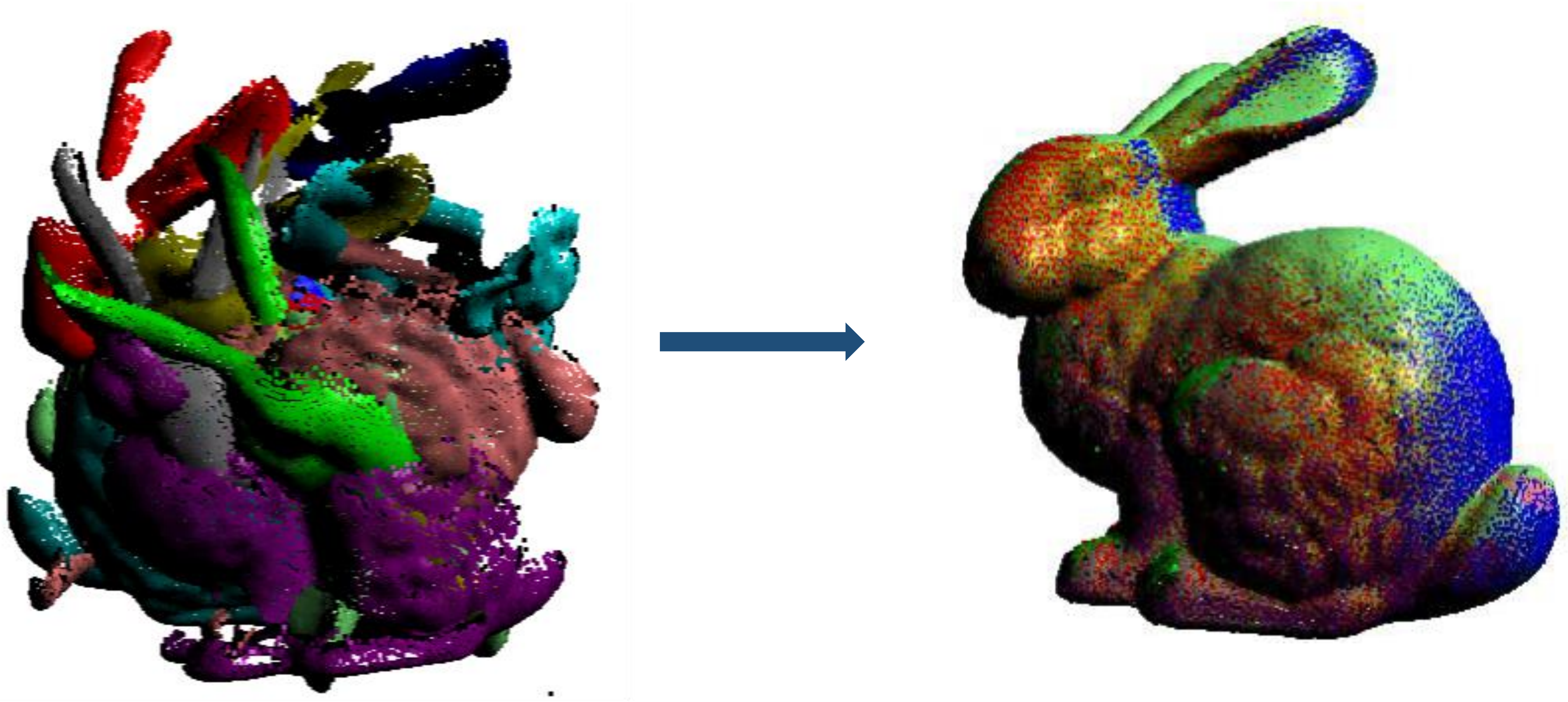
- Cleanup:
  - Remove inconsistencies
  - Make watertight (well defined inside/outside, for 3D printers)
  - Simplify – keep only the main “structure”
  - Remove noise, small holes, etc…
- Touch-up /Edit:
  - Texturing, painting, carving
  - Deformation
  - Stitch together pieces
- Lots of other stuff – similar to image processing

Scan Registration



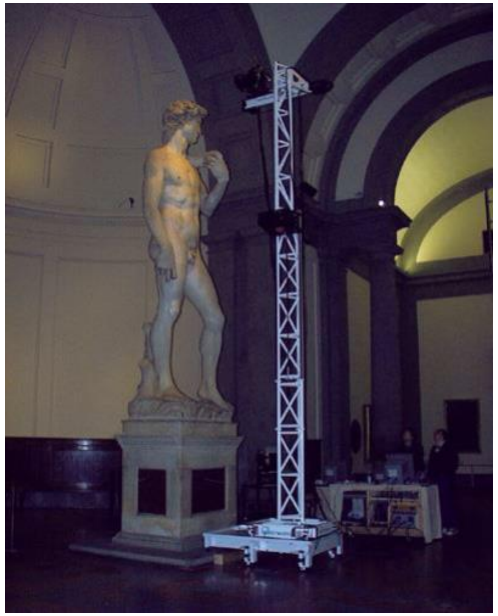
Feature Tracking

Fully Automatic:

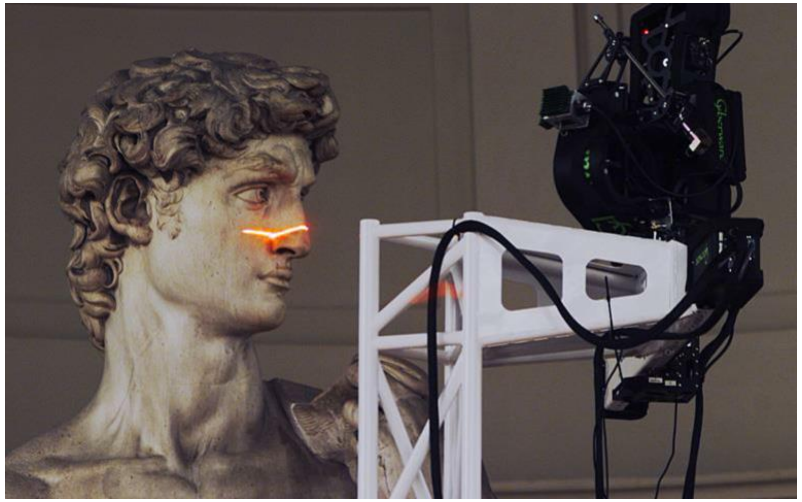


Example

Example: The Stanford "Digital Michelangelo Project"



scanning

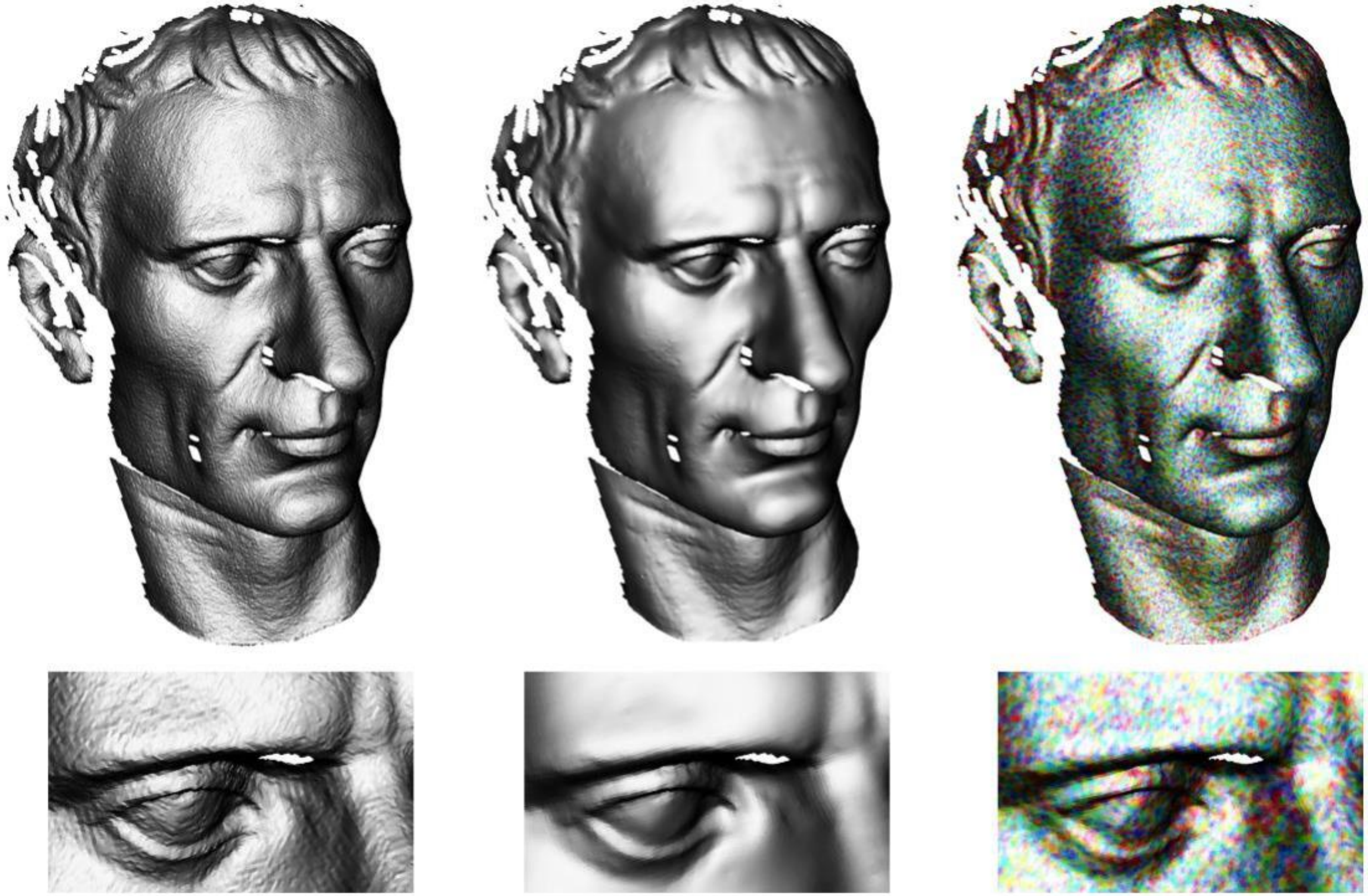


scanning

rendered reproduction

[Levoy et al.: The Digital Michelangelo Project, Siggraph 2000]

