

Computer Graphics

Lecturer: Rong Chen



Outlines

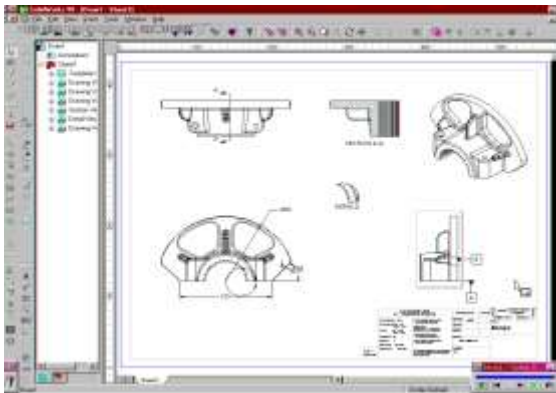
- **Why**
 - **Many Applications Based on CG**
- **What**
 - **Visualization Compute, History , Frontiers**
- **How**
 - **Course Content**

Related Applications

- 辅助设计 CAD/CAM
- 计算可视化, 商业可视化, 信息可视化 Visualization
- GIS系统 Presentation Graphics
- 教学培训 Education and Training
- 计算机艺术 Computer Art
- 娱乐, 计算机动画, 多媒体系统 Entertainment
- 图形用户界面 Graphical User Interfaces
- 虚拟现实 Virtual-Reality Environments

CG Related Applications

- 1: CAD/CAM



工程图纸



建筑物设计布局

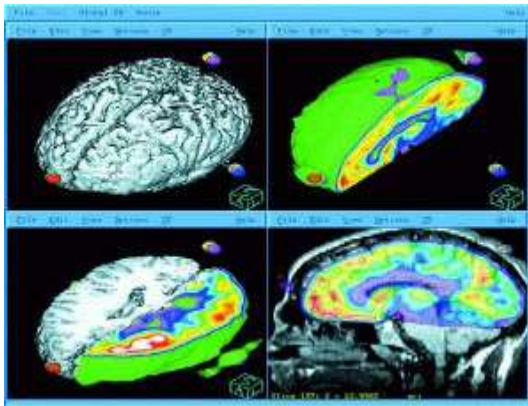


产品效果图

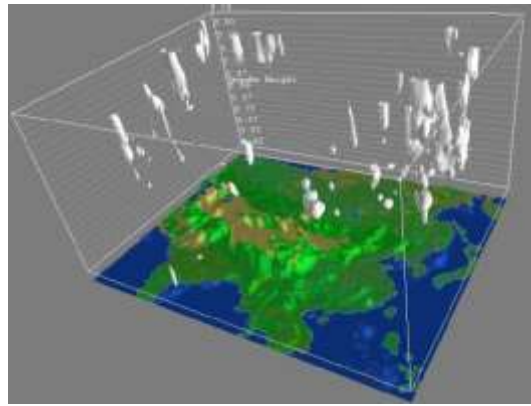
CG Related Applications(cont.)

2: Visualization

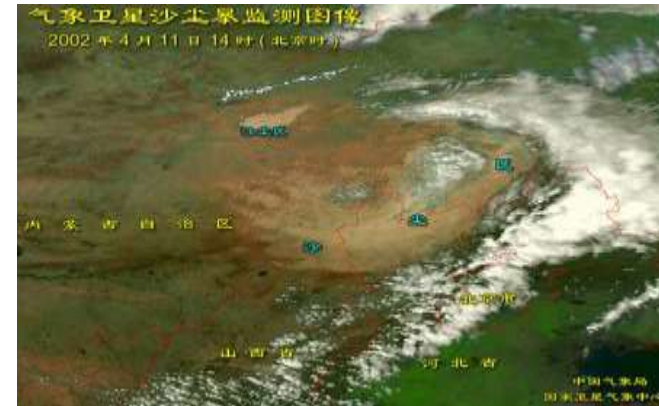
- Visualization in Scientific Computing



体视化技术



流场的可视化

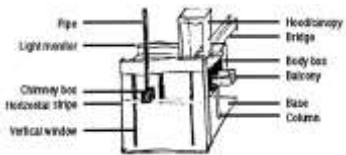
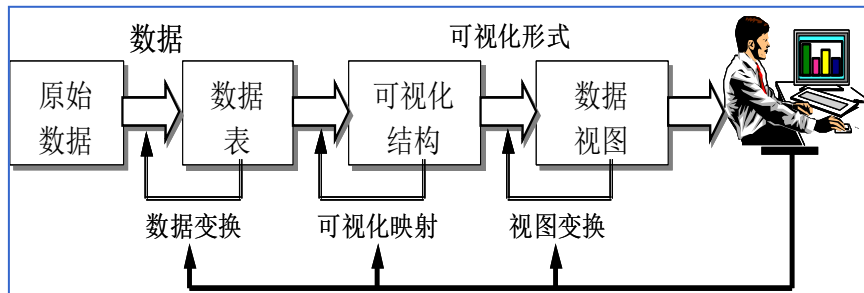


气象卫星云图

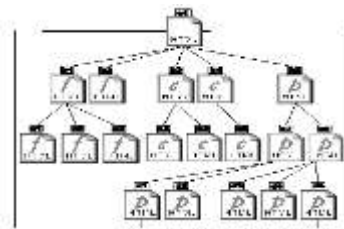
CG Related Applications(cont.)

2: Visualization(cont.)

- General Information visualization** :Image thinking: symbolic or shape representation of abstract, non-numerical information.



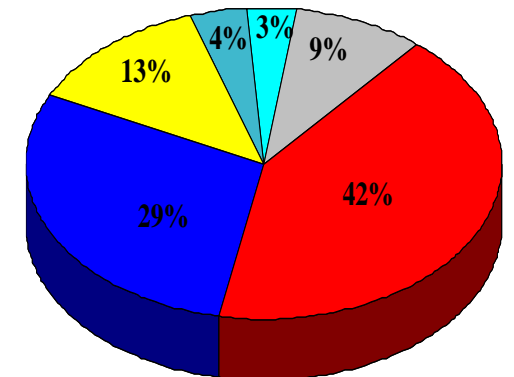
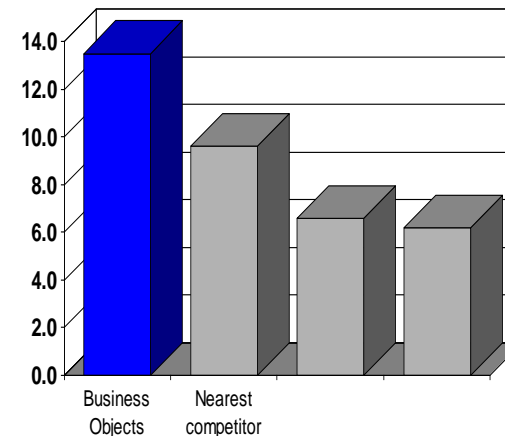
物体构造图



