

计算机辅助几何设计 2023秋学期

课程介绍

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自我介绍：陈仁杰

- 个人经历

- 2001.9-2005.6, 浙江大学, 应用数学, 本科
- 2005.9-2010.6, 浙江大学, 应用数学, 博士
- 2011.3-2013.9, 以色列理工, 博士后
- 2013.9-2015.6, 美国北卡教堂山分校, 博士后
- 2015.7-2019.6, 德国马普计算机研究所, 高级研究员
- 2019.7-至今, 中国科技大学, 国家创新人才计划, 教授

- 个人主页: <http://staff.ustc.edu.cn/~renjiec>

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课程助教

- 林哲晖

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- 张汉昌

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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...



designed on a computer
(the building)

designed on a computer as well
(the cars)

fortunately, not (yet) designed
on a computer (the trees)

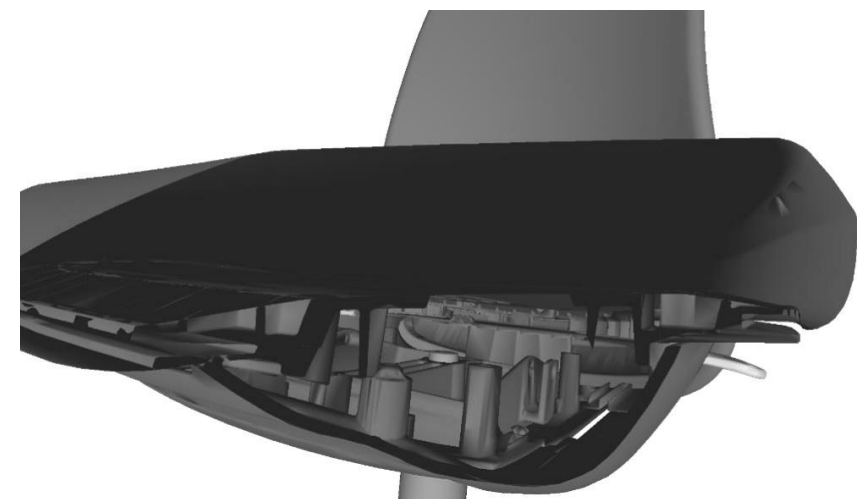
Impact of Geometric Modeling

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

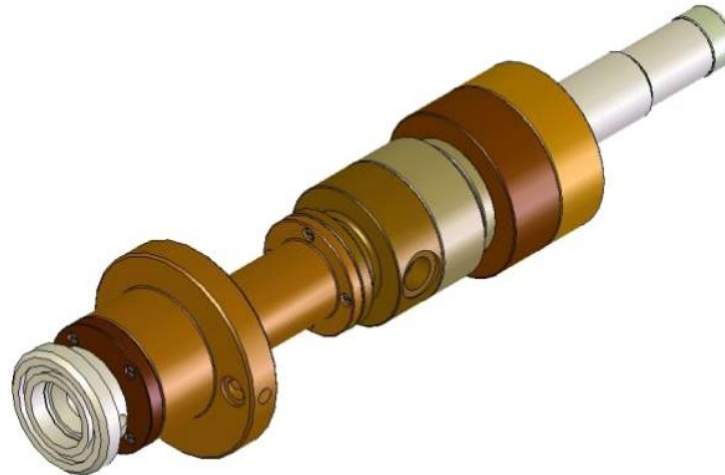
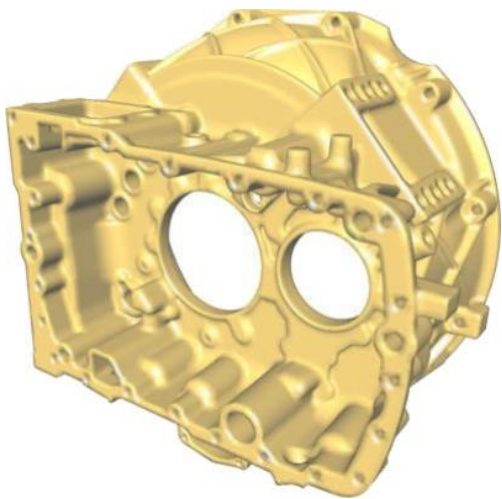
Different requirement for different setups



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]

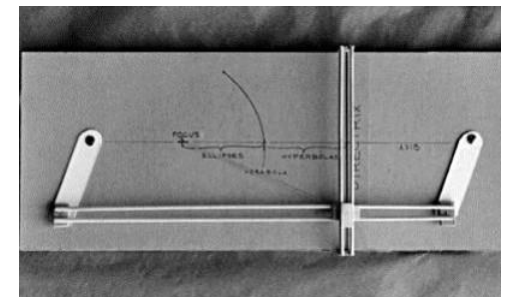
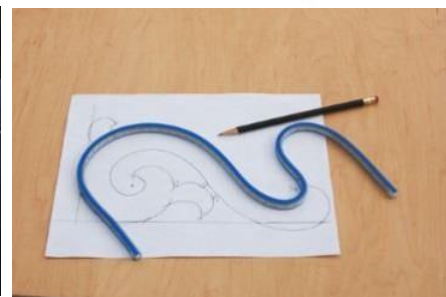
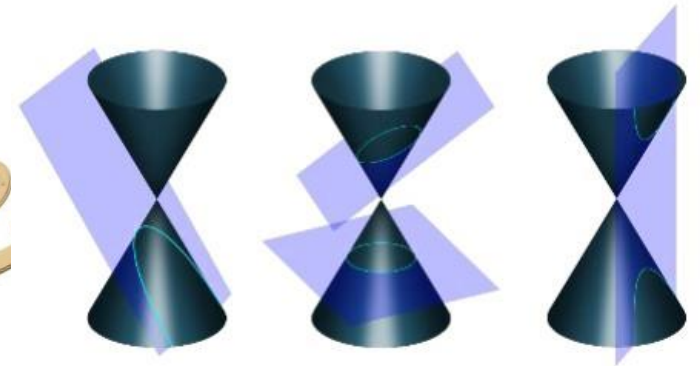
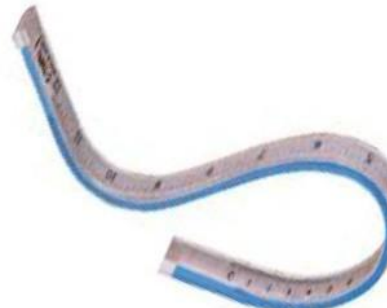
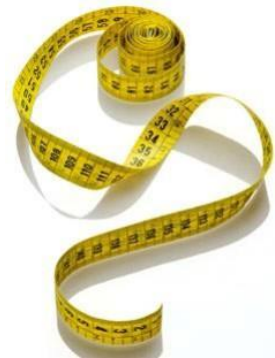
Geometric Modeling