Denoising

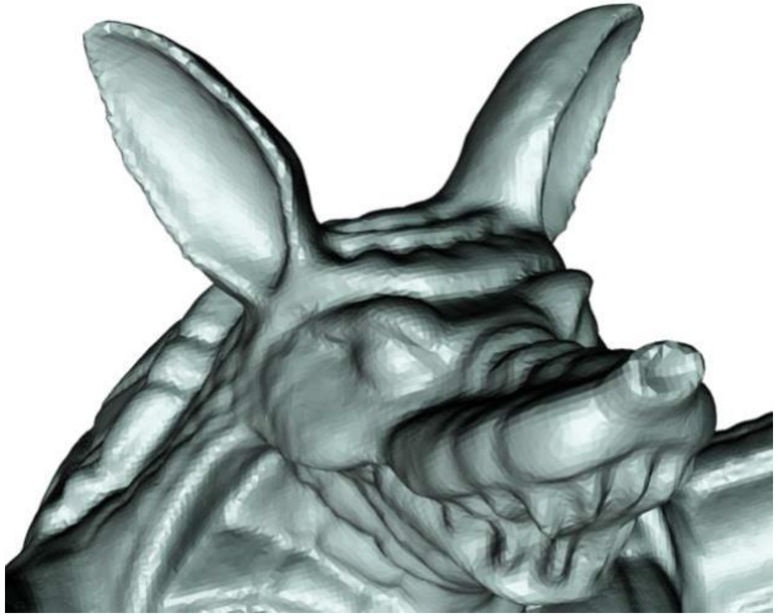


Size ~300mm

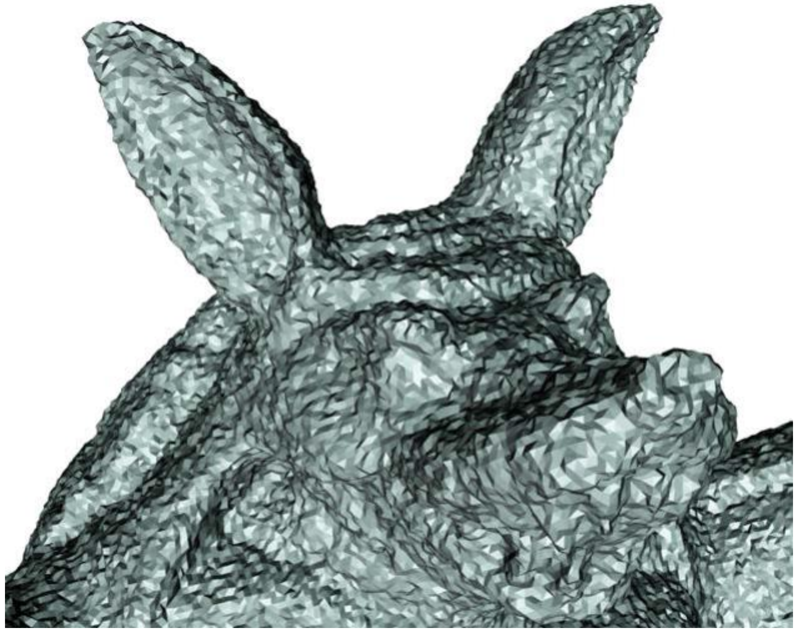
Max. deviation : 0.1mm

Denoising

Remove noise, but preserve features



Original

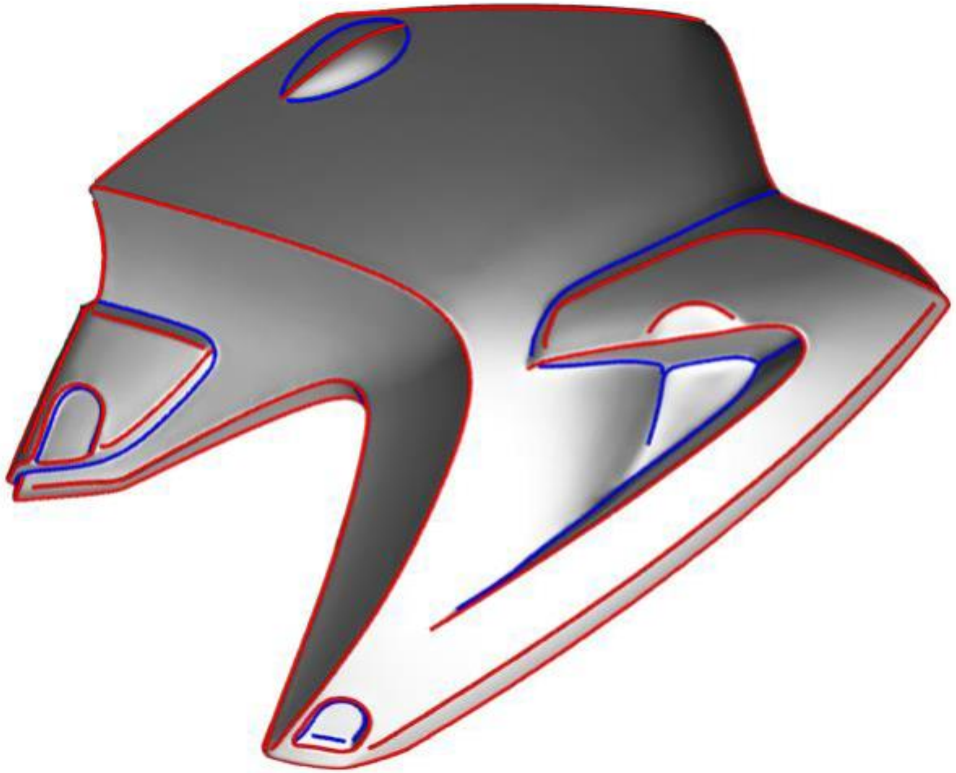


Noise added

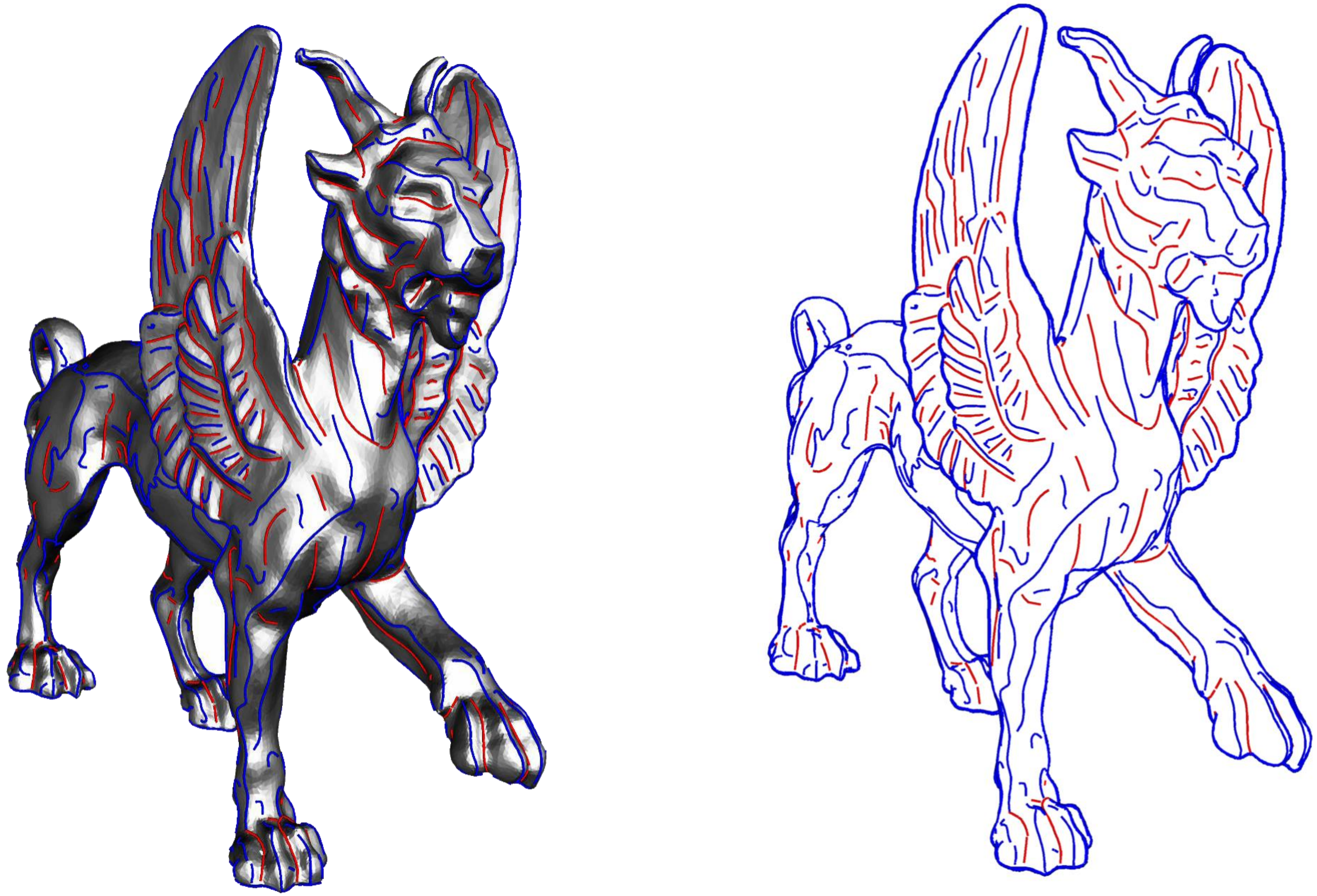
Denoised

Feature Detection

Find curves on a surface that carry visually most prominent characteristics