网页结构图



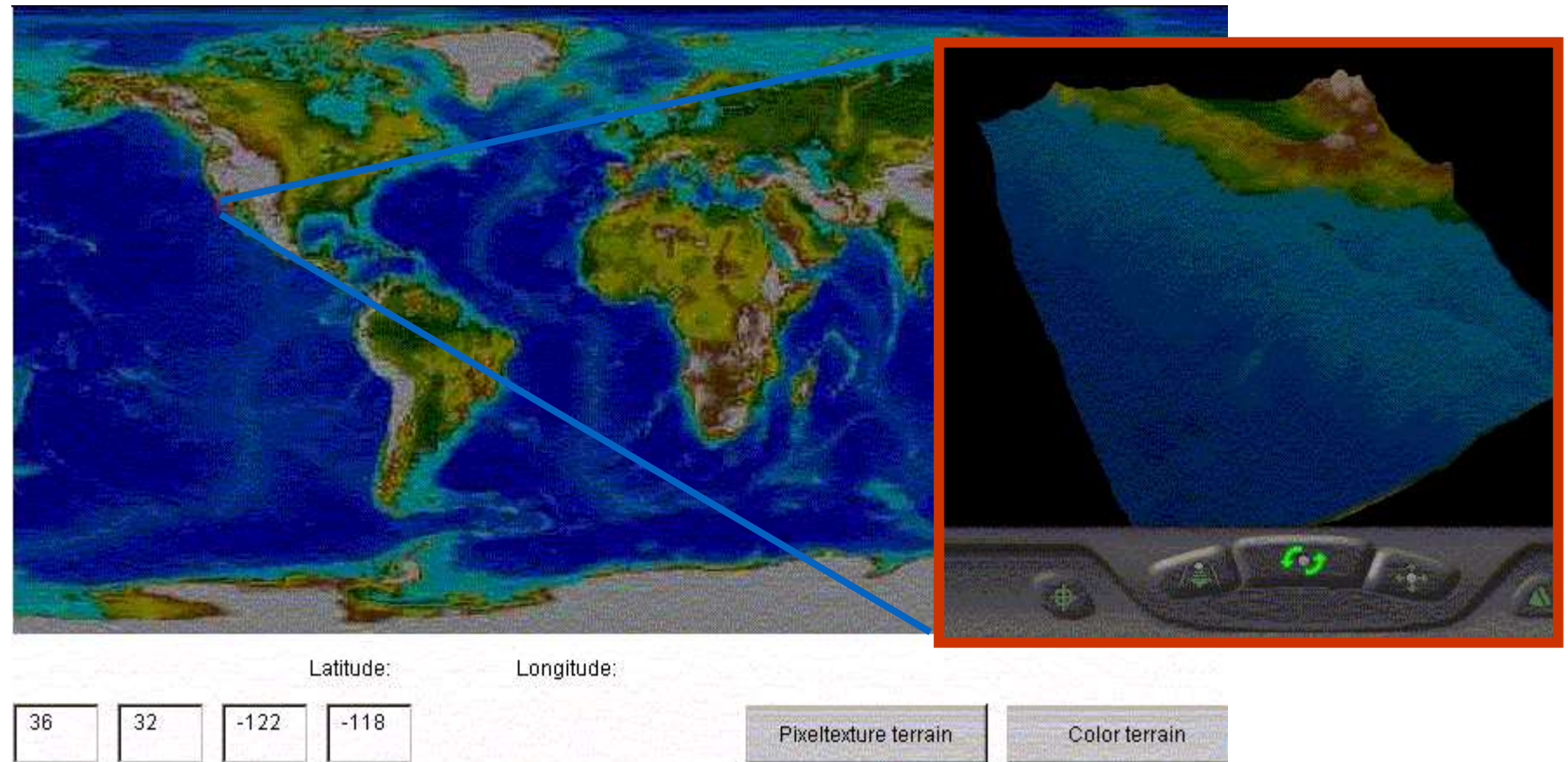
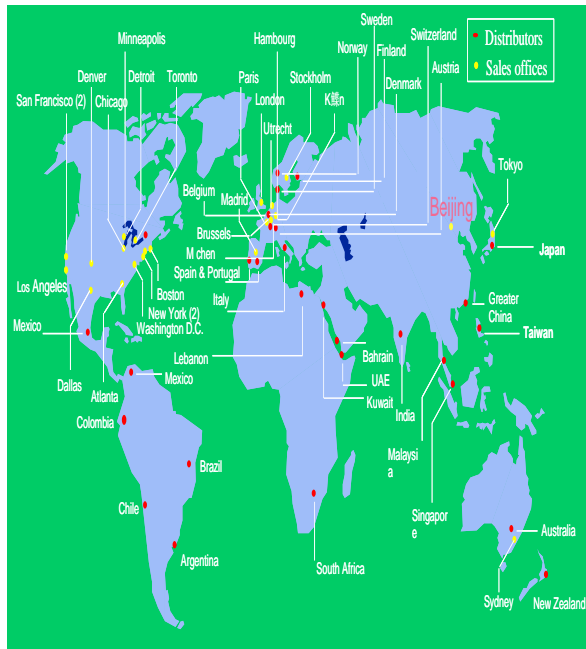
网页设计图



CG Related Applications(cont.)

3: Presentation Graphics

- Geographic information system (GIS) is an important application field of computer graphics, which can also be regarded as an application field of computing visualization.



CG Related Applications(cont.)

4.Education and Training

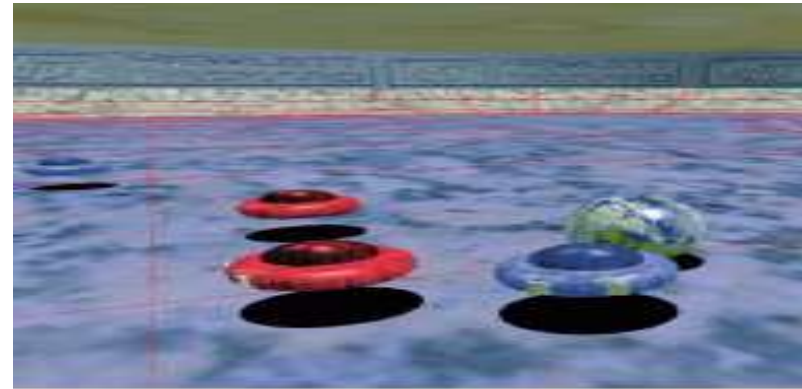
- Operation simulation:
e.g. Sichuan zhisheng: controller simulation system)



CG Related Applications(cont.)

5. Computer Art

- Fine arts and commercial art applications



CG Related Applications(cont.)

- **6. Entertainment**

- *Animation, movie, game*



CG Related Applications(cont.)