A look back

Modeling the old way

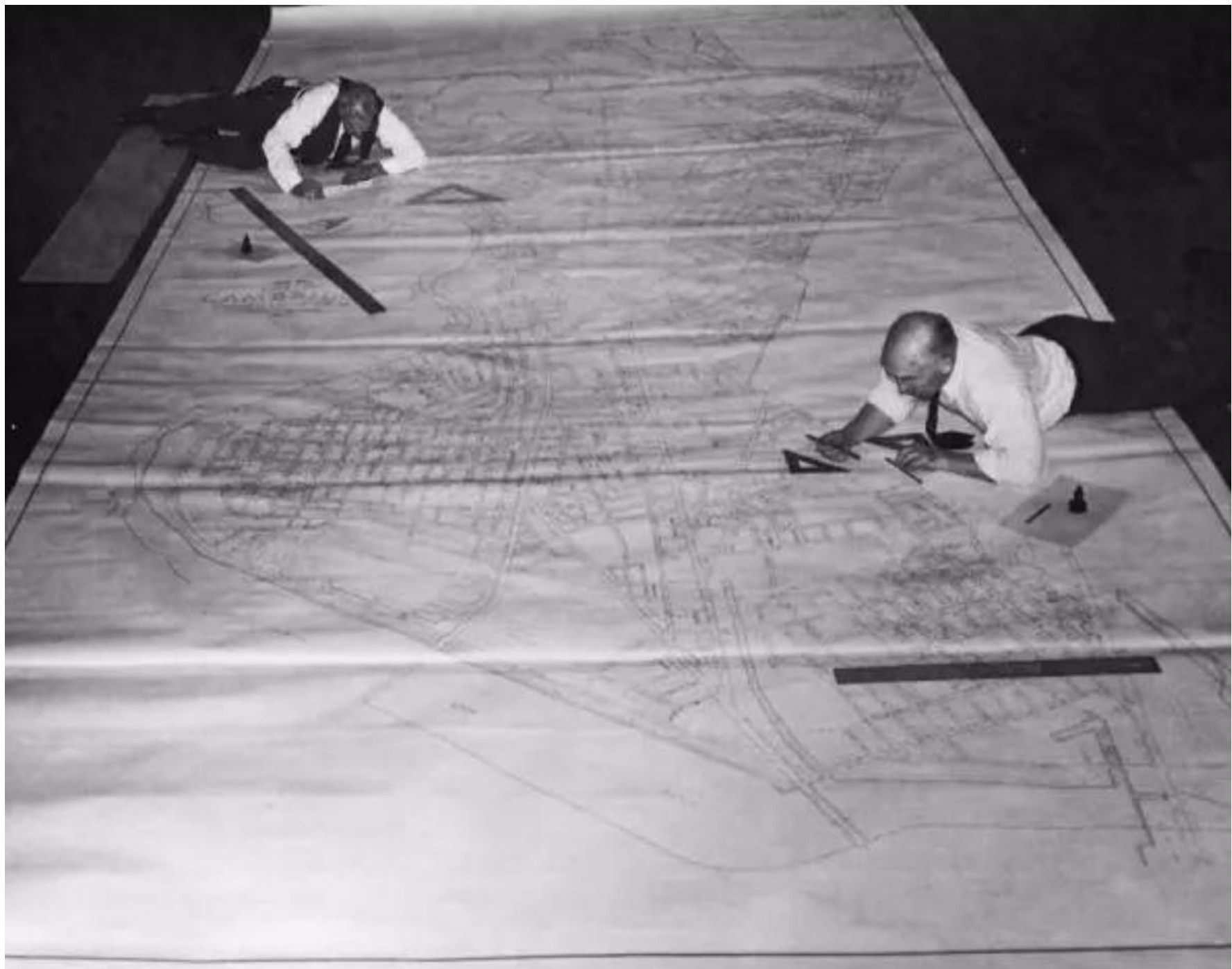
Basic tools

- Measuring and drafting tools











Industrial modeling developments

Industrial modeling: Two distinct shape classes

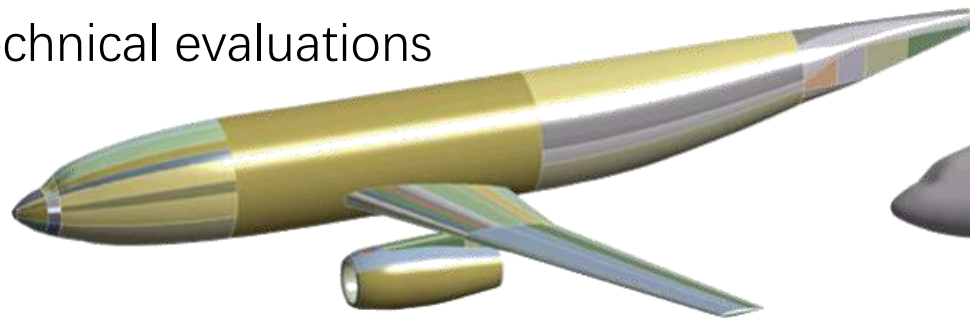
- Complex combination of elementary surfaces
 - Easy to model (blueprint)
 - Easy to produce
 - Easy technical evaluations (volume, moment of inertia)



Industrial modeling developments

Industrial modeling: Two distinct shape classes

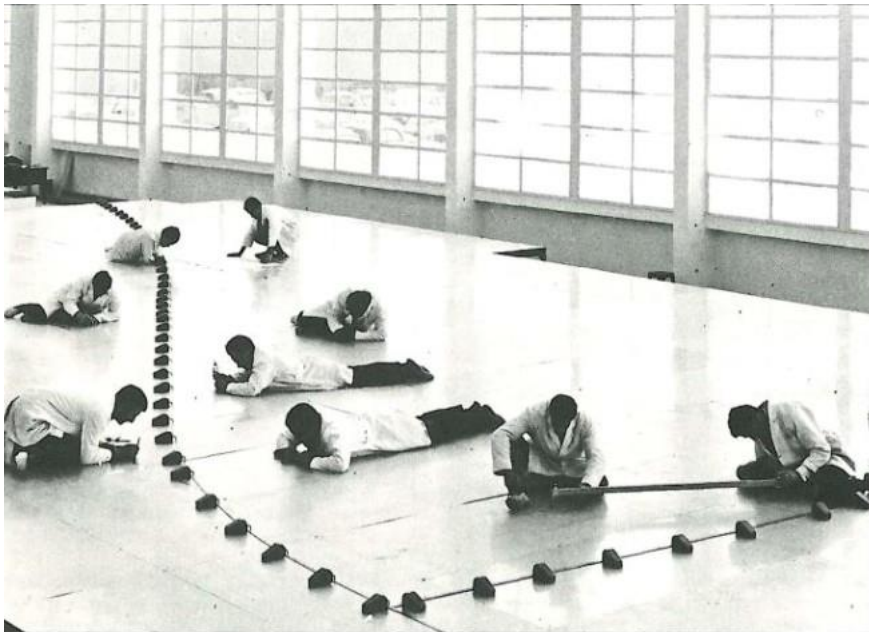
- Complex combination of elementary surfaces
 - Easy to model (blueprint)
 - Easy to produce
 - Easy technical evaluations (volume, moment of inertia)
- Free-form shapes
 - Required mainly by modern industries e.g. aeronautics, shipbuilding, auto industry
 - Not easy to describe mathematically
 - Harder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



Early modeling of free-form curves and surfaces

Splines

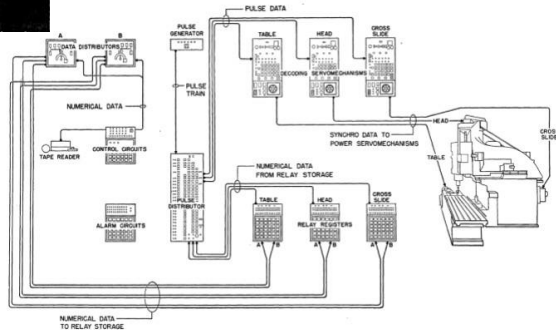
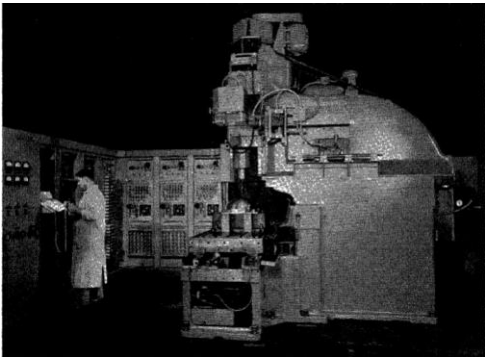
- Thin flexible band made out of wood, plastic or steel
- Can be held in shape using weights
- Smooth energy minimizing curves



Birth of computer aided design (CAD)

Two major events

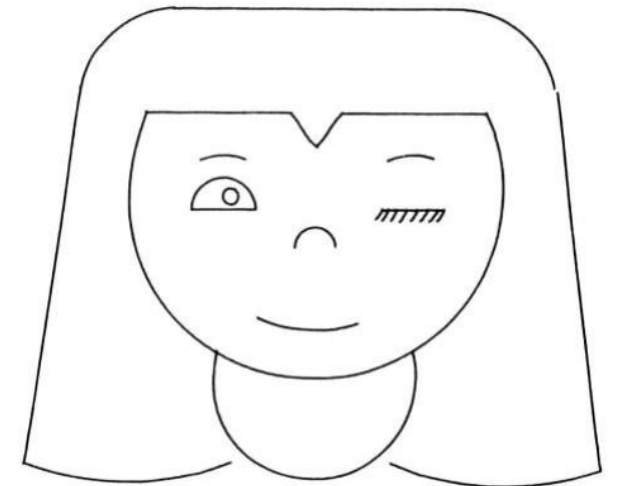
- The world's first NC 3D milling machine (MIT 1951)
 - Shapes can be described mathematically
 - Read shape information from drawing



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**...

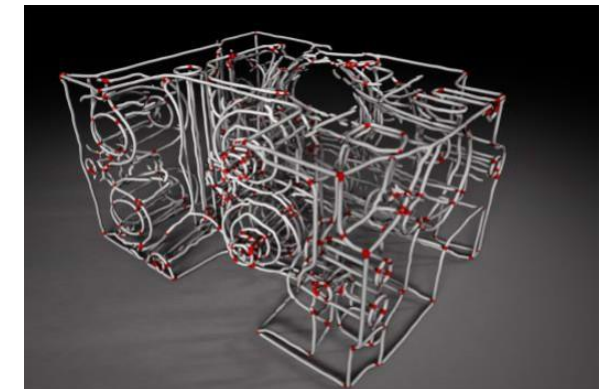
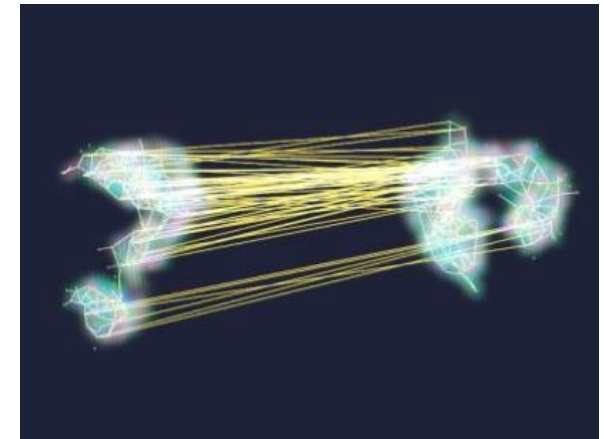
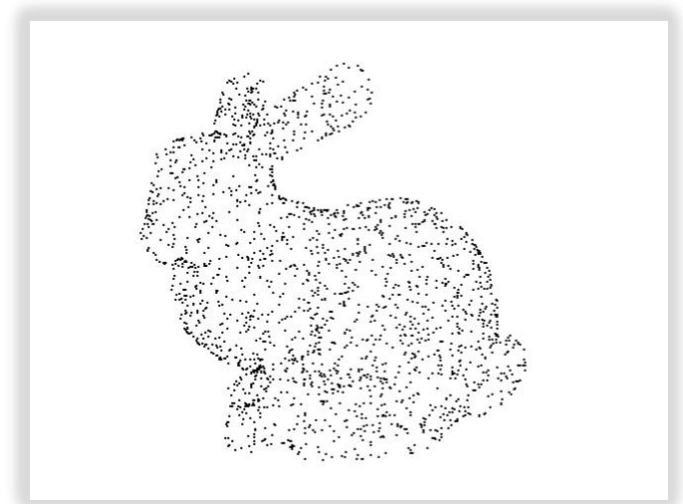
Geometry Processing