Feature Detection



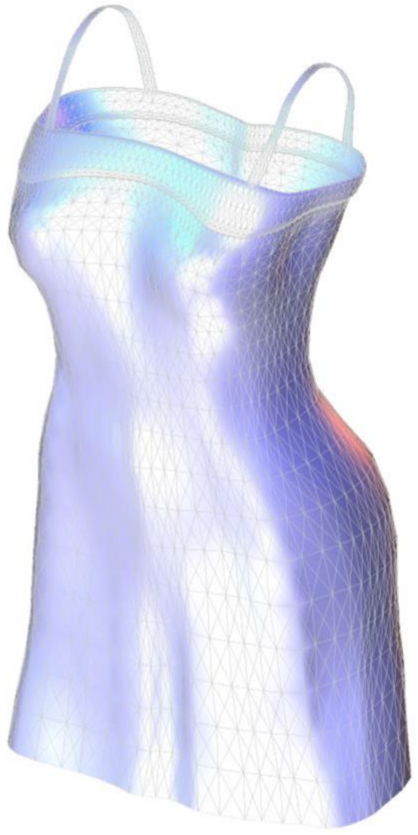
Surface Parameterization: Motivation

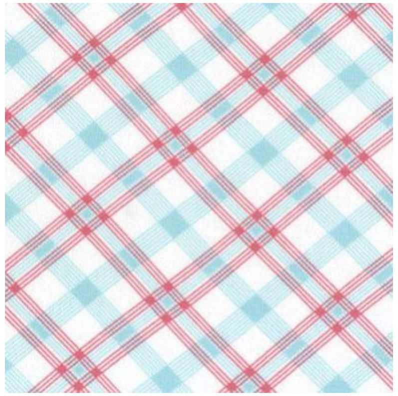
Texture mapping

Graphics ingredients

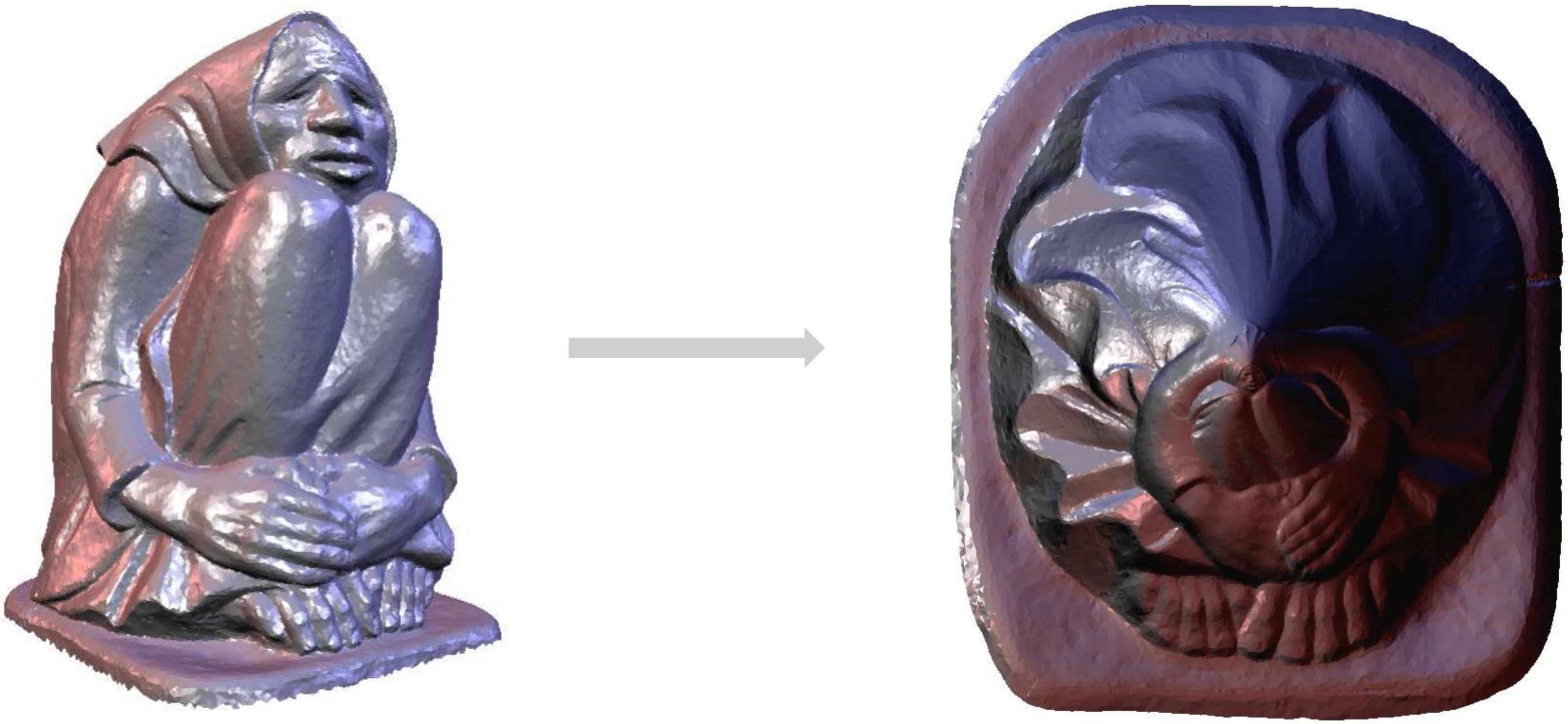
Real world

Texture mapping example





Surface Parameterization

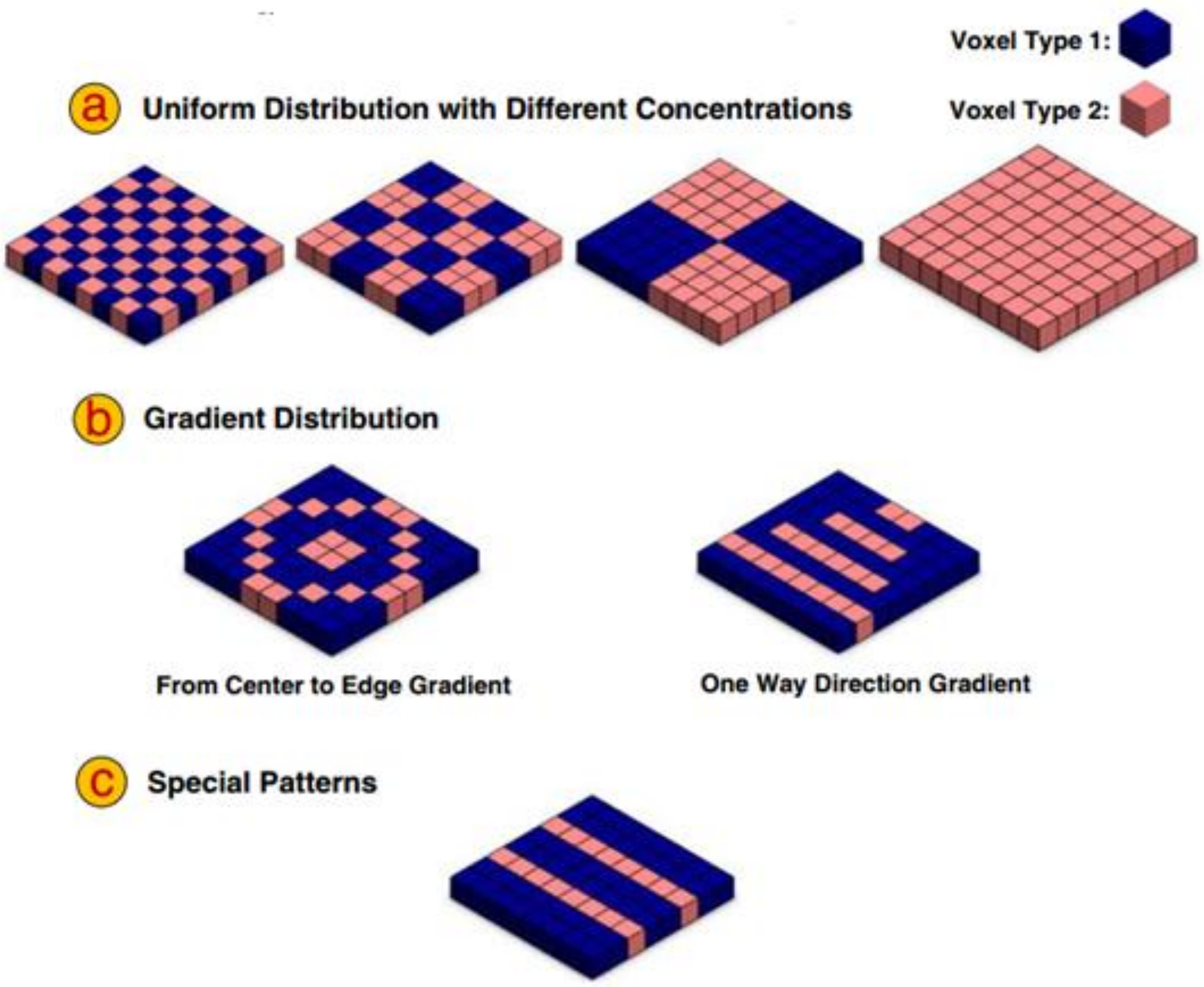


Surface Parameterization

Latest Development

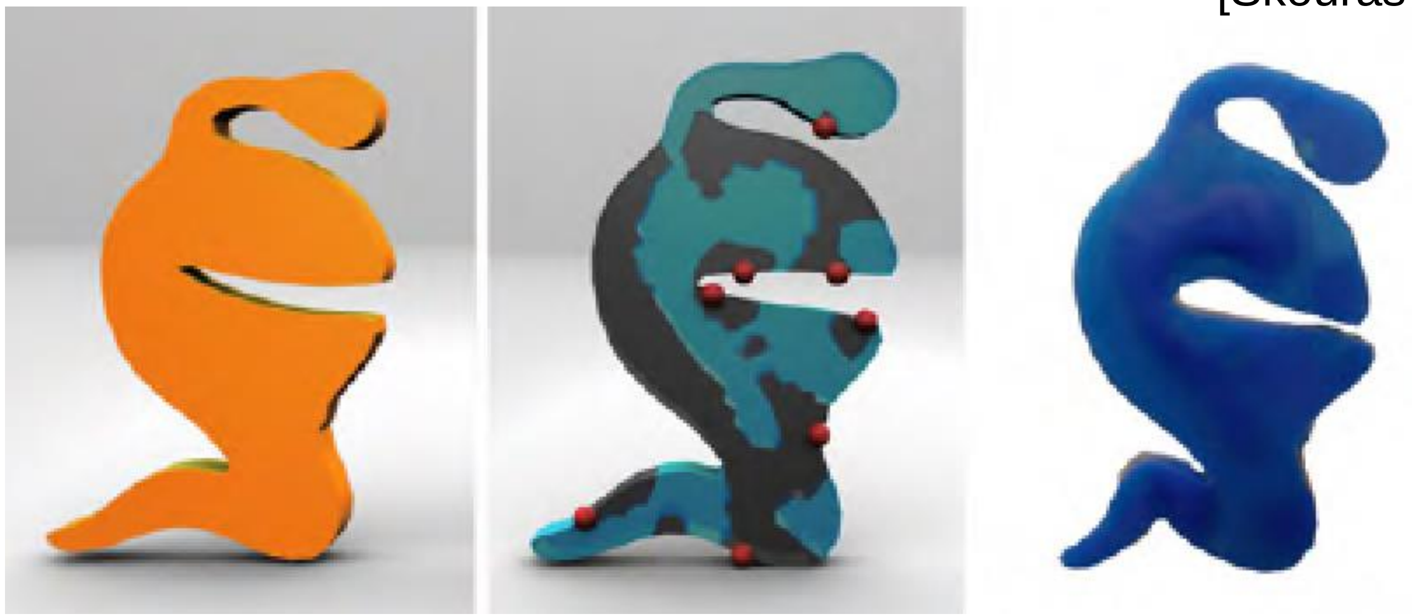