7: Graphical User Interfaces(WIMP)

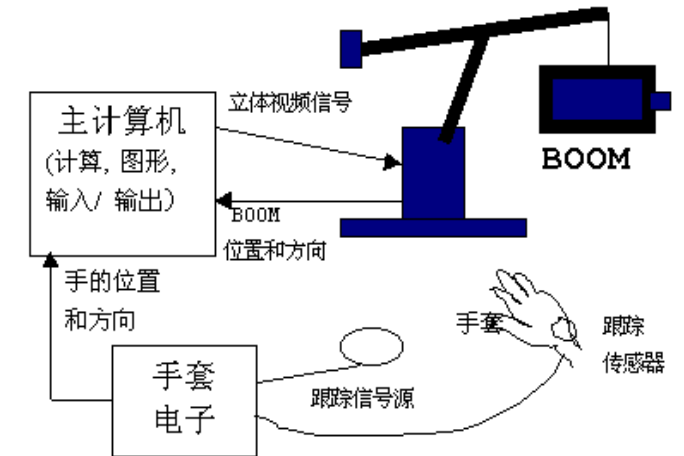
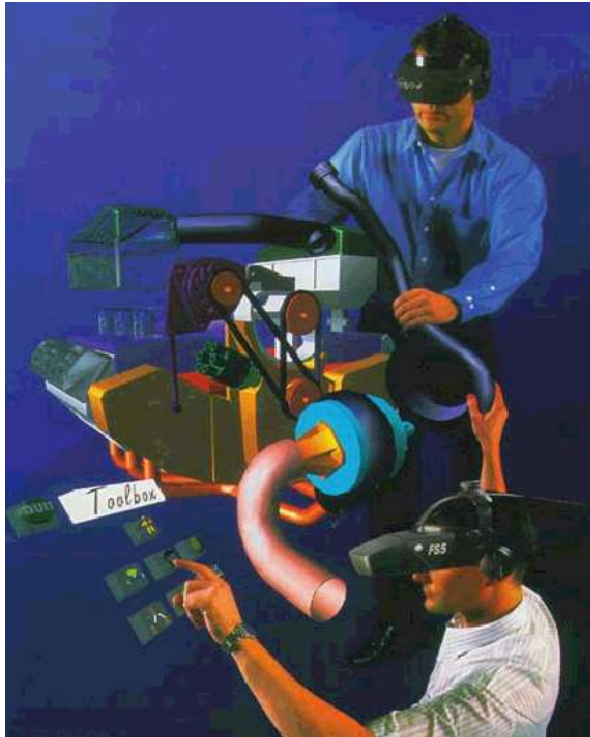
- Human-computer interaction since the 1990s has been a graphical user interface featuring WIMP
- Fastest browser on the Mac



CG Related Applications(cont.)

• 8: Virtual Reality

- A real-time three-dimensional space generated by a computer.
- Give the user an immersive feeling.
- Multichannel natural interaction: gestures, eye contact, facial expressions, voice.
- Used for flight simulation training, games and so on.



Outlines

- Why
 - Many Applications based on CG
- What
 - Visualization calculation, History , Frontiers
- How
 - Course Content

CG: Visualization Compute

Vision is the most important sense of humans

A significant portion of a human brain processes visual information

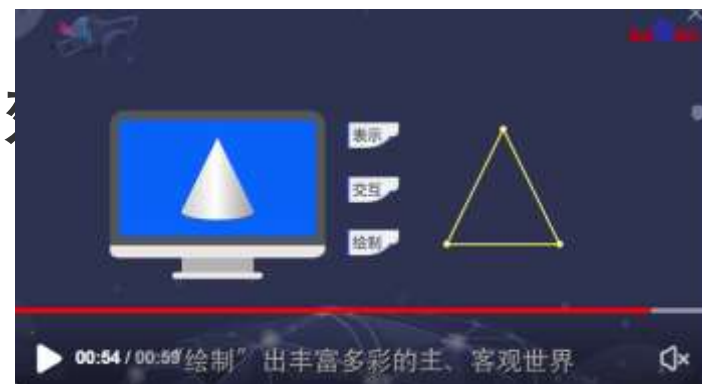
“One picture is better than a thousand words”



CG: Visualization Compute(cont.)

- 计算机图形学核心目标(视觉交流)可以分解为交互、绘制，即如何在计算机中“交互”地“表示”主、客观世界。
- “**表示**”是如何将主、客观世界放到计算机中去表示与建模；
- “**绘制**”是指如何将计算机中的对象用一种直观地表现出来——二维、三维对象的绘制；
- “**交互**”是指通过计算机输入、输出设备，以有“绘制”的技术。

参：百度。



CG: Visualization Compute(cont.)

- IEEE definition: Computer graphics

is **the art or science**
of **producing** graphical images
with the aid of **computer**.

- James Foley: Computer graphics

运用计算机
描述、输入、表示、存储、处理、显示和输出图形图像的
一门学科。

CG Producing Graphical Image

Image: a visual representation of the relations between certain quantities plotted with reference to a set of axes

- Vector image (向量图)
- Raster image (光栅图/点阵图/像素图)

CG Producing Graphical Image(cont.)

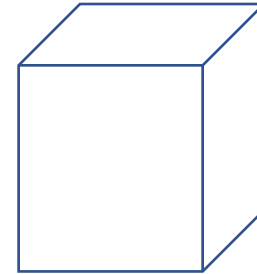
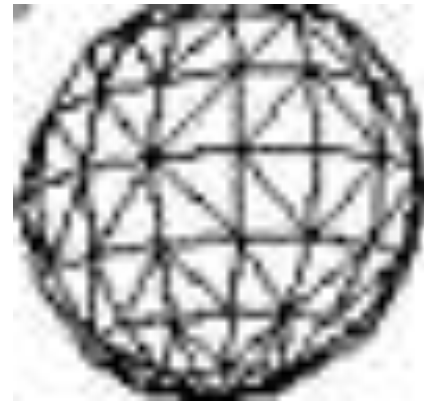
Vector graph (向量图)

- A **vector graph** (矢量图/参数图) is a set of vectors used to describe the contents of a graph:
- The greatest advantage of **vector graph** is: it will not be anamorphic变形 whether enlarge, reduce or revolve

point(x,y)

line(p1.x,p1.x, p2.x, p2.y)

polygon(p1,p2,p3,...)



CG Producing Graphical Image(cont.)

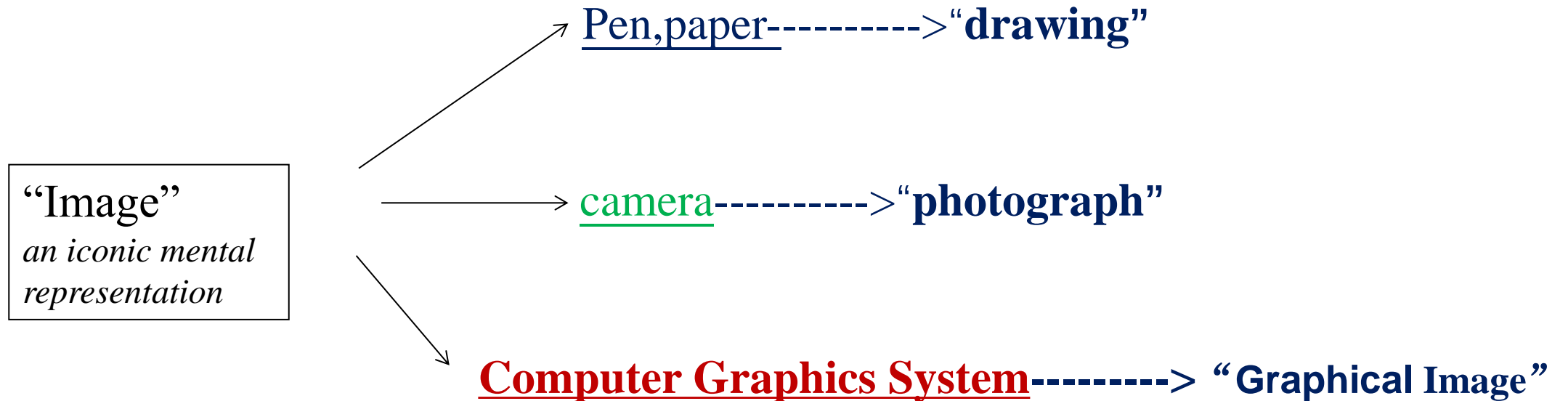
- Raster map(光栅图)