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

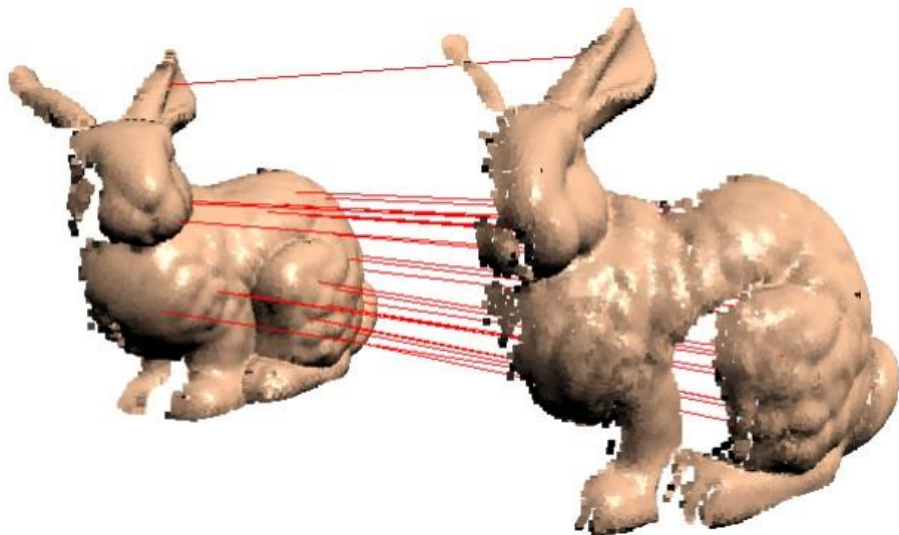
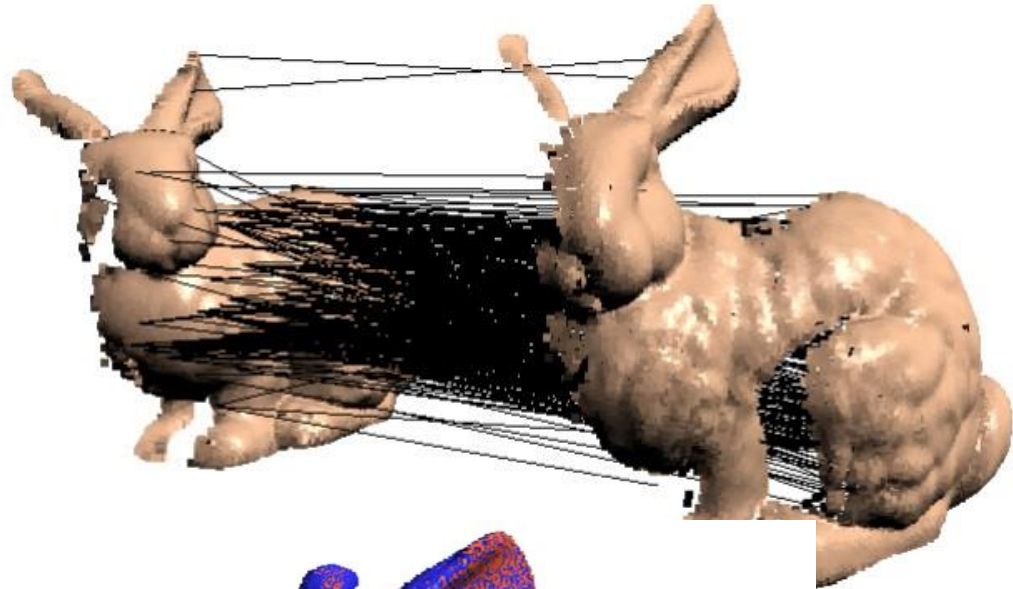
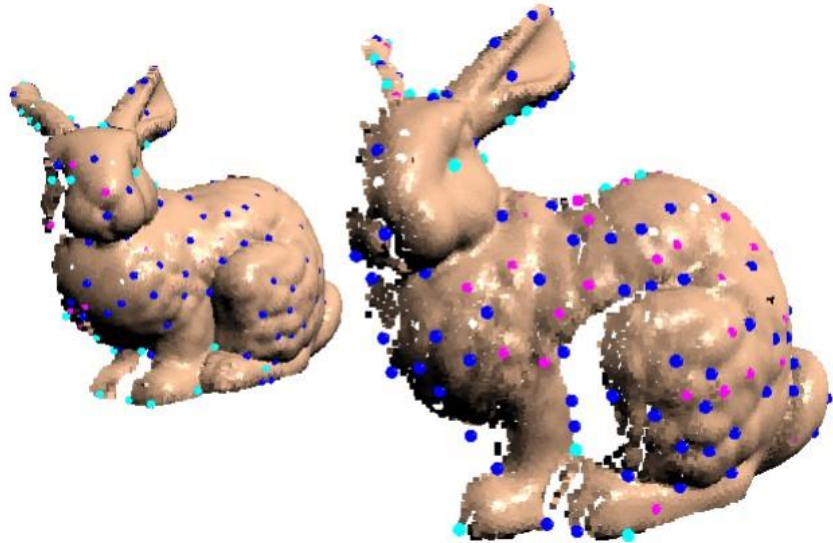


Photoshopping Geometry

Geometry Processing:

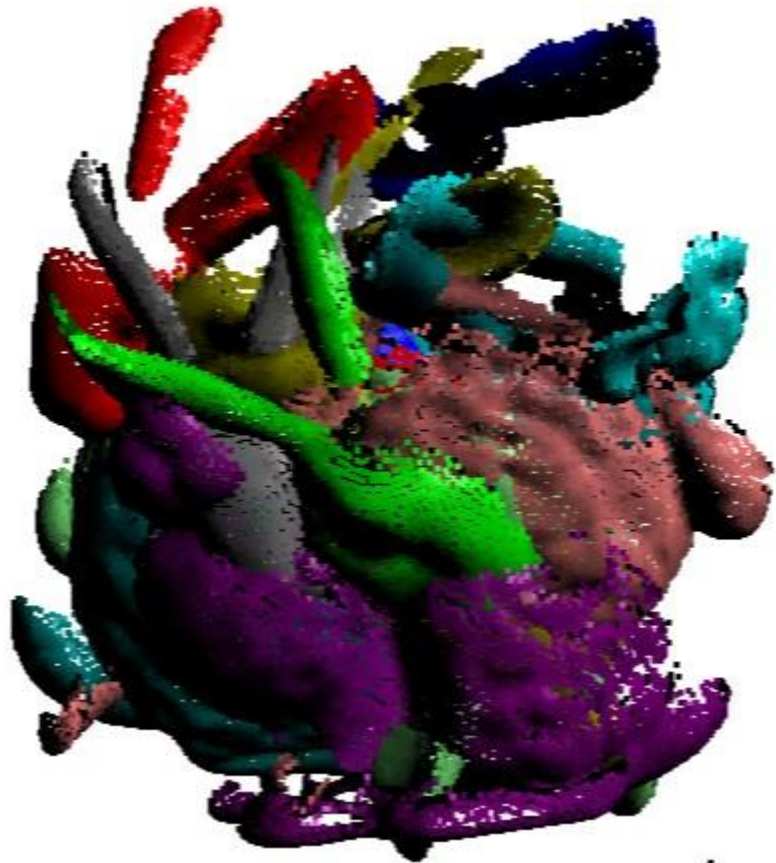
- Cleanup:
 - Remove inconsistencies
 - Make watertight (well defined inside/outside, for 3D printers)
 - Simplify – keep only the main “structure”
 - Remove noise, small holes, etc...
- Touch-up /Edit:
 - Texturing, painting, carving
 - Deformation
 - Stitch together pieces
- Lots of other stuff – similar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

Scan Registration



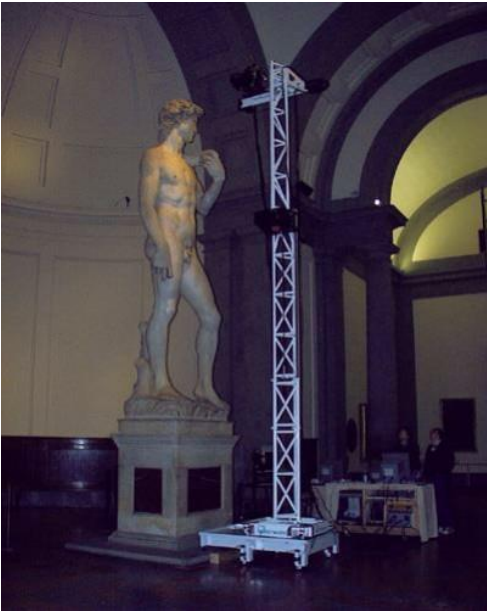
Feature Tracking

Fully Automatic:

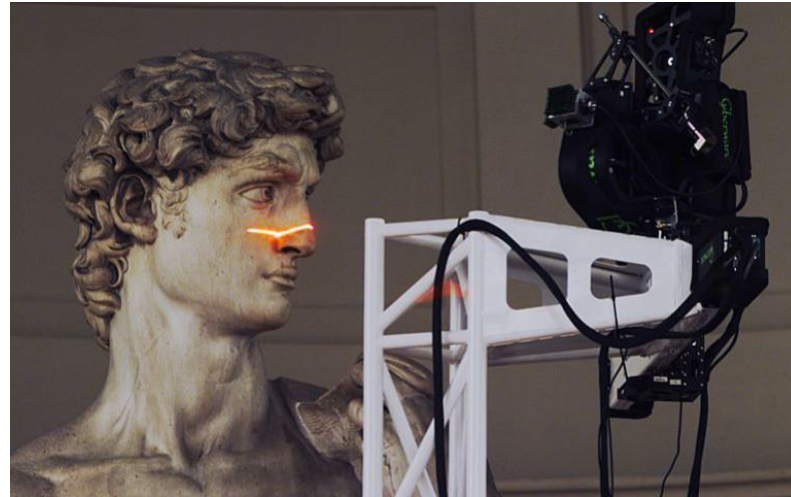


Example

Example: The Stanford “Digital Michelangelo Project”