Geometric Design

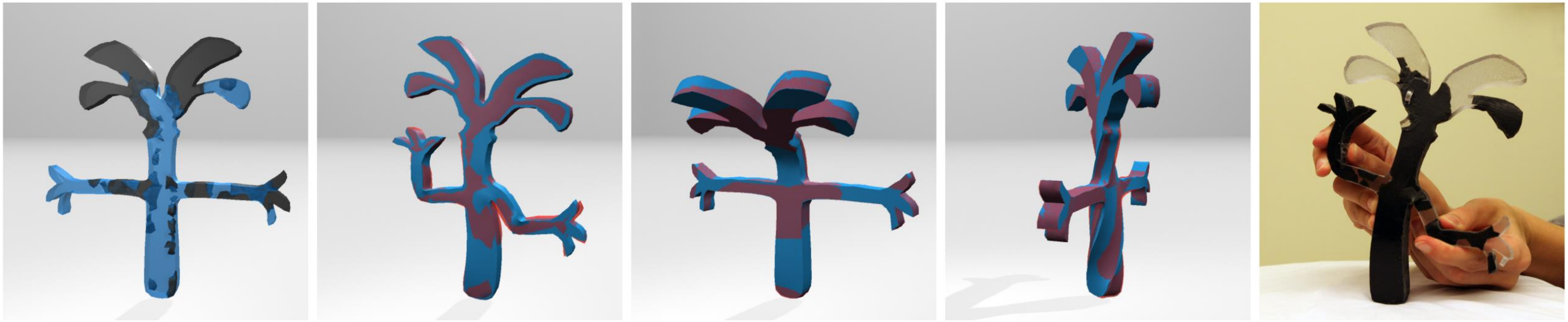
Trend 1: Material design



Material distribution optimization

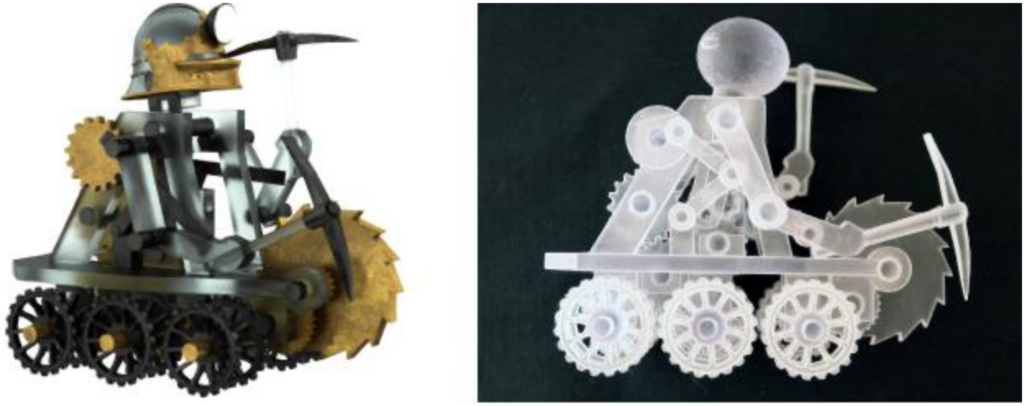
[Skouras et al. 2013]





Trend 2： Structure Design

Design

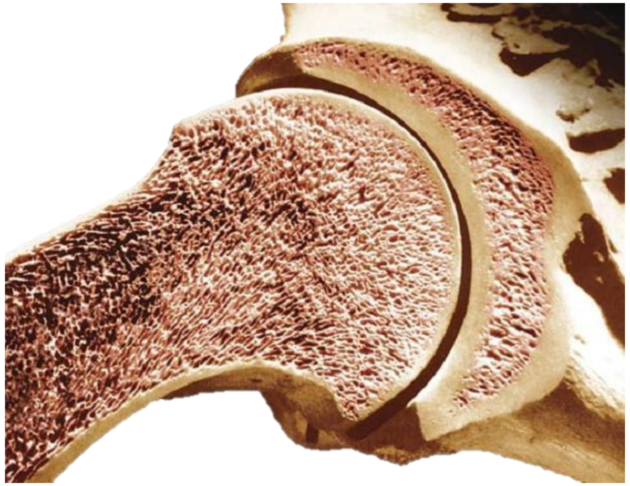


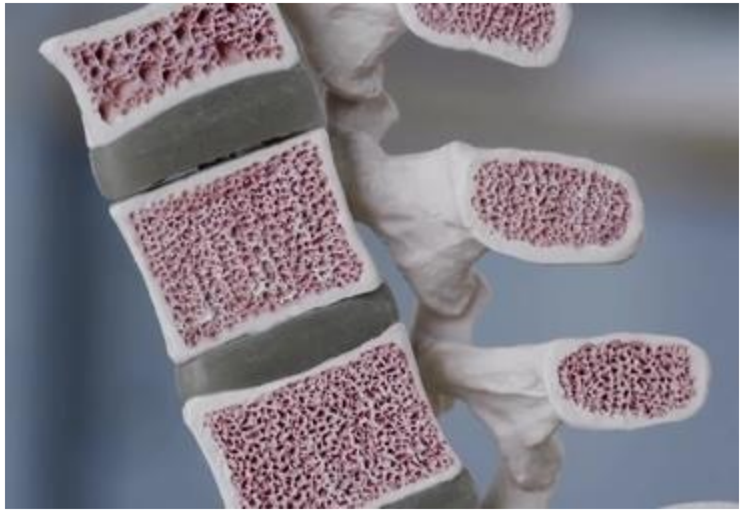
Small scale:
Micro-structure,
Frame, Foam, etc.

Large scale:
Assembly,
Mechanical, etc.