Bitmap/Pixmap (位图/像素图) : an image represented as a two dimensional array of brightness values or color values for pixels

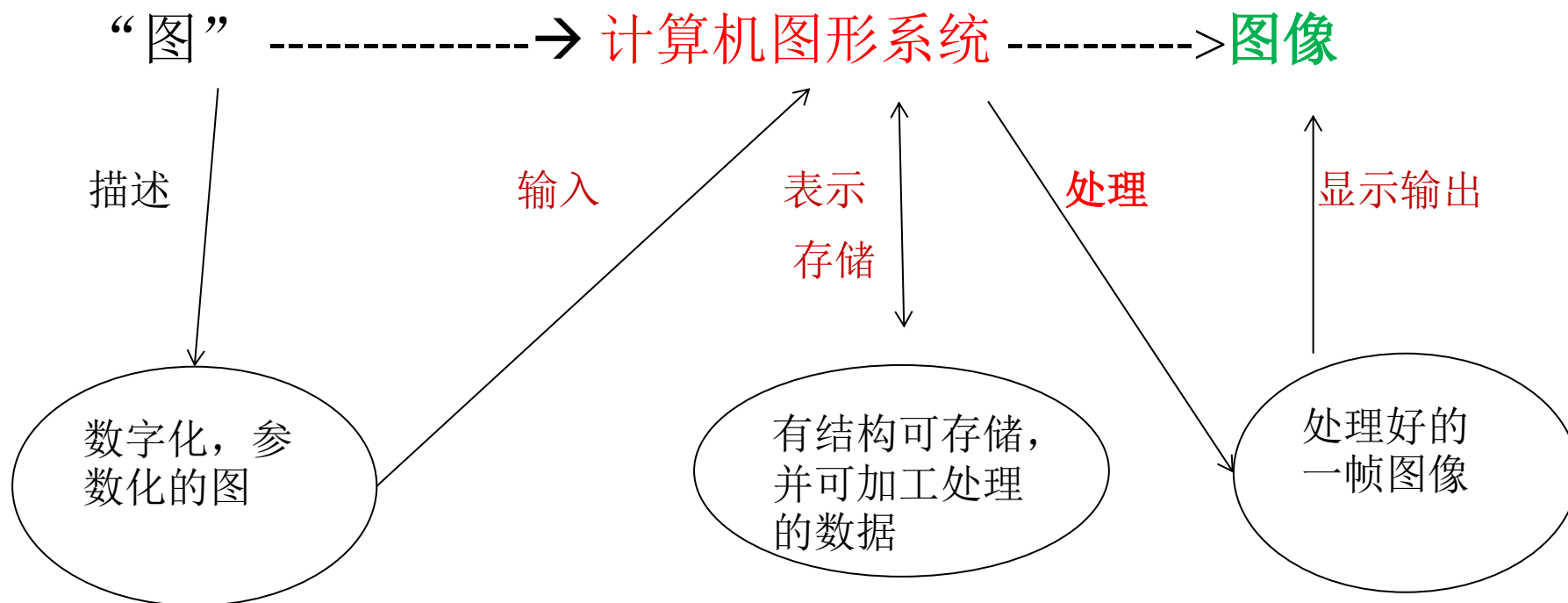


CG is the art or science

- **Graphics**: 制图学; 制图法; 图表算法



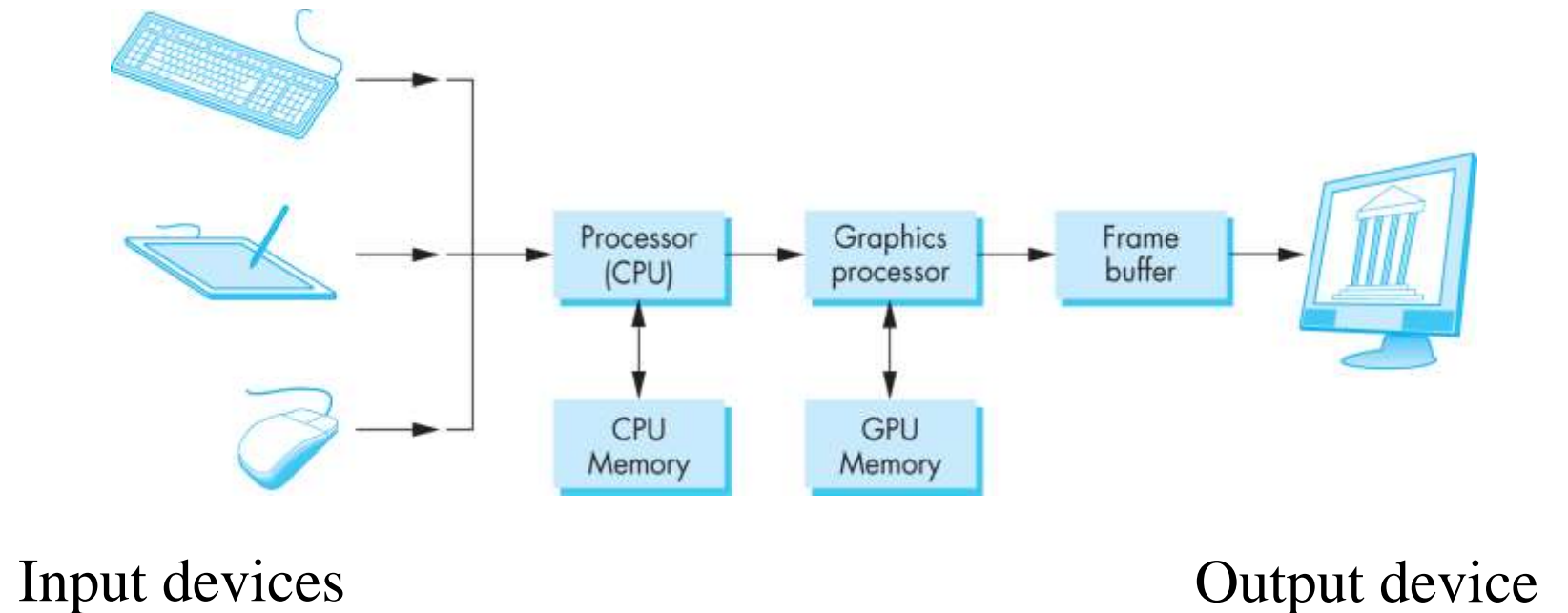
CG is the art or science(cont.)