scanning

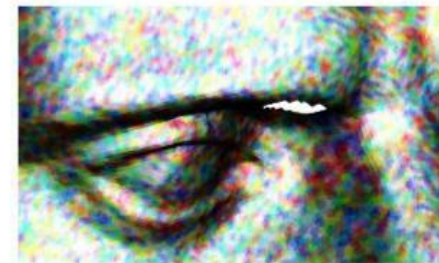


scanning



**rendered
reproduction**

Denoising



Size ~300mm

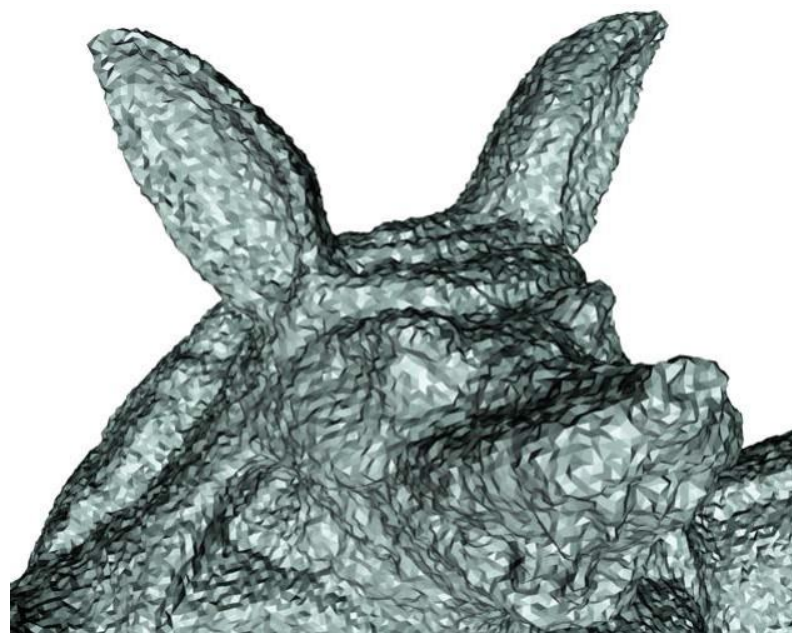
Max. deviation : 0.1mm

Denoising

Remove noise, but preserve features



Original



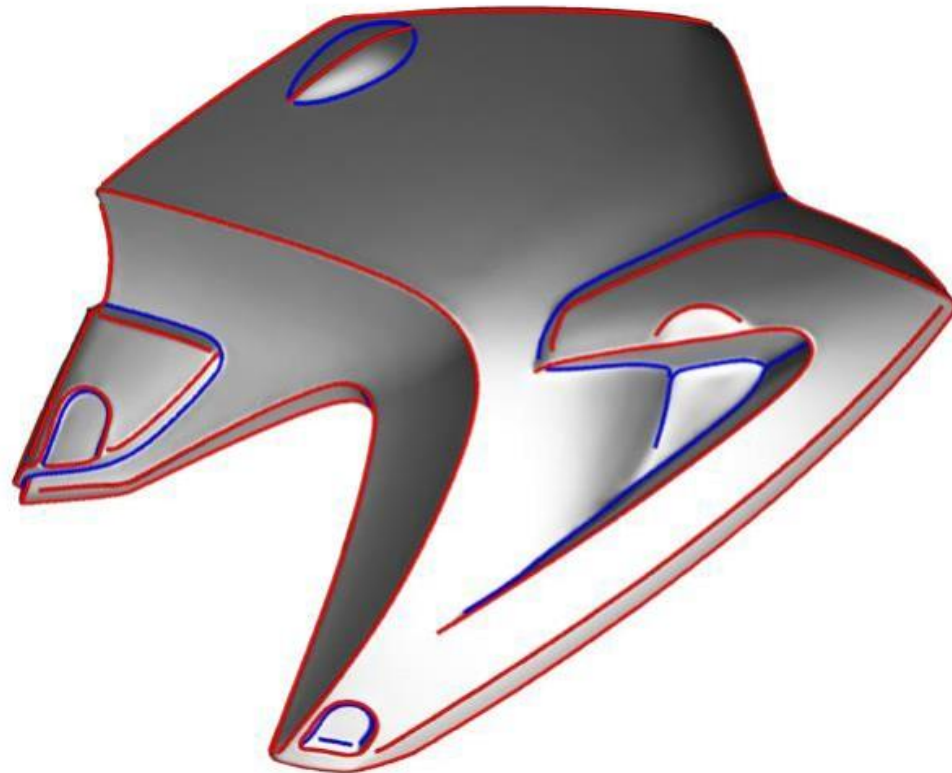
Noise added



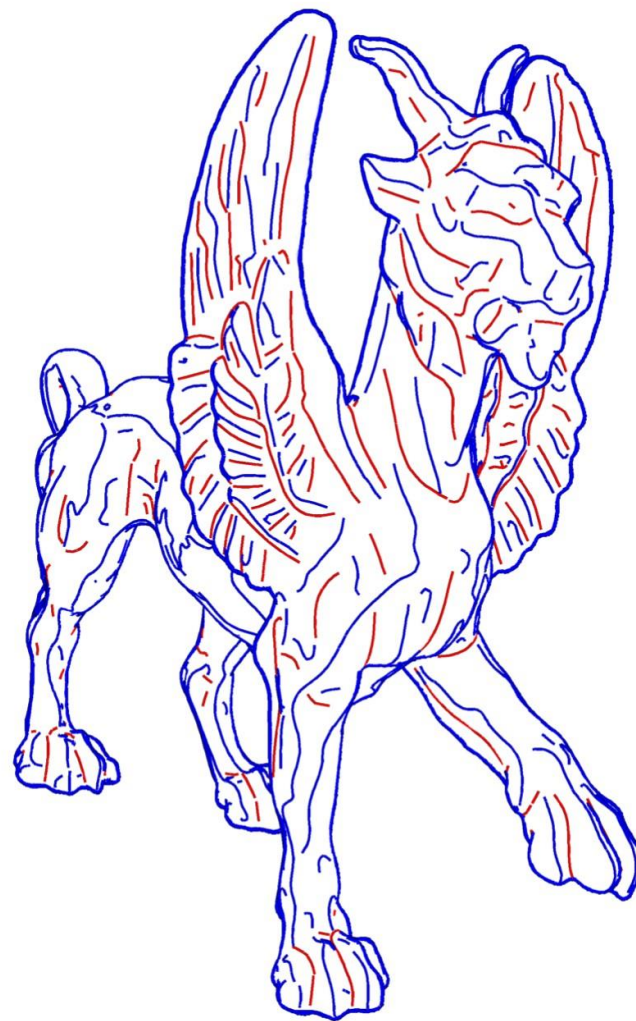
Denoised

Feature Detection

Find curves on a surface that carry visually most prominent characteristics



Feature Detection



Surface Parameterization: Motivation

Texture mapping

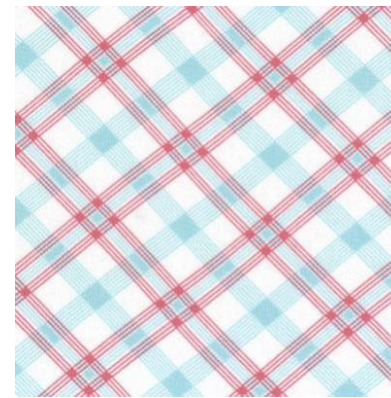
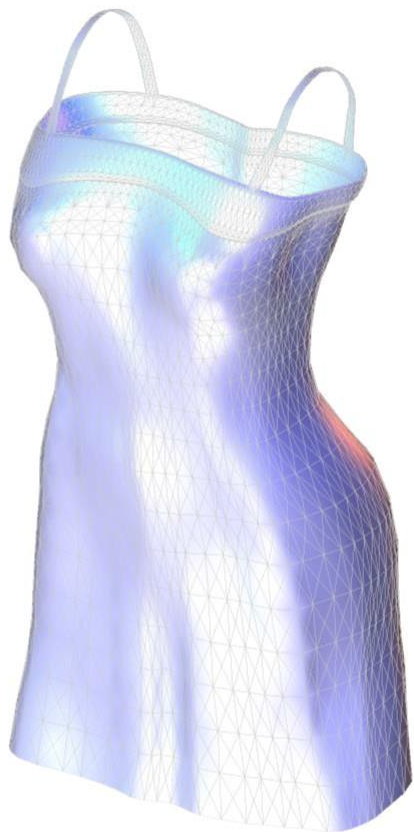