Microstructure Design

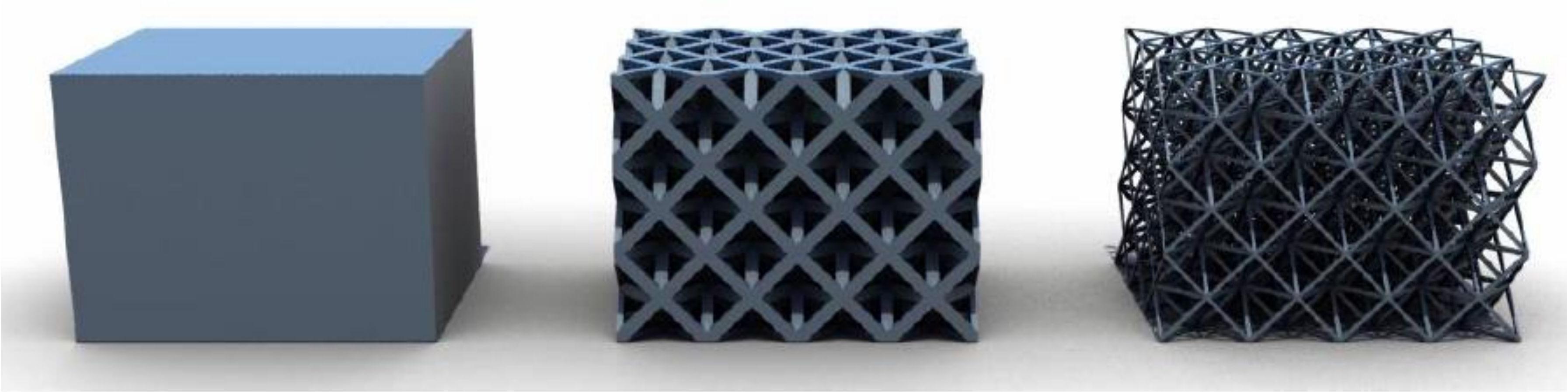
Microstructure in nature

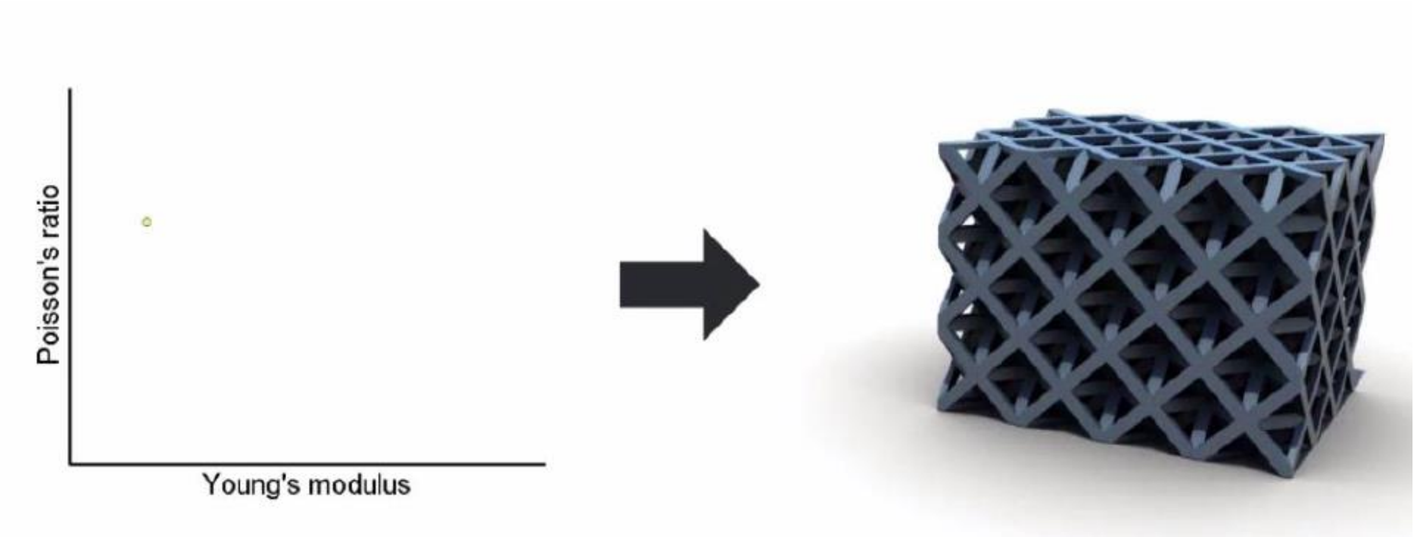




Ack Lin Lv

Material Structure



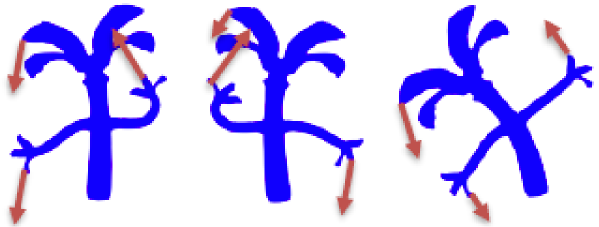


Problem

Input

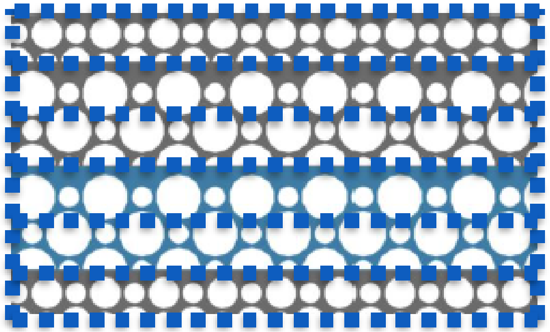
- Shape with assigned Material Parameters

- Deformation Specification



Output

- Spatially-varying material structure



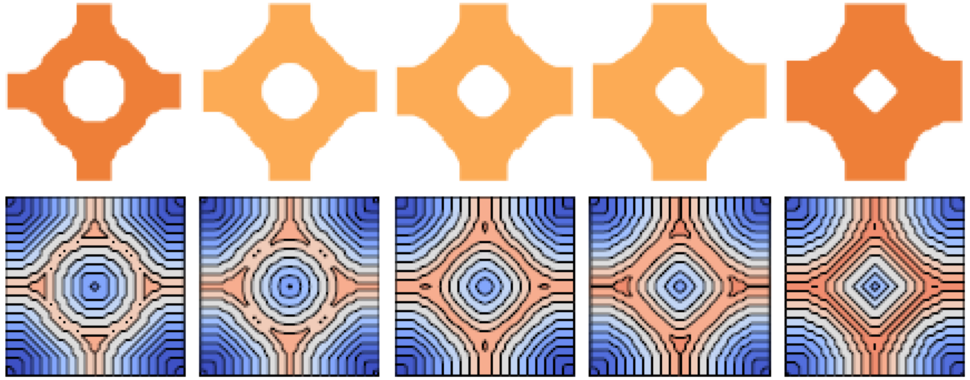
Meso-structure

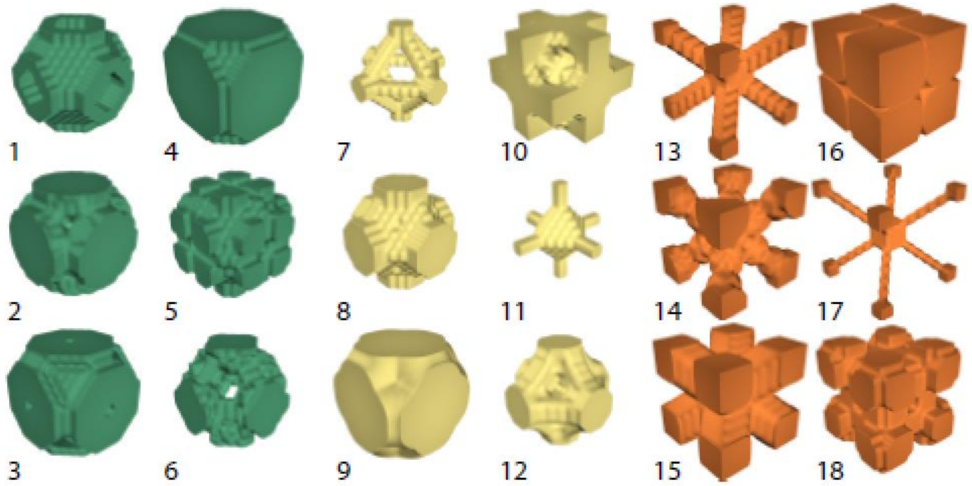
[Wang et al. 2013]

[Lv et al. 2014]

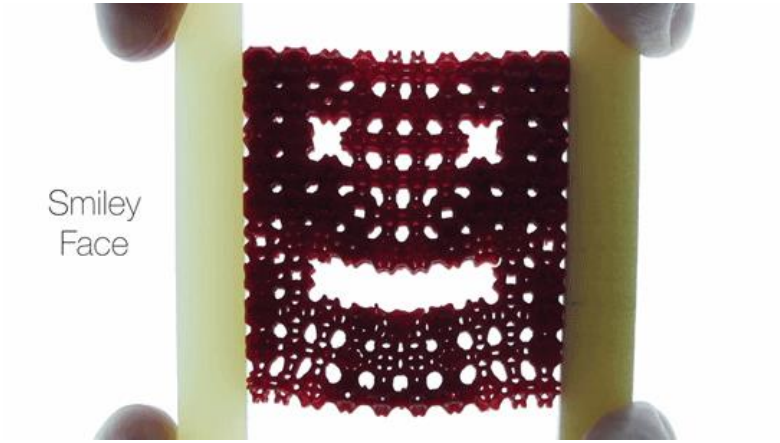
Elastic microstructure design

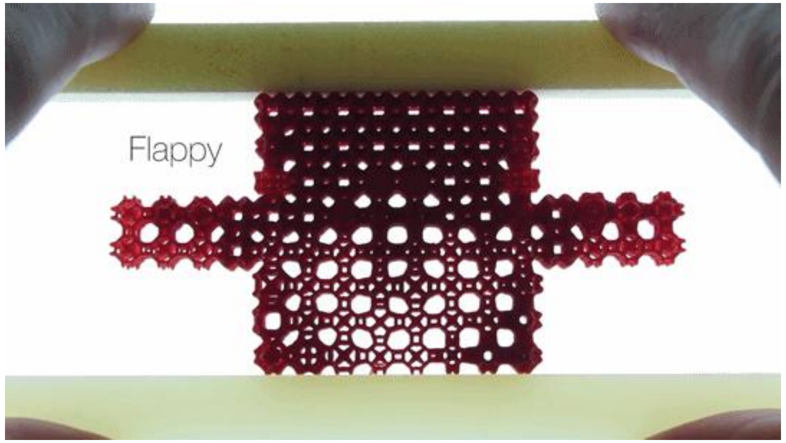
[Schumacher et al. 2015]