CG with computer

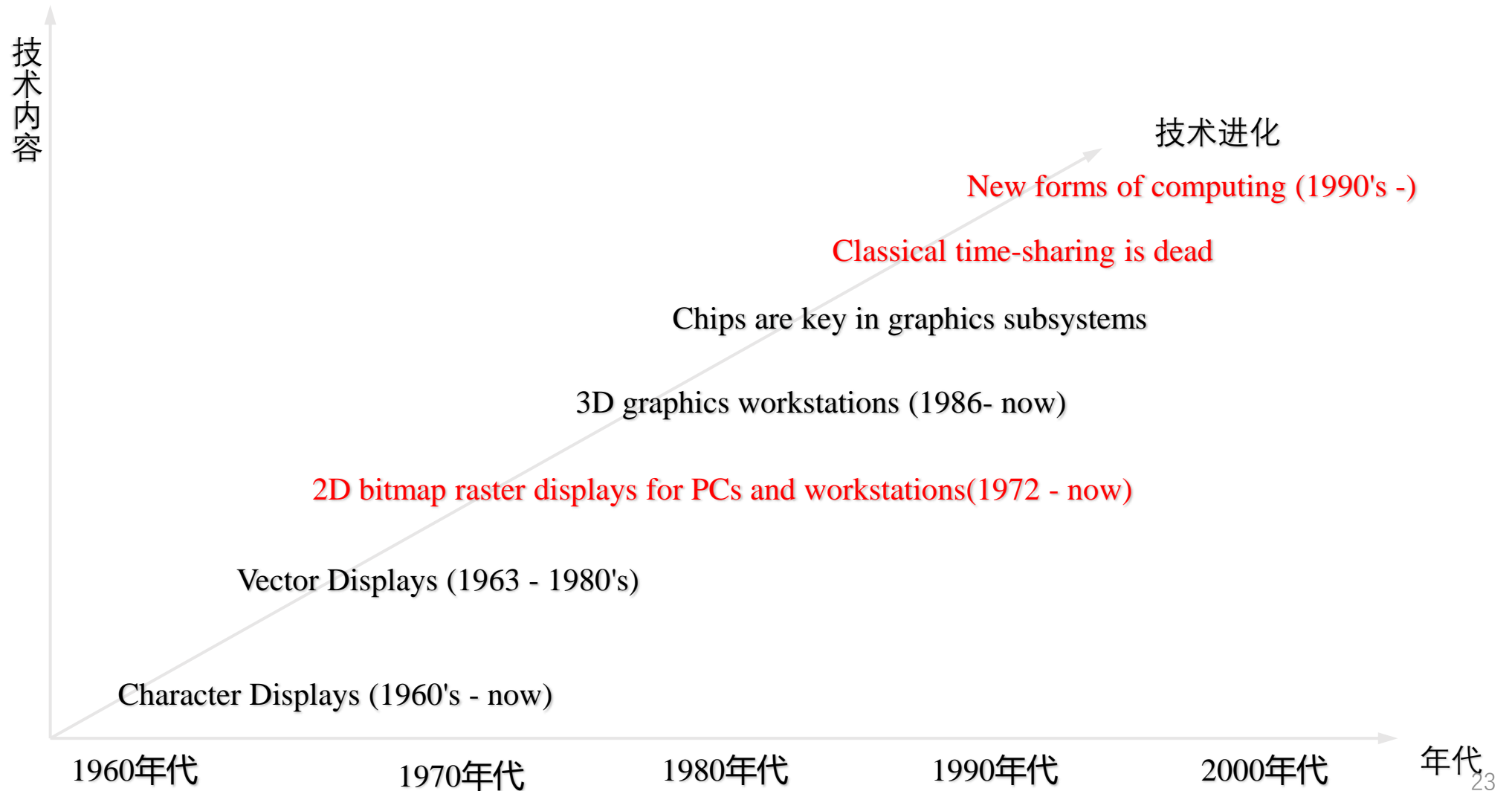
CG deals with all aspects of creating images with a **computer**

- Hardware
- Software
- Applications



Basic Graphics System

CG History



CG History(cont.)

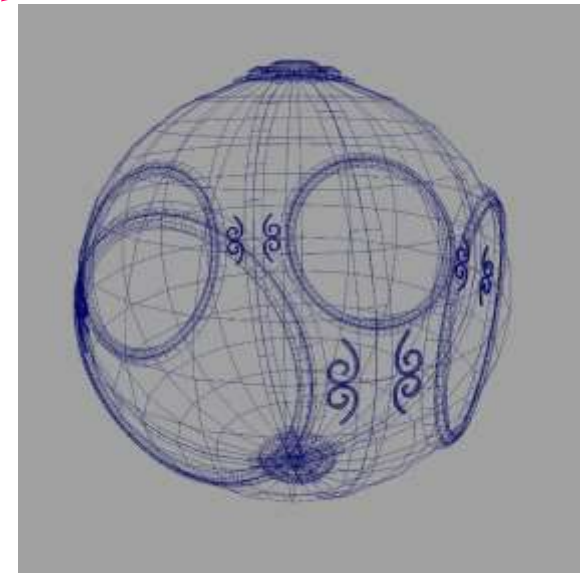
1.Computer Graphics: 1950-1960 (酝酿期)

- Computer graphics goes back to the earliest days of computing
 - Strip charts (带状记录纸)
 - Pen plotters(笔式绘图仪)
 - Simple displays (简单显示器) using A/D converters to go from computer to calligraphic CRT
- Cost of refresh for CRT too high
 - Computers slow, expensive, unreliable

CG History(cont.)

2.Computer Graphics: 1960-1970 (萌芽期)

- *Wireframe* graphics Draw only lines
- Sketchpad- Ivan Sutherland
- Display Processors
- Storage tube



wireframe representation
of sun object

CG History(cont.)

2.Computer Graphics: 1960-1970 (萌芽期) (cont.)

- Ivan Sutherland: 计算机图形学之父

- Sutherland invented Sketchpad in 1962 while at MIT.
- https://www.youtube.com/watch?v=6orsmFndx_o

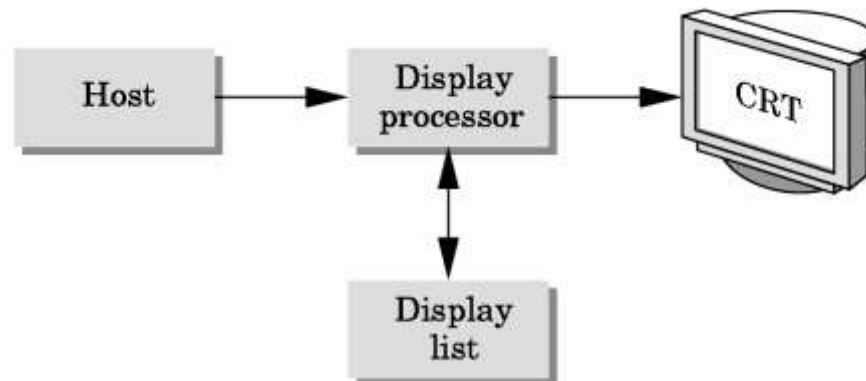


Ivan Sutherland Sketchpad Demo 1963

CG History(cont.)

2.Computer Graphics: 1960-1970 (萌芽期) (cont.)

- Display Processor and Direct View Storage Tube
 - Direct View Storage Tube Created by Tektronix
 - Did not require constant refresh, Standard interface to computers, Allowed for standard software, Plot3D in Fortran
 - Relatively inexpensive, Opened door to use of computer graphics for CAD community



CG History(cont.)