Graphics ingredients



Real world

Texture mapping example



Surface Parameterization



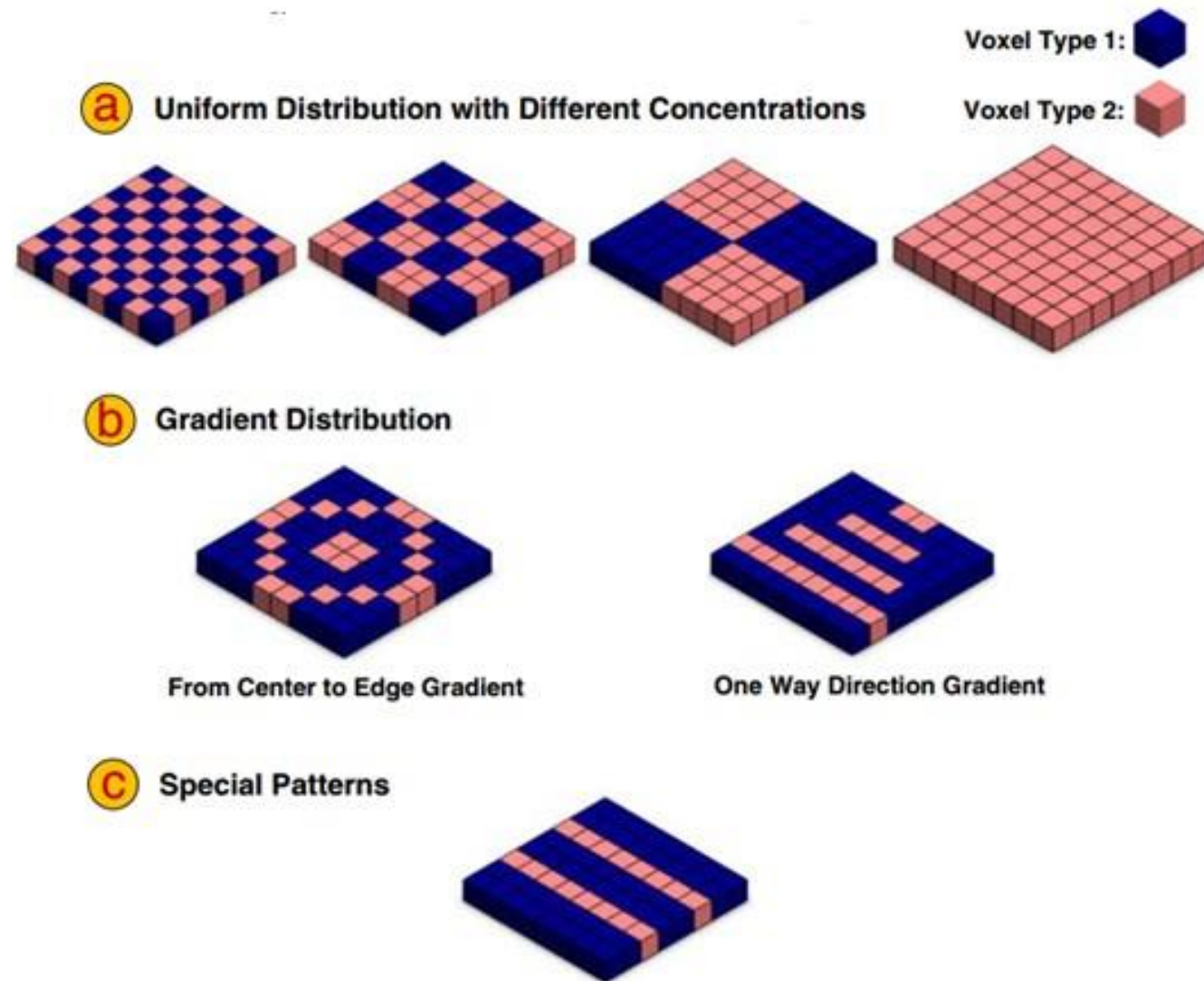
Surface Parameterization



Latest Development

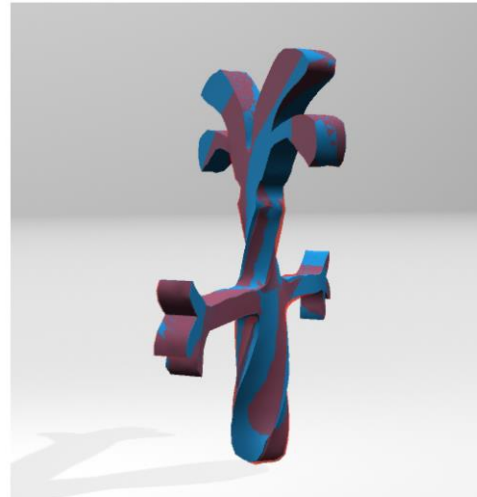
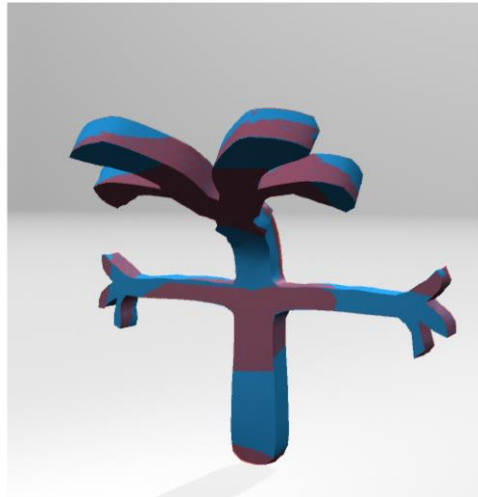
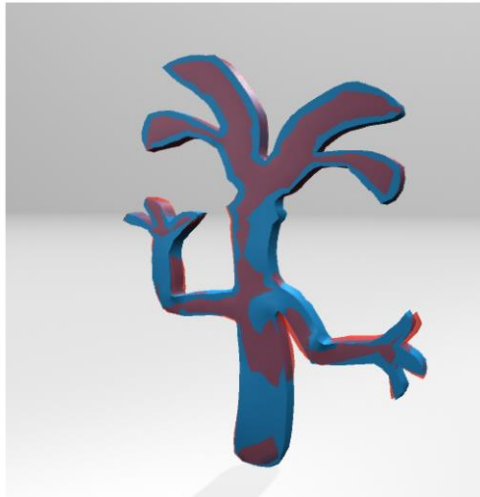
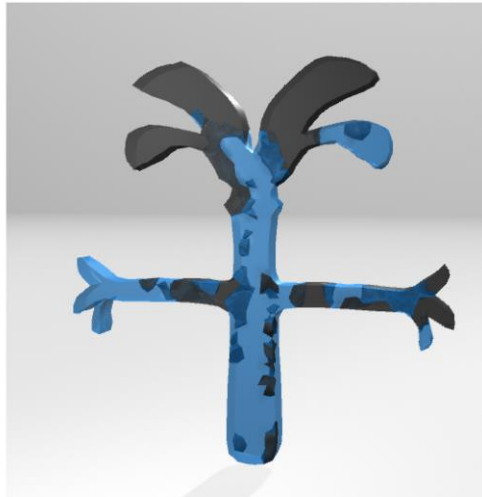
Geometric Design

Trend 1: Material design



Material distribution optimization

[Skouras et al. 2013]



Trend 2: Structure Design



← Design →

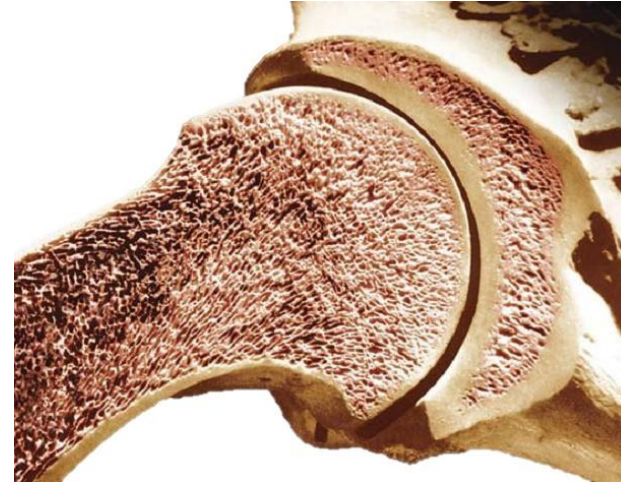


Small scale:
Micro-structure,
Frame, Foam, etc.

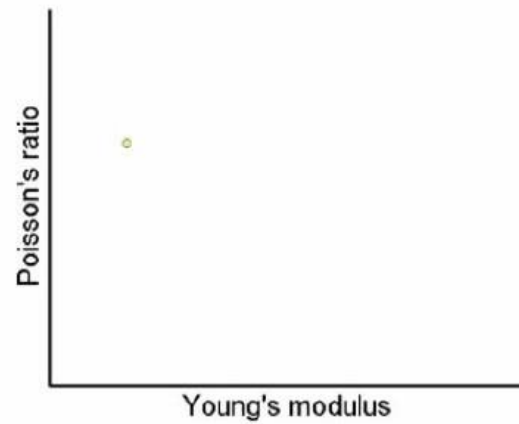
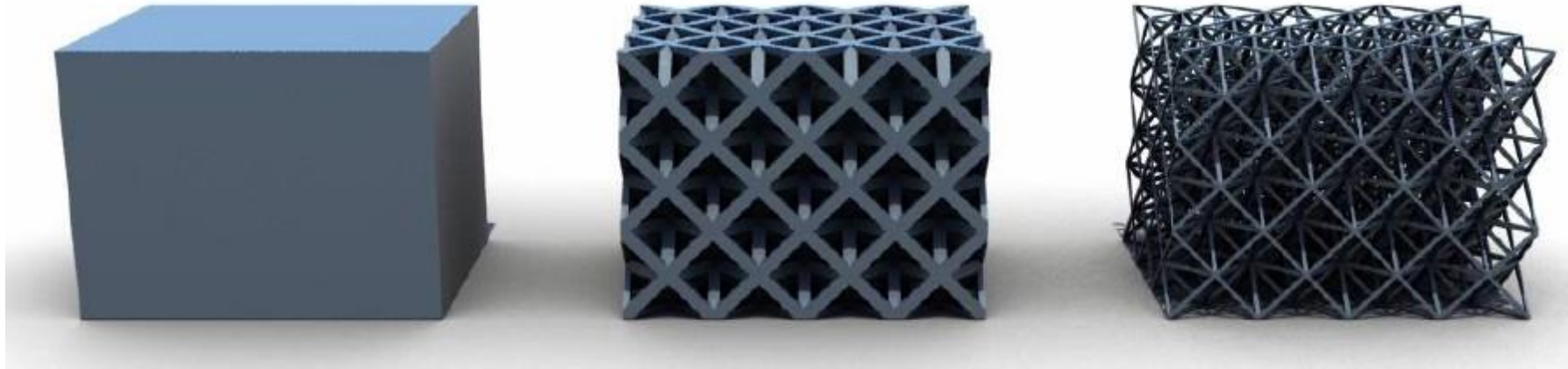
Large scale:
Assembly,
Mechanical, etc.