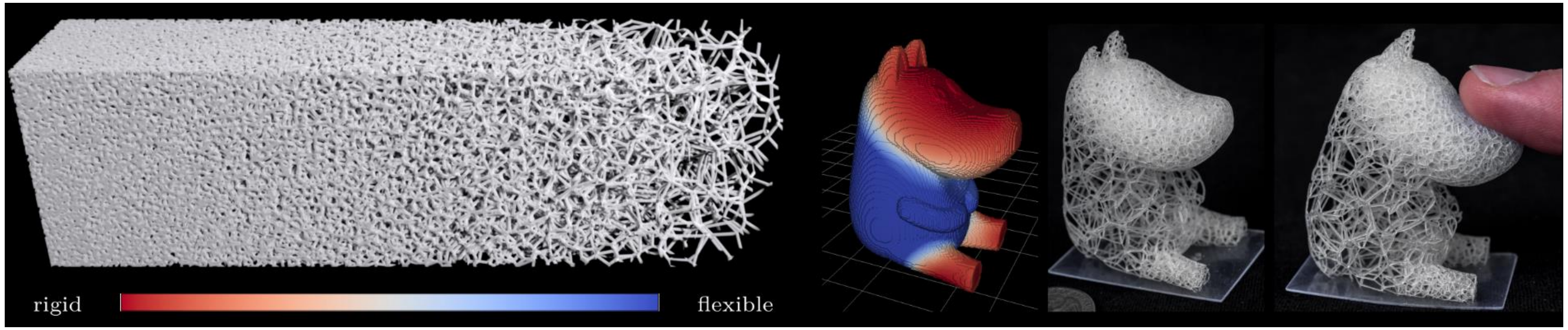


Elastic microstructure design





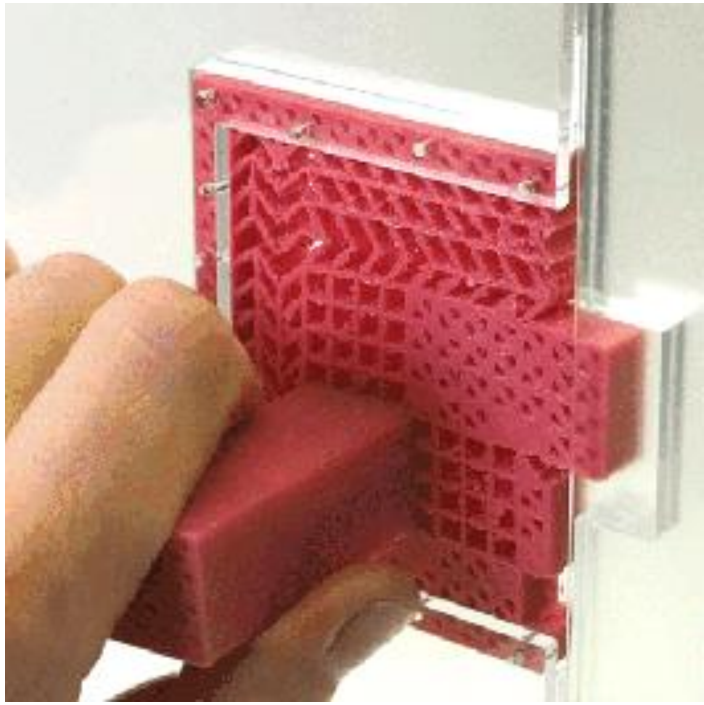
[Panetta et al. 2015]

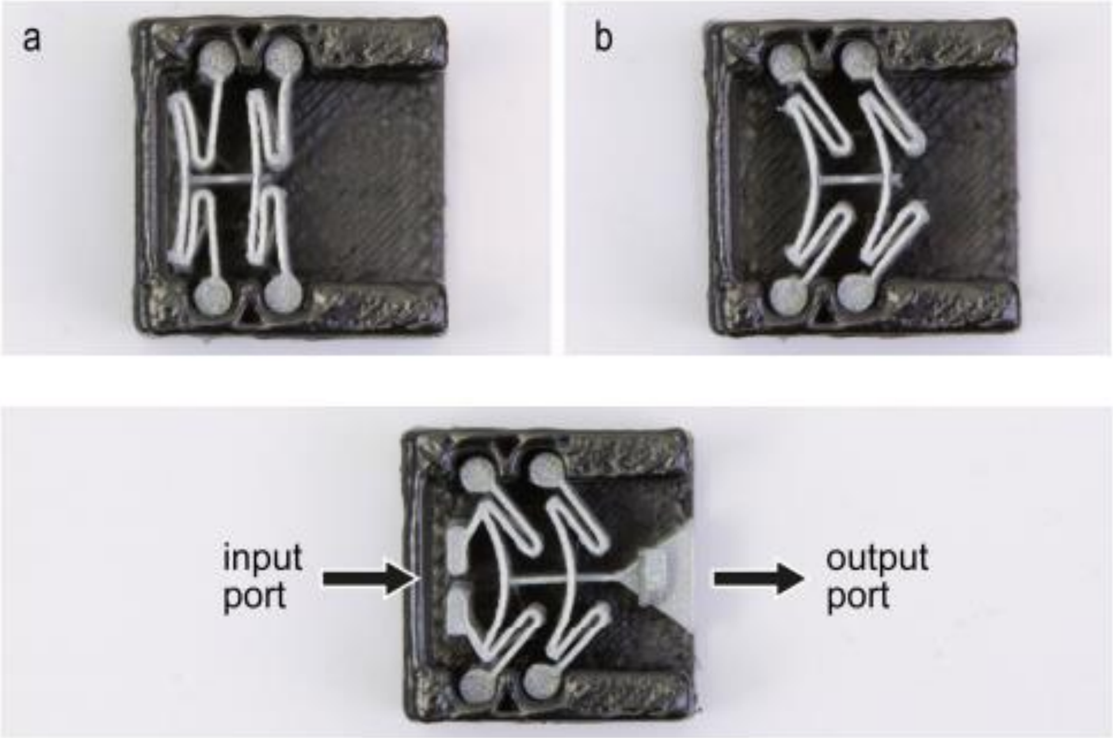


[Martínez et al. 2016]

Functional microstructure design

[Ion et al. 2017]





本课程内容

课程主页

http://staff.ustc.edu.cn/~renjiec/CAGD_2021S1/default.htm

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Teaching

Computer Aided Geometric Design (Autumn-Winter 2021-2022)
Summer School for Advances in Computer Graphics 2021 (计算机图形学前沿进展)
Computer Graphics (Spring-Summer 2020-2021)

课程目标

- 几何表达的基本方法
- 几何建模与处理
- 计算机图形学及几何设计的新发展

- 授之以鱼，不如授之以渔

预备知识：数学

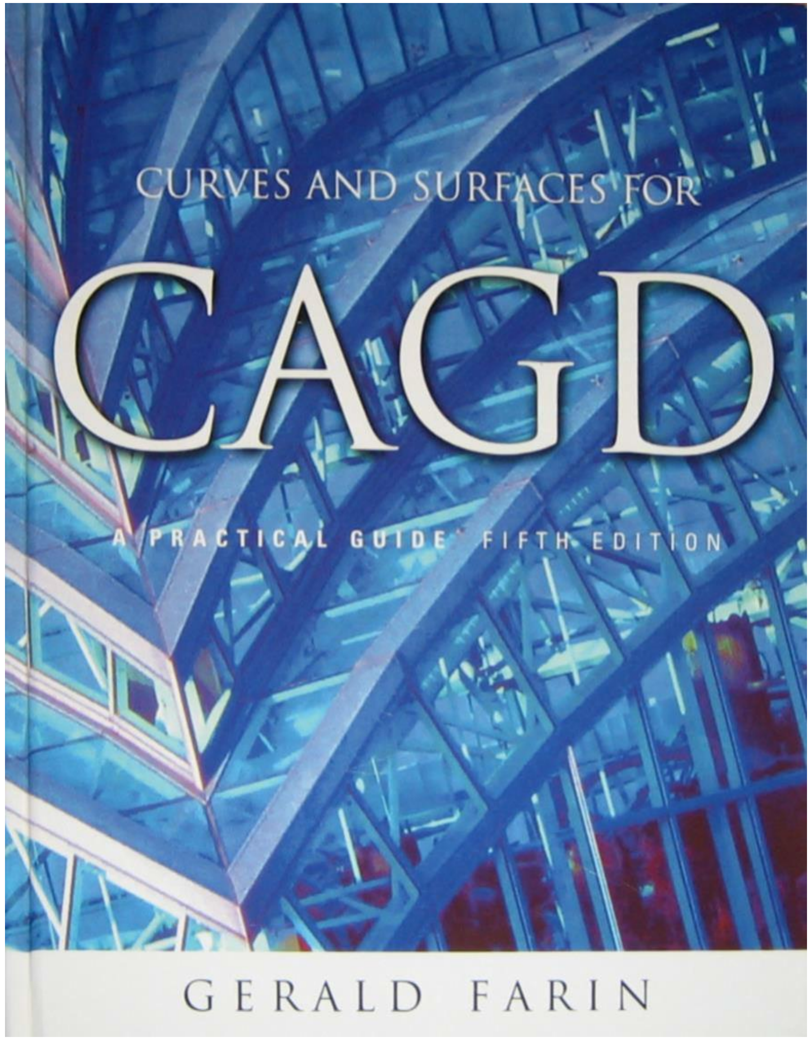
- 线性代数
- 微积分
- 几何：空间几何、微分几何
- 微分方程
- 最优化
- 数值方法与计算
- …