3.Computer Graphics: 1970-1980 (发展期)

➤ Raster Graphics(光栅图形学)

➤ **Raster Graphics** Allows us to go from lines and wire frame images to filled polygons

➤ Beginning of graphics standards

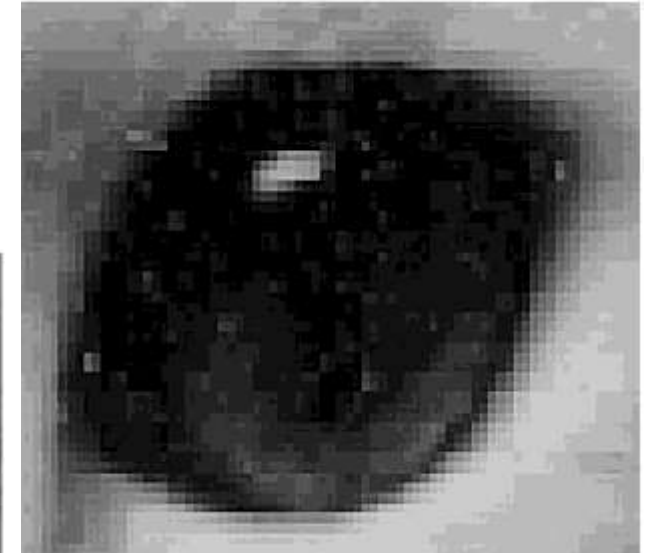
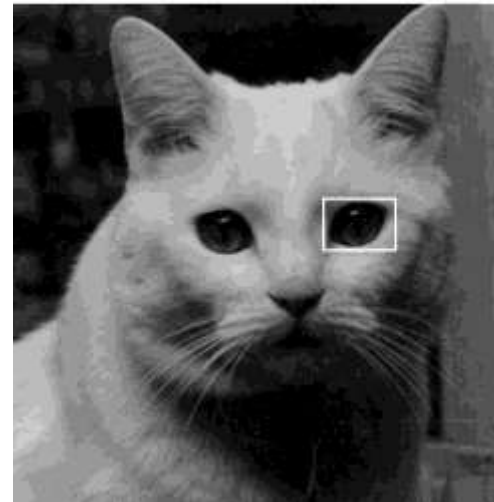
GKS: European effort

Becomes ISO 2D standard

Core: North American effort

3D but fails to become ISO standard

➤ Workstations and PCs

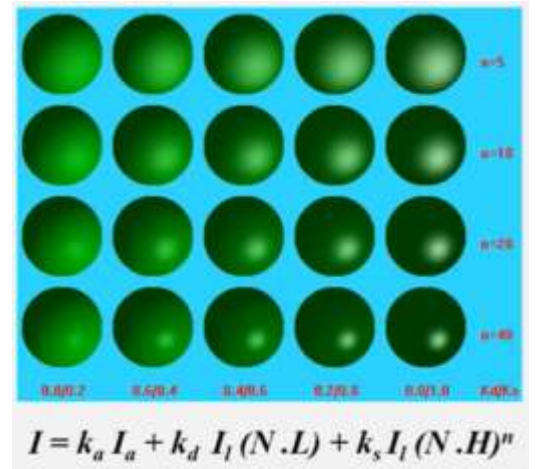


CG History(cont.)

3.Computer Graphics: 1970-1980（发展期cont.）

➤Reality Rendering technology(真实感技术)

- 1970年Bouknight提出了第一个光反射模型,
- 1971年Gourand提出“漫反射模型 + 插值”的思想,
- 1975年Phong 提出了著名的简单光照模—Phong模型。



➤Physical modeling technology（实体造型技术）

- 从1973年开始，相继出现了英国剑桥大学CAD小组的Build系统、
- 美国罗彻斯特大学的PADL-1系统等实体造型系统。

CG History(cont.)

4.Computer Graphics: 1980-1990 (普及期)

- Special purpose hardware

 - Silicon Graphics geometry engine

 - VLSI implementation of graphics pipeline

- Industry-based standards

 - PHIGS, RenderMan

- Networked graphics: X Window System

- Human-Computer Interface (HCI)

- Realism(真实感) comes to computer graphics



CG History(cont.)

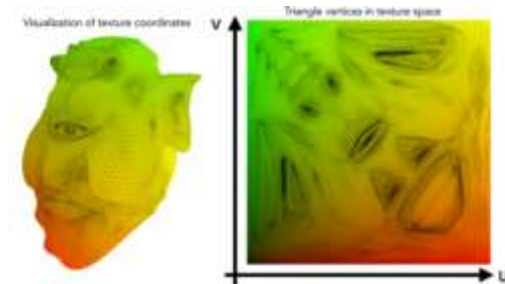
➤ 5. Computer Graphics: 1990-2000(飞跃期)

- OpenGL API, DirectX (图形工业标准接口)
- Completely computer-generated feature-length movies
 - Toy Story: 完全由电脑CG制作的长篇电影



➤ New hardware capabilities

- Texture mapping
- Blending
- Accumulation, stencil buffers



CG History(cont.)

6.Computer Graphics: 2000-2010（变革期）

➤ Photorealism 照片级真实感

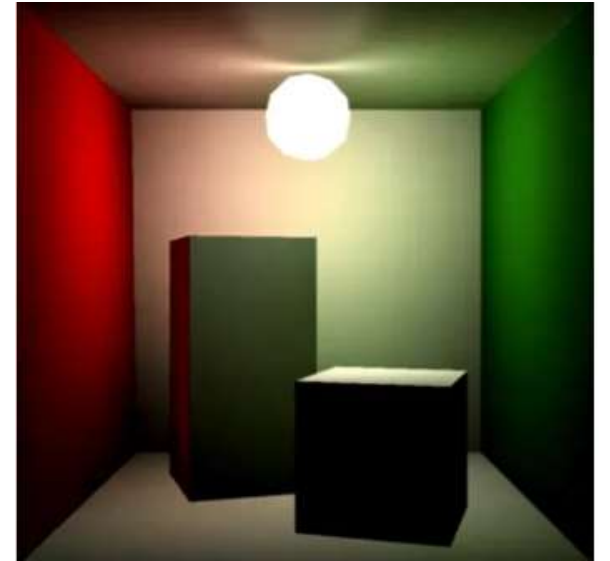
➤ Graphics cards for PCs dominate market

Nvidia(英伟达), ATI, 3DLabs

Game boxes and game players determine direction of market

➤ Computer graphics routine in movie industry

- Maya,
- Lightwave



➤ Programmable pipelines（可编程渲染流水线）

CG History(cont.)

➤ 7. Computer Graphics: 2010...2017(移动应用)

➤ Graphics is now ubiquitous (图形无处不在)

- Cell phones, Embedded
 - OpenGL ES and WebGL,
 - metal, DirectX12, Vulkan and webGPU

➤ 3D movies and TV



Research frontier

1. photo realism graphic rendering

PBR: physical Based Rendering

基于预计算的全局光照实时绘制



- 提出一种球面线性常数基函数，实现同时支持高频和低频的动态场景实时绘制



IEEE Transactions on Visualization and Computer Graphics 2008

表面细节绘制与体纹理



- **VDM, ACM SIGGRAPH 2003**



参：清华胡事民课件

Research frontier(cont.)

2. Animation

计算机动画



基于特征的图象变形（猫变虎）：[演示](#)

计算机动画



晓媛的鱼：智能生命之人工鱼

Research frontier(cont.)