Microstructure Design

Microstructure in nature



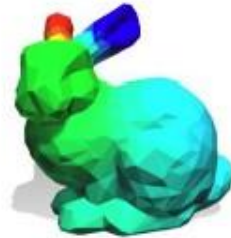
Material Structure



Problem

Input

- Shape with assigned Material Parameters

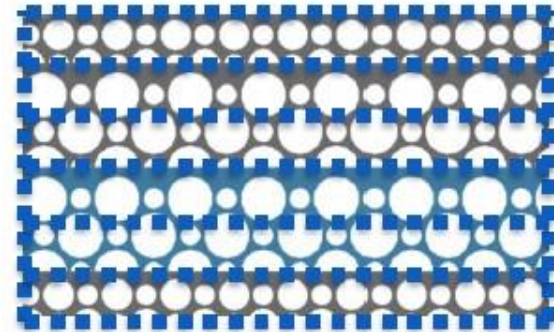


- Deformation Specification

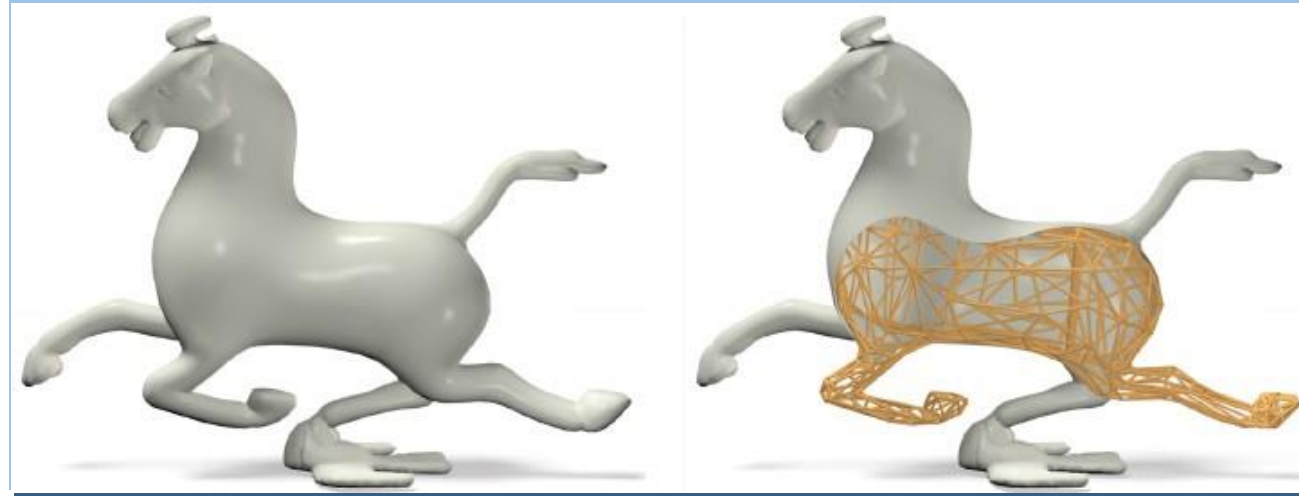


Output

- Spatially-varying material structure



Meso-structure



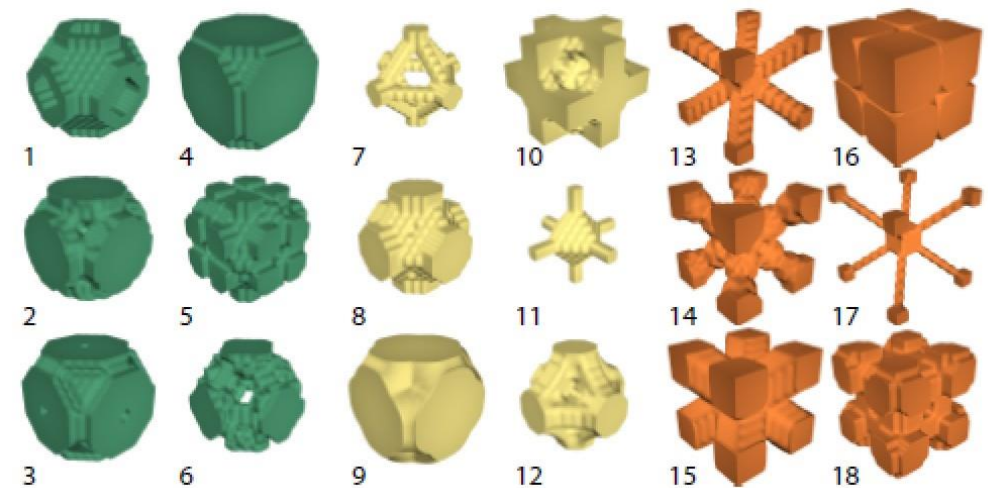
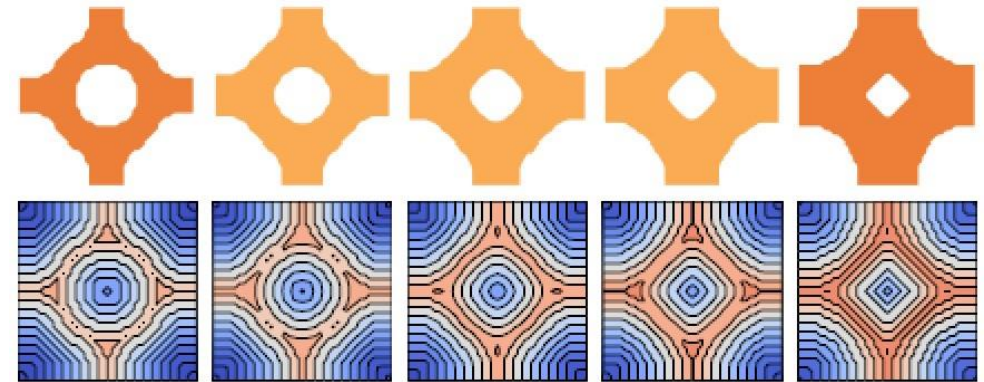
[Wang et al. 2013]



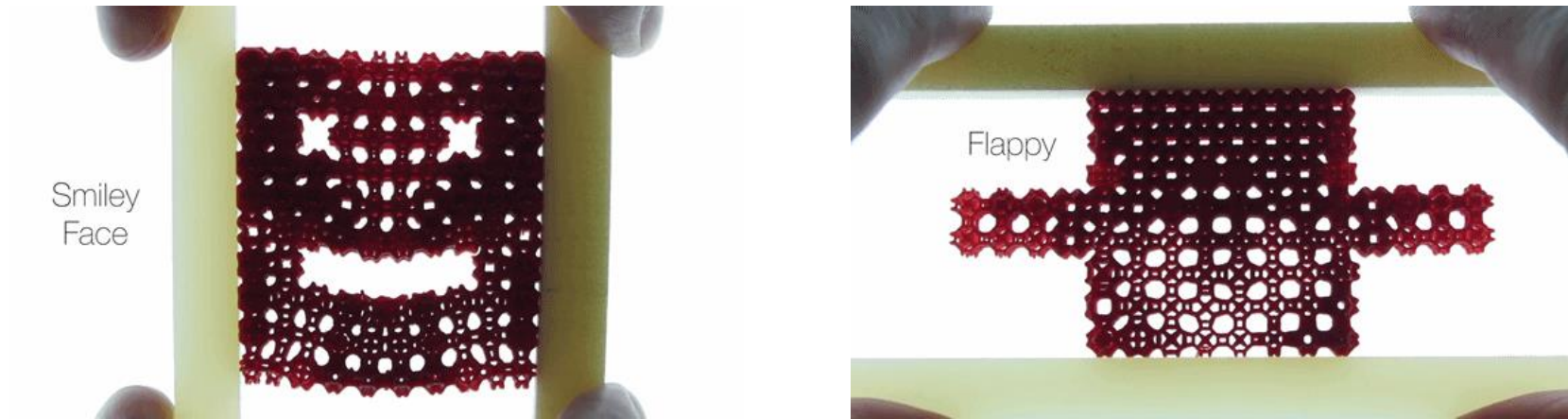
[Lv et al. 2014]

Elastic microstructure design

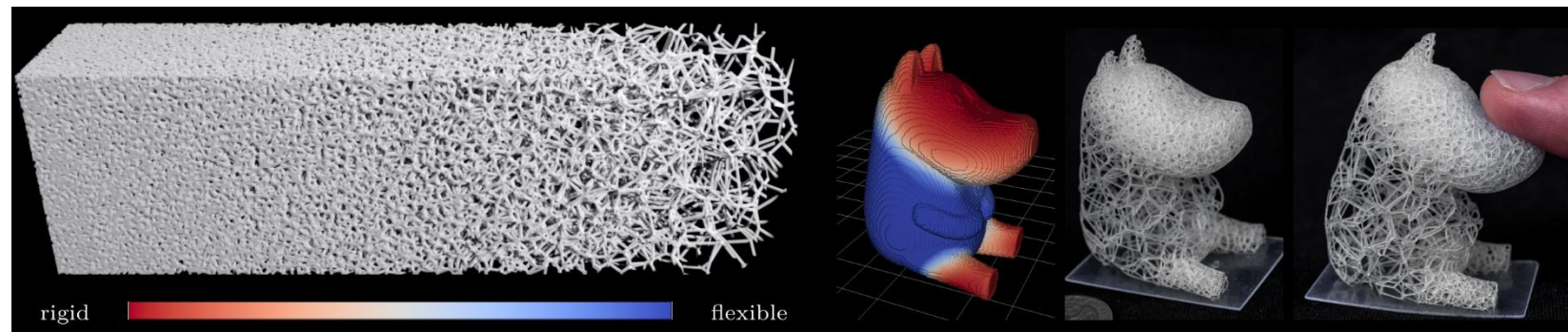
[Schumacher et al. 2015]