预备知识：编程

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

Literature

Textbook: Splines

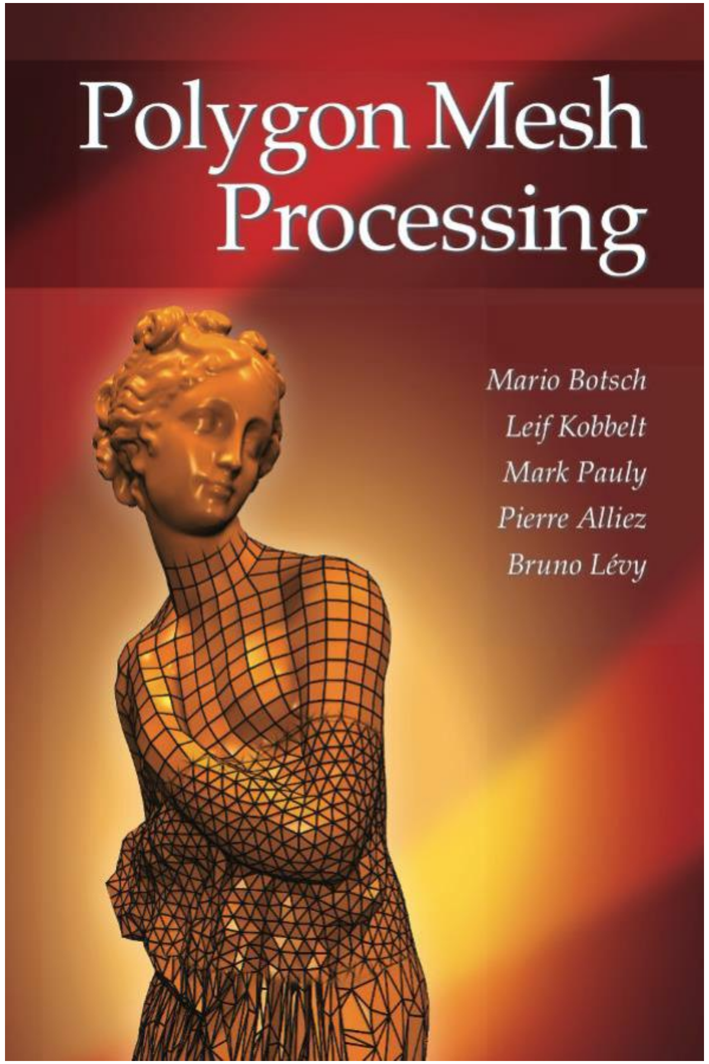


Gerald Farin

Curves and Surfaces for Computer Aided Geometric Design

(Fifth Edition)

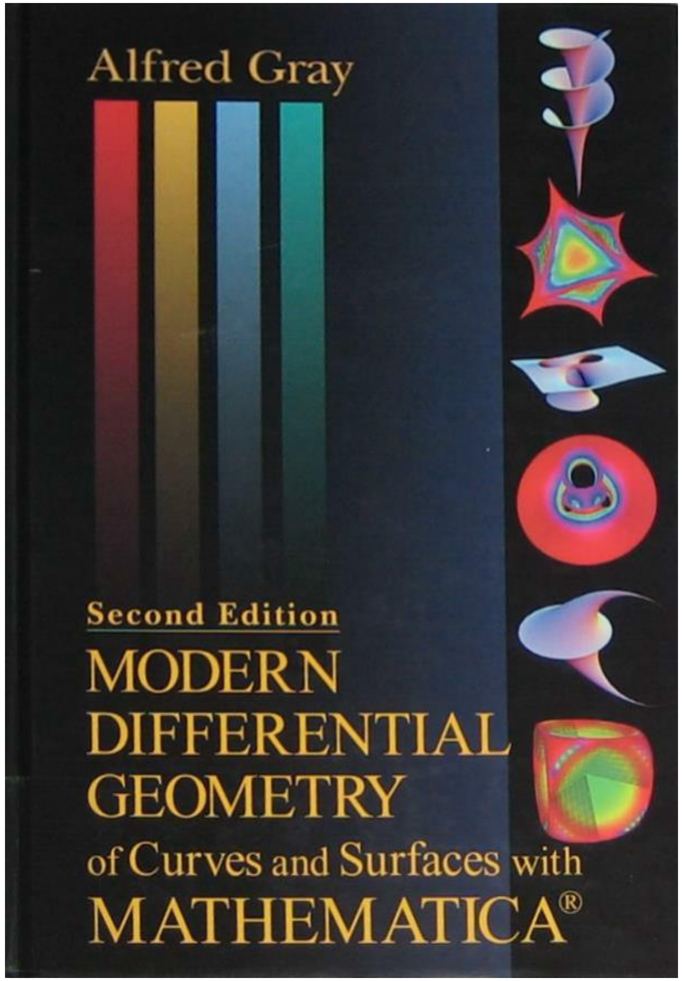
Textbook: Mesh Processing



Mario Botsch, Leif Kobbelt, Mark Pauly, Pierre Alliez, Bruno Levy

Polygon Mesh Processing

Differential Geometry

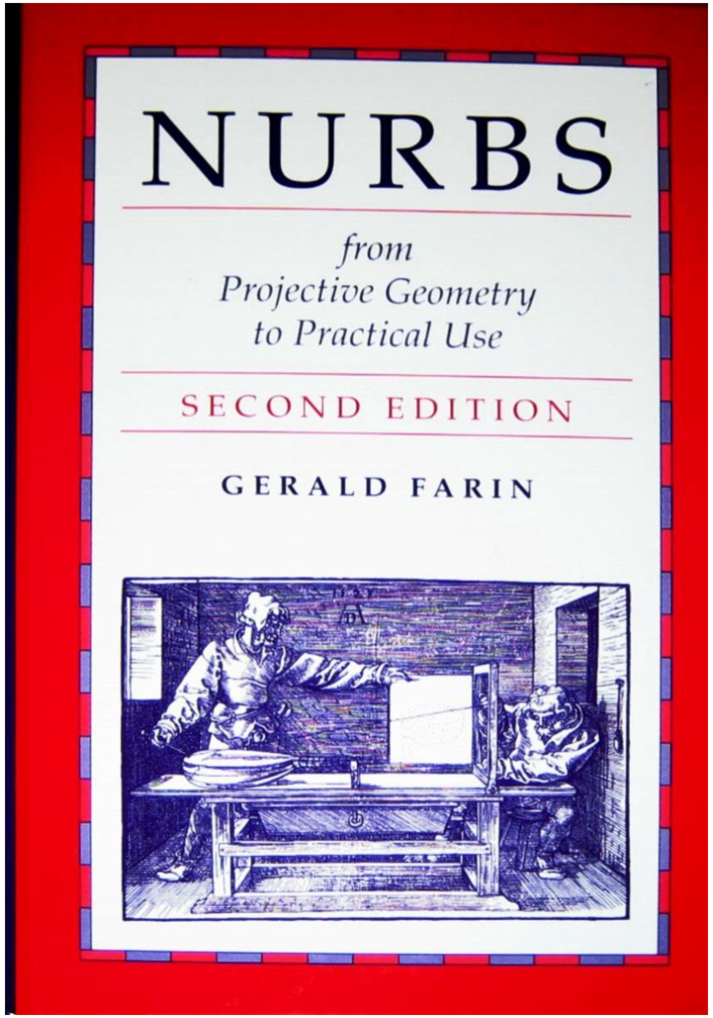


Alfred Gray

Modern Differential Geometry of Curves and Surfaces with Mathematica®

(Second Edition)