3.Geometry

Sketch2Scene: 草图到3D场景



- **Sketch2Scene**: 提出一个实时的建模系统, 将手绘草图直接转化为三维场景模型。在游戏设计、三维动画、影视特技等方面有重要应用

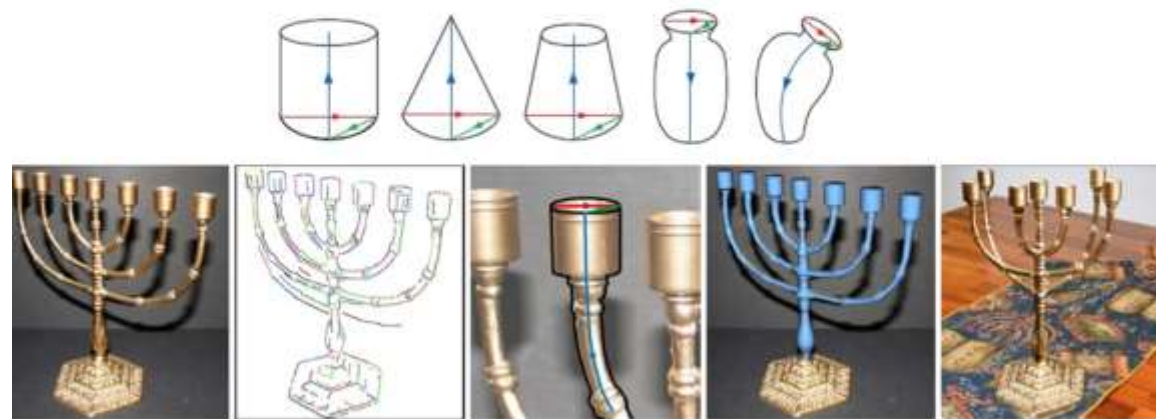


ACM SIGGRAPH 2013
ACM Transactions on Graphics

3-Sweep: 基于单张图像的物体建模



- 从单张图像抽取三维物体:



ACM SIGGRAPH ASIA 2013
ACM Transactions on Graphics

Research frontier(cont.)

4. Image synthesis and editing based on massive data

- 海量的网络数据中蕴含着图像智能处理所需要的重要知识
- 利用网络海量内容，基于认知计算模型和机器学习的图像智能处理成为重要趋势

基于互联网的图像融合系统



ACM Transactions on Graphics
(SIGGRAPH 2009)

Research frontier(cont.)

5.CG+AI

- <https://www.youtube.com/watch?v=-gPvoZHtuGE>
- <https://cg.cs.tsinghua.edu.cn/jittor/>
 - 2018 Nvidia RTX “Turing Card”,
 - DSLL(Deep Learning Super Sampling)
 - 2021 Metaverse



计算改变人类文明进程

- 计算技术与系统每10—15年发生一次重大变革

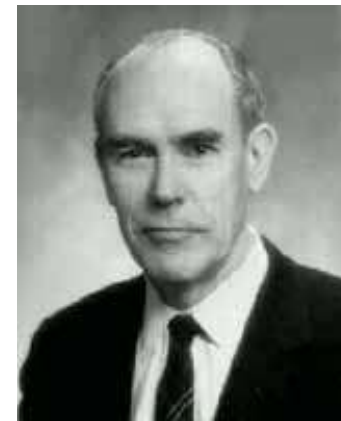


Industry figures-图灵奖获得者

- 1988年图灵奖:

- 伊凡·苏泽兰 Ivan Sutherland

- ~ 计算机图形学之父和虚拟现实之父



1988 年	伊万·萨瑟兰		表彰他对计算机图形学的开创性和远见性贡献，从 Sketchpad 开始，并在此之后继续。↵
--------	--------	--	---

Industry figures (cont.)

- 2019图灵奖:

- Patrick M. Hanrahan (帕特里克·汉拉汗),

- Edwin E. Catmull (艾德文·卡特姆)

2019 年	埃德温·卡特莫尔		表彰对 3D 计算机图形学的基本贡献，以及这些技术对电影制作和其他应用中计算机生成图像 (CGI) 的革命性影响。 ^[49]
	帕特·汉拉汗		

Outlines

- Why
 - Many Applications based on CG
- What
 - Visualization Compute, History , Frontiers
- How
 - Course Content

a.Prerequisites(预备知识)

- **Math Knowledge**

- High-School level Geometry & Trigonometry
- Basic Linear Algebra
- some calculus, statistics

- **Basic Data Structures and Algorithm**

- Lists , Arrays, Trees, Index, Stack , ...

- **Good programming skills**

- C/C++ ...

b. Objectives (目标)

- Broad introduction to Computer Graphics(*primary*)
 - Hardware
 - Software
 - Applications
- Shader-Based Programming(*practice*)
 - make use of the full capabilities of the graphics processing unit (GPU)

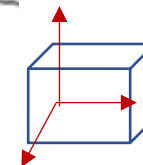
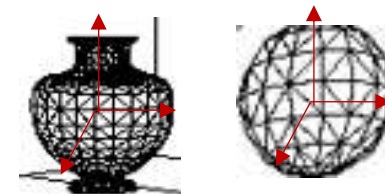
Eg: WebGL:

- *With HTML5, WebGL runs in the latest browsers*
- *makes use of local hardware*
- *no system dependencies*

c. Contents (教学内容)

Objects and Material Representation Data,
Light sources Attributes Data,

Modeling建模(Geometry几何)



MC

Room?

Interaction and Animation 交互和动画

SC/DC



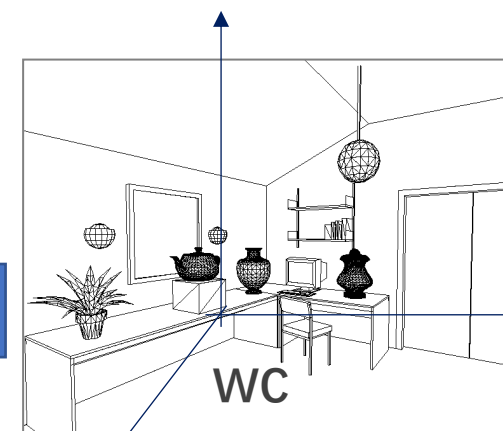
colored Image 2D

Rendering渲染

片元处理:
Fragment

图元组装和光栅化
Rasterization

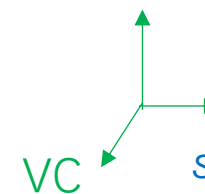
顶点处理:
Vertex



WC

Scene 3D

Scene description: objects, light, texture etc.



c. Contents (教学内容)

- What we will cover

- Fundamentals of Computer Graphics(primary)

- Graphics algorithms and data structures
 - Applied linear algebra (yes, math!)
 - Image generation principles
 - Projective 3D Pipeline

Geometry: 几何表示(网格表示, 自然景物表示, 曲线曲面)和几何变换

Rasterization: 光栅化渲染 (实时快速, 但真实感差)

Ray Tracing: 光线跟踪渲染(计算复杂, 基于物理的真实感渲染 PBR)

Animation/Simulation: 交互, 动画模拟, 基于物理的动画

- lec1-part1 CGIntroduction
- lec2-part1 CG System
- lec3-part1 CG Pipeline and API
- lec4-part1 Modeling
- lec5-part2 Transformation
- lec6-part2 Viewing-ModelView Trans
- lec7-part2 Viewing-Projection&Window Trans
- lec8-part2 Clipping&Hidden
- lec9-part3 Rasterization
- lec10-part3 Lighting&Shading
- lec11-part3 Texture Mapping
- lec12-part3 FragmentProcess
- lec13 part4 Ray Tracing
- lec14 part4 Path Tracing
- lec15-part4 Other Topics

c. Contents (教学内容)

• What we will cover(cont.)