Elastic microstructure design



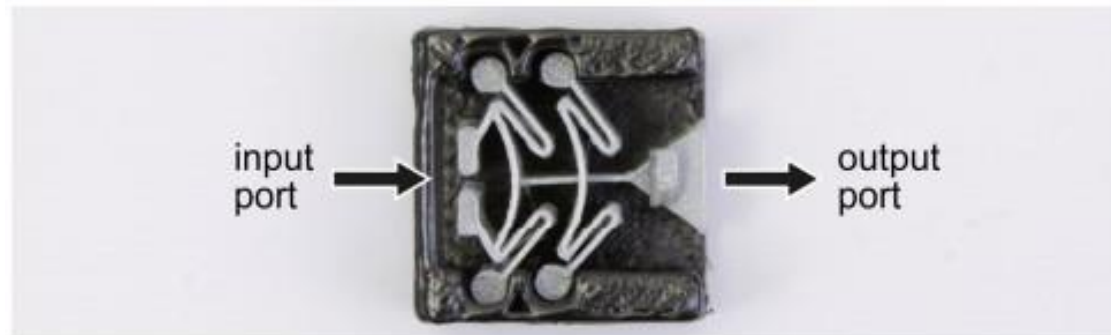
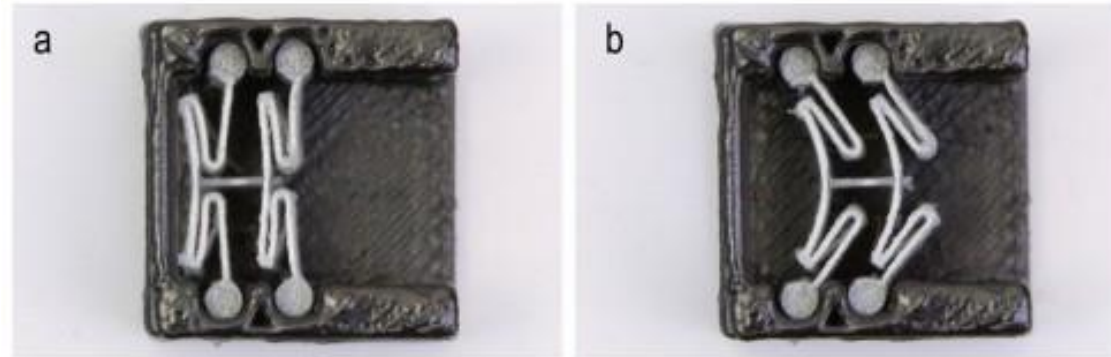
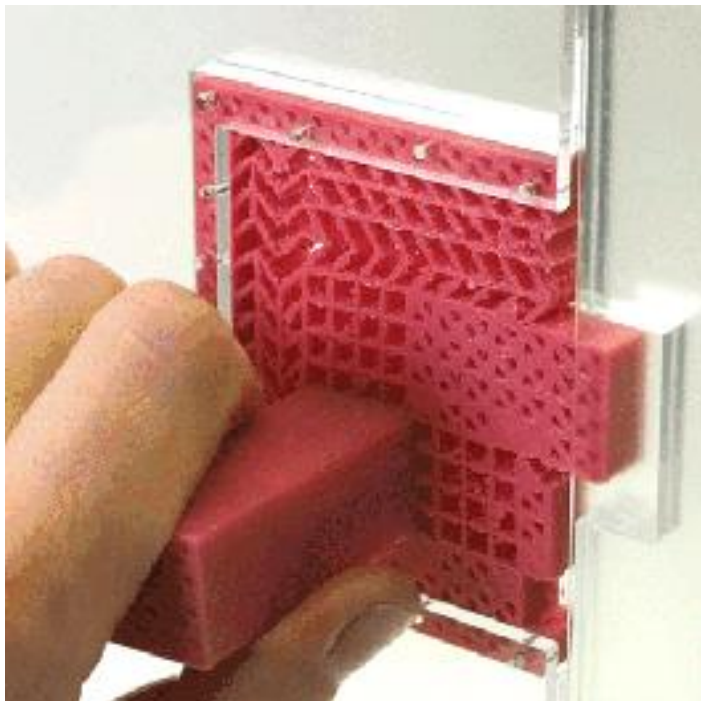
[Panetta et al. 2015]



[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/~renjie/CAGD_2023S1/default.htm



Renjie Chen (陈仁杰)

[Graphics & Geometric Computing Laboratory \(GCL\)](#)
[School of Mathematical Sciences](#)
[University of Science and Technology of China \(USTC\)](#)

Email: renjie at ustc.edu.cn

Teaching

~~[Computer Aided Geometric Design \(Autumn-Winter 2023-2024\)](#)~~
[Computer Graphics \(Spring-Summer 2022-2023\)](#)
[GAMES 301: Surface Parameterization](#)
[Summer School for Advances in Computer Graphics 2022 \(计算机图形学前沿进展\)](#)
[Summer School for Advances in Computer Graphics 2021 \(计算机图形学前沿进展\)](#)

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

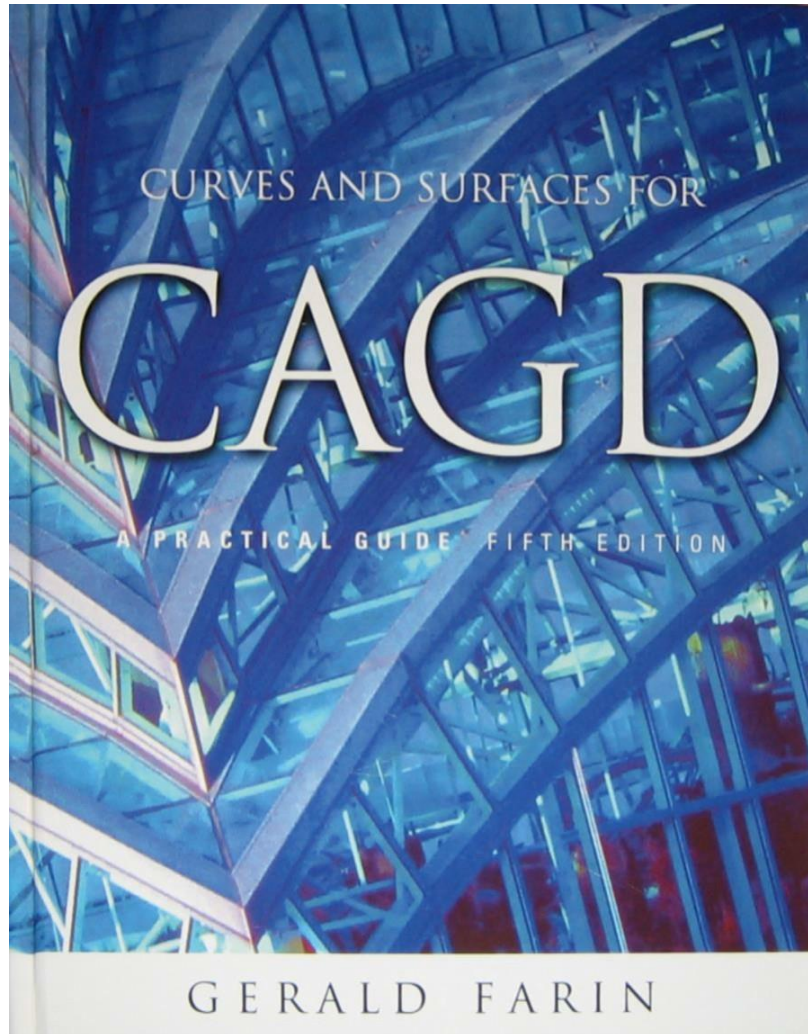
- 线性代数
- 微积分
- 几何：空间几何、微分几何
- 微分方程
- 最优化
- 数值方法与计算
- ...

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

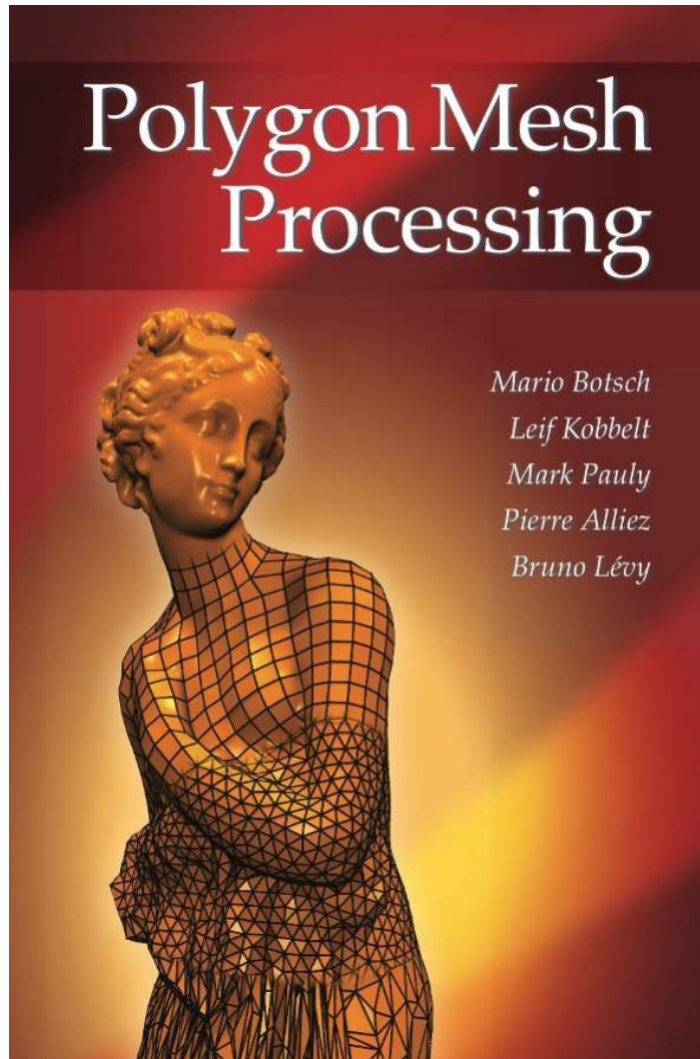


Gerald Farin

Curves and Surfaces for Computer
Aided Geometric Design

(Fifth Edition)

Textbook: Mesh Processing



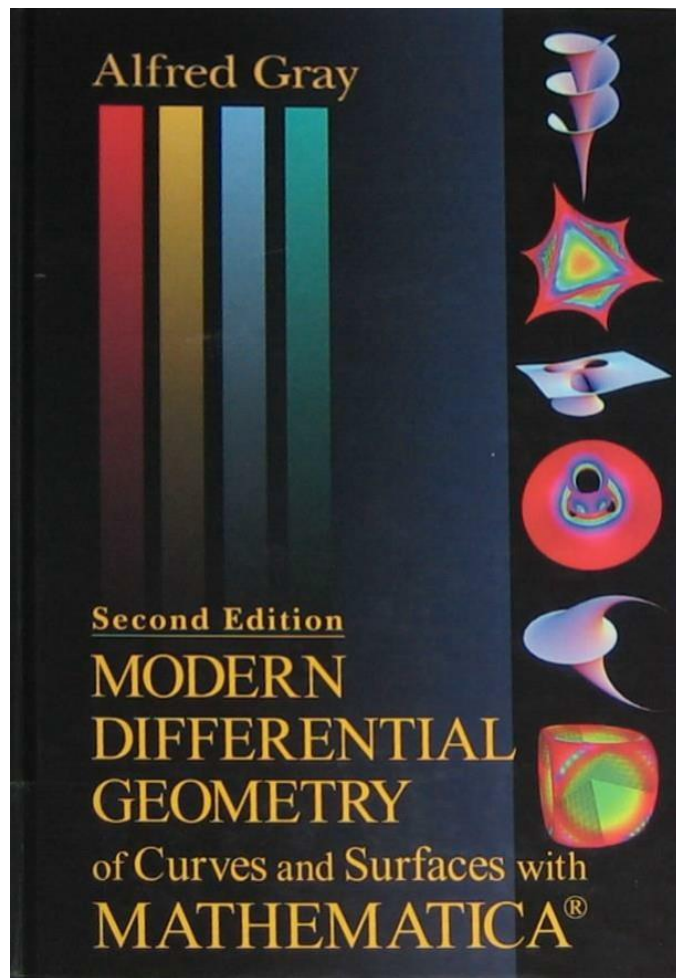
**Mario Botsch, Leif Kobbelt, Mark Pauly,
Pierre Alliez, Bruno Levy**
Polygon Mesh Processing