More on Rational Splines



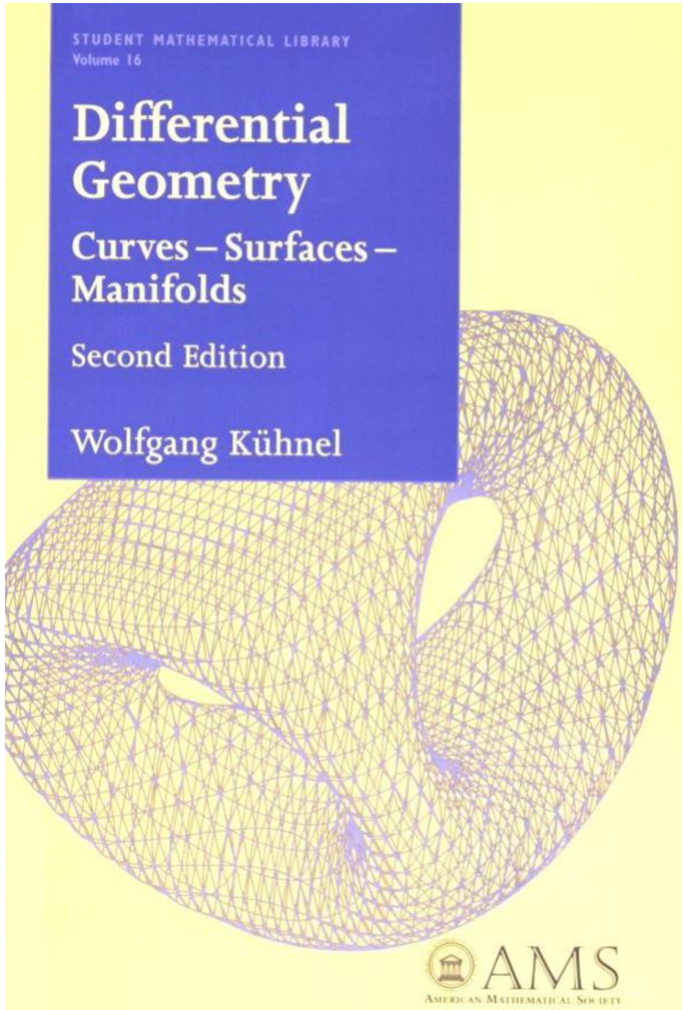
Gerald Farin

NURBS – from Projective Geometry to Practical Use

(Second Edition)

- More details on rational curves & surfaces and projective geometry

More on Differential Geometry



Wolfgang Kühnel

Differential Geometry:

Curves - Surfaces – Manifolds

More on CAGD

- Josef Hoschek and Dieter Lasser. Fundamentals of Computer Aided Geometric Design. A K Peters/CRC Press. 1996.
- Thomas W. Sederberg. Computer Aided Geometric Design. Lecture notes. 2012.
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- 王国瑾, 汪国昭, 郑建民. 计算机辅助几何设计. 高等教育出版社. 2001.
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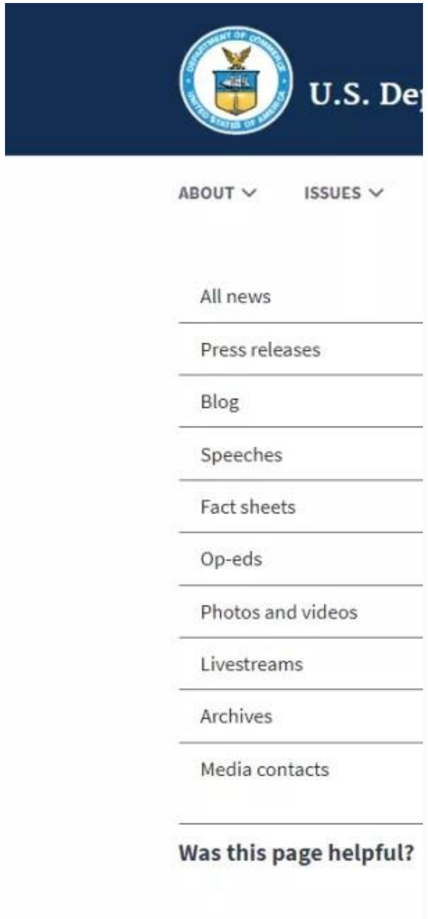
课程主页上有部分资料下载

作业

- 周三晚上布置作业，周一交，次周三讲解

课程寄语



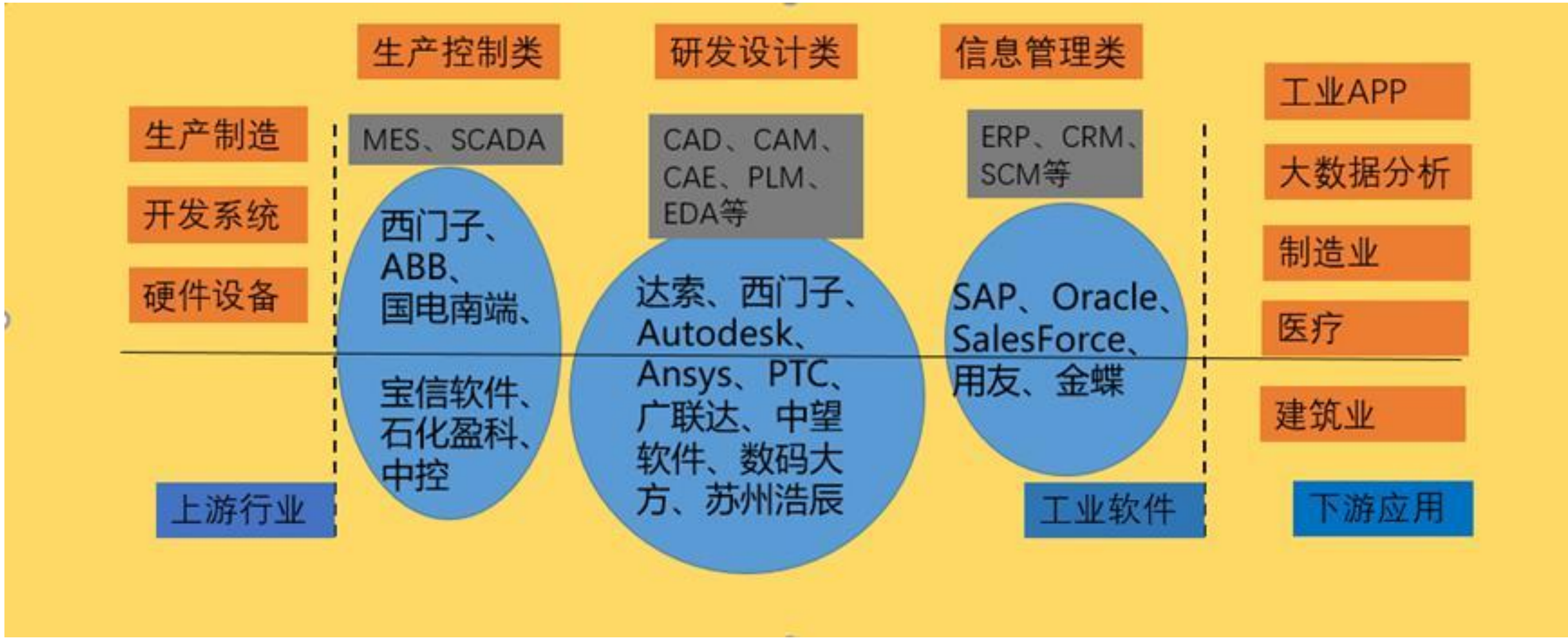
截止202

序号	实体
1	华为云计算技术
2	华为云北京
3	华为云大连
4	华为云广州
5	华为云贵阳
6	华为云香港
7	华为云上海
8	华为云深圳
9	华为OpenLab苏州
10	乌兰察布华为云计算技术

中国

序号	实体
1	昌吉溢达纺织有限公司
2	合肥宝龙达信息技术有限公司
3	合肥美菱有限公司
4	新疆和田浩林发饰品有限公司
5	和田泰达服饰有限公司
6	今创集团
7	南京新一棉纺织印染有限公司
8	南昌欧菲光科技有限公司
9	碳元科技
10	新疆丝路华大基因科技有限公司
11	北京六合华大基因科技有限公司

工业软件的核心地位



据统计，全球工业软件产品的市场规模每年约以 5%的速度增长， 2019 年已超过 4000 亿美元，到 2020 年市场规模将达 4332 亿美元。目前国内的工业软件市场规模较小，仅占全球的约 6%，远低于中国 GDP 的份额 16%，因此在未来智能制造、国产替代、软件上云的背景下，有巨大的发展潜力。

国内CAX软件的发展

- 六十年代中期开始研究CAD/CAM技术在航空、造船工程中的应用
- 七十年代中期以后，CAX技术的迅速发展
- 1975年，西安交通大学，751型光笔图形显示器
- 1984年，北航唐荣锡教授研制出中国第一个多面体实体造型原型系统PANDA
- 八十年代中期，统计发现各院校和研究机构已经开发出2000多套CAD系统
  - 我国第一个造船集成生产系统;
  - 南航B-SURF（3D-CAD）系统，可以建立两种型号无人机的全机数模，在IBM4341图形终端上呈现了全机及各部件的各种透视图、切面图等
- 1992年，超大规模集成电路计算机辅助设计（IC-CAD）熊猫系统通过国家鉴定
  - 在当下，这一类EDA软件是芯片领域的软肋
  - 去年Cadence断供中兴，就是EDA

国内CAX软件的发展现状

- 国外工业软件巨头占据着技术和市场优势
  - 国外工业软件巨头掌握着行业内几乎所有的核心技术和标准, 包括研发设计类软件领域的达索、西门子、欧特克等， 生产控制软件领域的西门子等
- 本土研发设计类软件公司的追赶之路仍相当漫长
  - 研发设计类软件市场中占有率前三的国内企业市占率之和仅为9%
  - 中望作为中国 CAD 市场占有率最高的国内公司， 营业收入仅 3.6 亿， 利润规模不足 1 亿， 与达索、欧特克相差60-100倍

中望软件3月12日开盘价420元，市值253.35亿!

CAGD&CG的挑战

- CAGD&CG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3D人才！！！

广阔天地，大有所为!

有趣、好玩、有前途！

Thank you!

Questions?