Differential Geometry

Alfred Gray

Modern Differential Geometry of Curves and Surfaces with Mathematica®

(Second Edition)



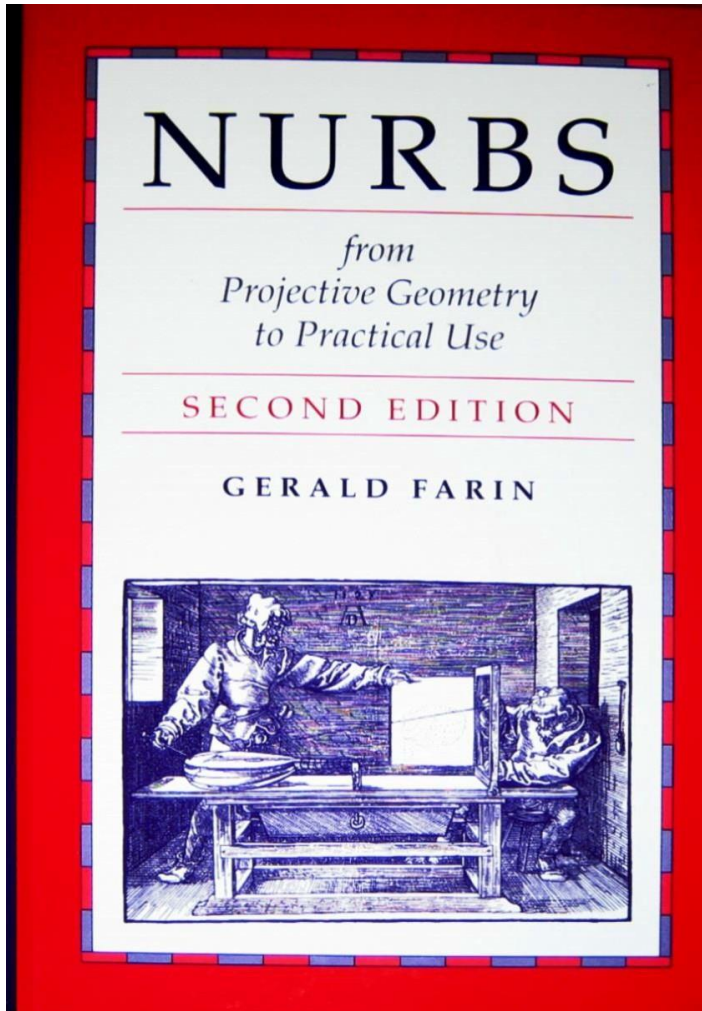
More on Rational Splines

Gerald Farin

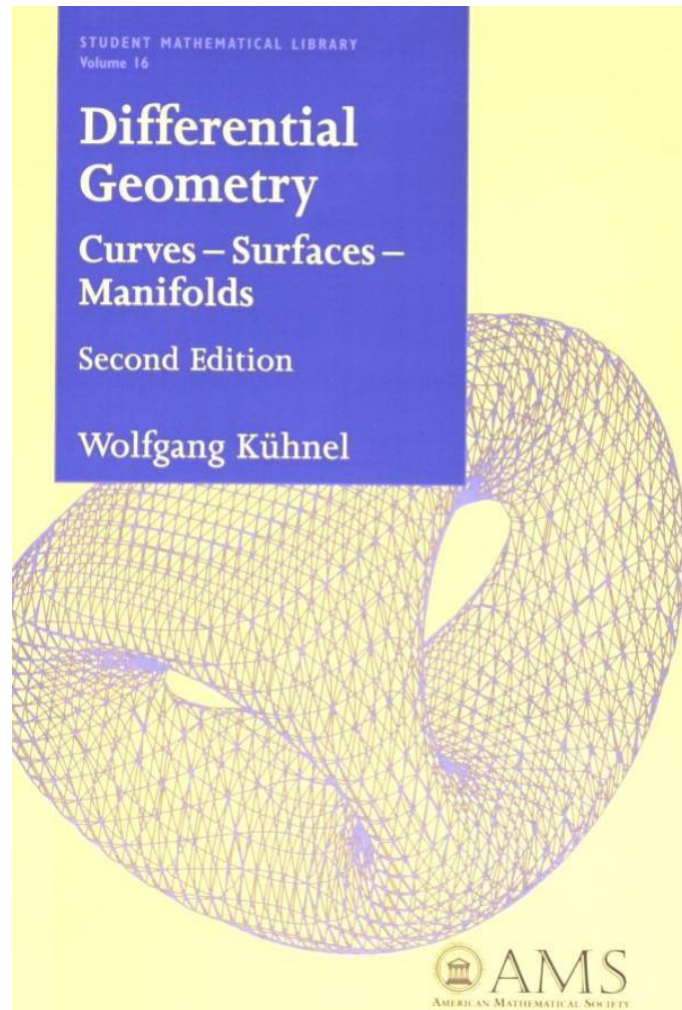
NURBS – from Projective Geometry to Practical Use

(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.
- 朱心雄. 自由曲线曲面造型技术. 科学出版社. 2000.
- 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.
- 施法中. 计算机辅助几何设计与非均匀有理B样条. 高等教育出版社. 2001.

课程主页上有部分资料下载

作业

- 周二晚上布置作业，周日交，次周二讲解

课程寄语



ABOUT ▾ ISSUES ▾

- All news
- Press releases
- Blog
- Speeches
- Fact sheets
- Op-eds
- Photos and videos
- Livestreams
- Archives
- Media contacts

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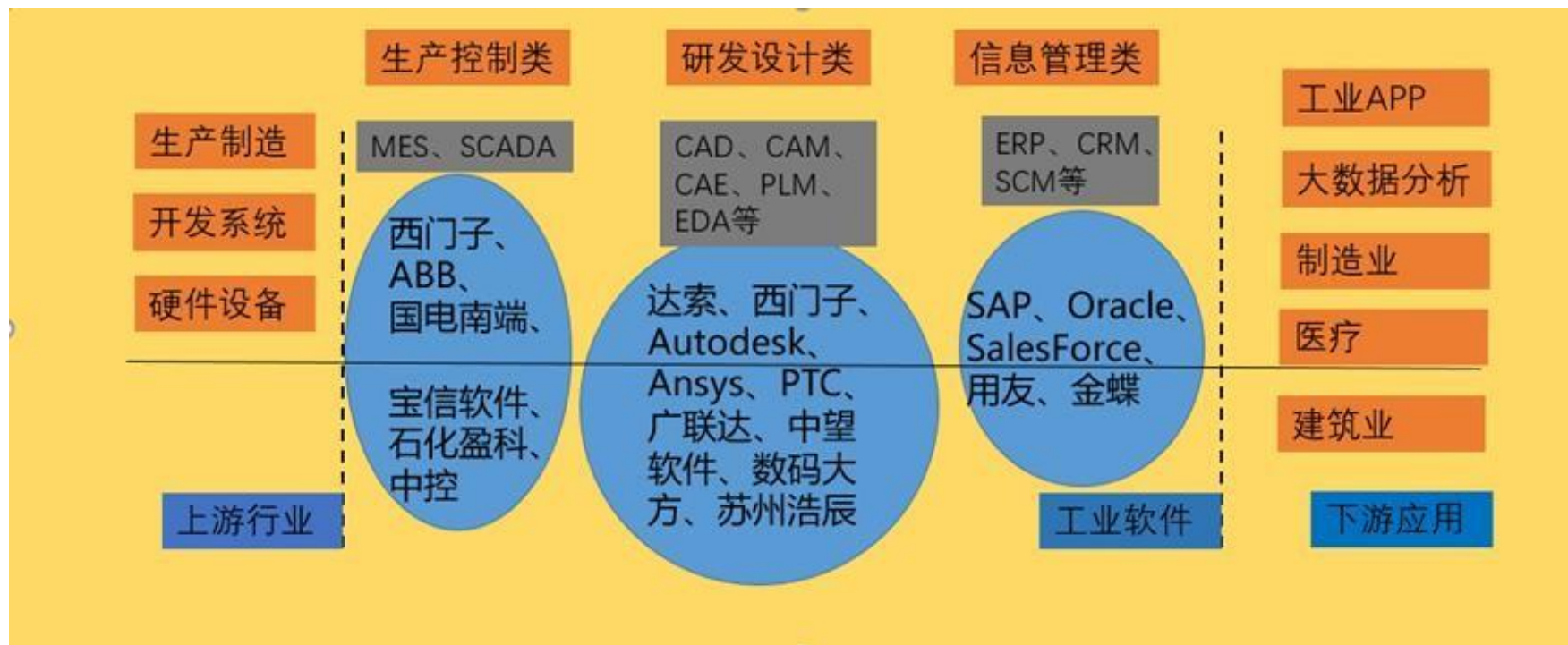
截止202

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2021年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, 大有可为!

有趣、好玩、有前途!

北斗
讲坛

北斗讲坛

第八期



数学科学学院



自主创新与国产替代之路

2023

9 / 13

Wed.

16:00

东区五教5101会议室



唐晔

柏楚电子联合创始人
董事长兼总经理

【摘要】

制造业是立国之本、兴国之器、强国之基。随着工业4.0时代的到来，制造行业以自动化、智能化的高质量发展为主。柏楚电子作为国家光纤激光切割成套控制系统开发的先驱者，坚持自主研发，攻关“卡脖子”技术，成立16余年，逐步实现激光行业关键技术和部件的国产替代。基础研究作为整个科学体系的源头，是科技创新的“总开关”，柏楚电子致力于源头创新，推动基础理论与激光制造涉及到的多应用科学交叉融合，解决更多的制造难题。

【报告人简介】

唐晔，上海交通大学硕士，企业导师。南京工业大学兼职教授。柏楚电子联合创始人、董事长兼总经理。曾获“上海领军人才”，“上海市产业菁英高层次人才”。

主办：数学科学学院

协办：数学科学学院团委、数学科学学院学生会、研究生会

Thank you!

Questions?