- **OpenGL /WebGL**
- 安排四次编程练习（每4周1次，最后1次作期末报告）
 - Animation/Simulation: 2D图形交互绘制
 - Geometry: 3D几何表示和变换
 - Rasterization: 光栅化渲染着色
 - RayTracing: 光线跟踪渲染着色

c. Contents (教学内容)

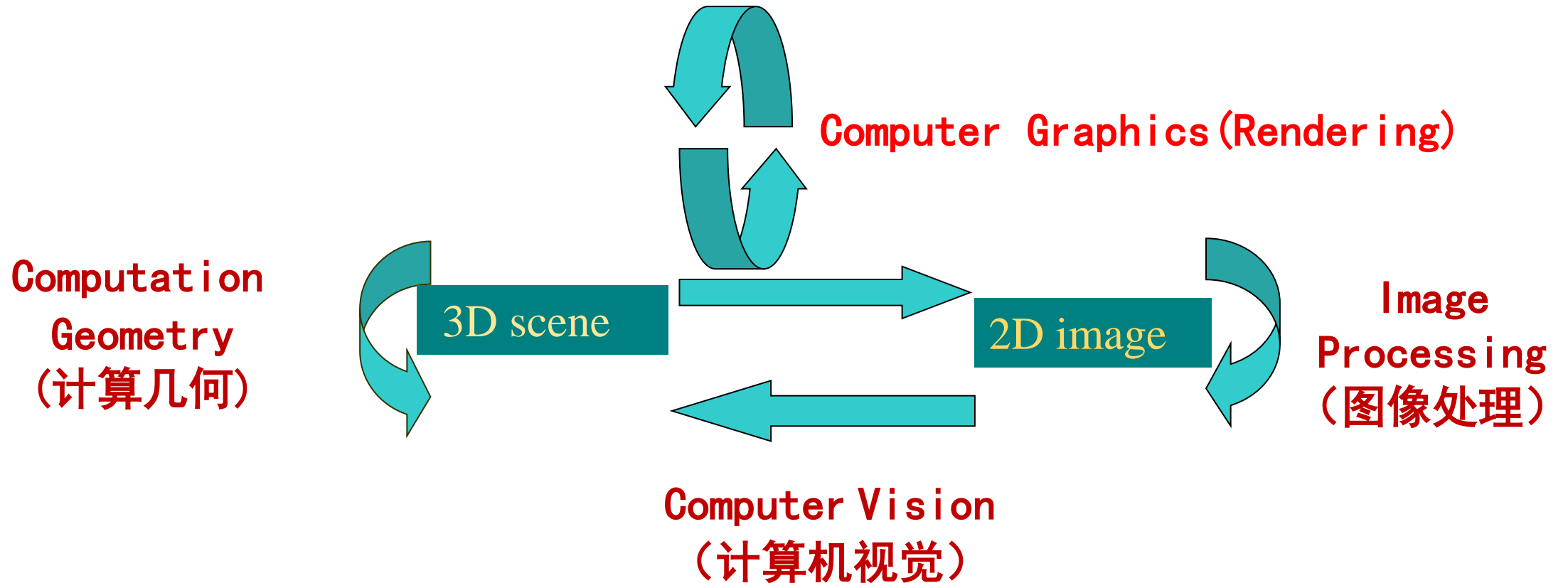
- What this course is not about...

- Paint and Imaging packages (Adobe Photoshop)
- CAD packages (AutoCAD)
- Rendering packages (Lightscape)
- Modeling packages (3D Studio MAX)
- Animation packages (Maya)



d.Related Disciplines

Computer graphics: Rendering, Geometry, Simulation



Reference Resources:参考资料

- 1.交互式计算机图形学（第八版）(英文版) （美）爱德华 安杰尔，戴夫 斯赖纳 著。-北京：电子工业出版社，2020.8，ISBN:978-7-121-39398-3（注：第七版有中文翻译版）
<https://www.cs.unm.edu/~angel>（注：第七版有中文版）
2. Fundamentals of Computer Graphics(5th Edition); Steve Marschner , Peter Shirley. 2015（注：第二版有中文翻译版）
<https://www.cs.cornell.edu/courses/cs4620/2014fa/index.shtml>
3. Computer Graphics with openGL(fourth version) , Donald Hearn M.Pauline Baker , 2014(有中文翻译版，蔡士杰等译，电子工业出版社)
4. Computer Graphics: Principles and Practice(Third Edition), John F. Hughes.2014(有中文翻译版，彭群生等译，北京机械工业出版社)
5. Real-Time Rendering (4th Edition); Tomas Akenine-Möller , Eric Haines , Naty Hoffman .2018
6. *GAMES101*: <https://games-cn.org/gamescoursescollection/>
7. 中国大学MOOC“计算机图形学”, 华中科技大学, 万琳 <https://www.icourse163.org/>

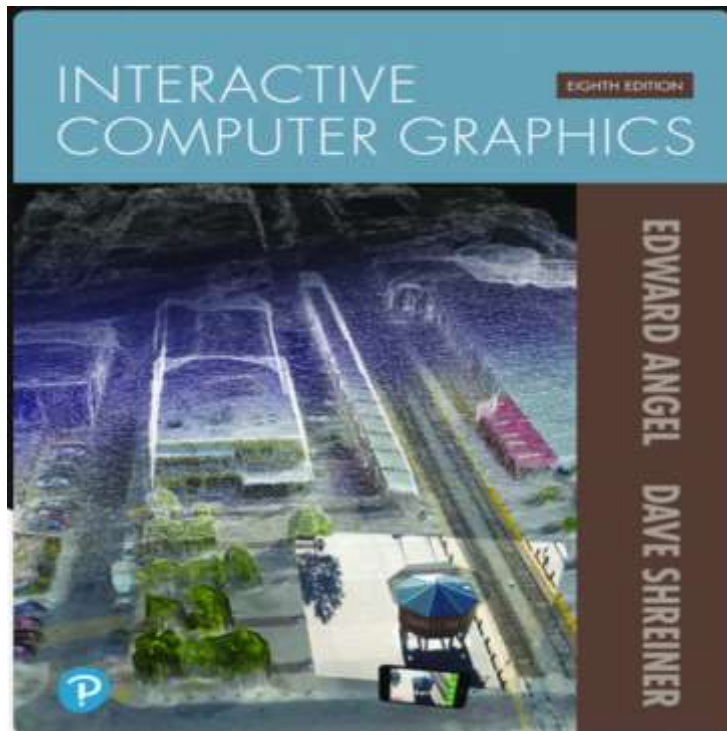
Reference Book 1

Edward Angel and Dave Shreiner, Interactive Computer Graphics, A Top-down Approach with WebGL (Eighth Edition), Addison-Wesley,

电子工业出版社, 英文版, 2020.8 ISBN:978-7-121-39398-3

These lectures cover Chapters 1-7 in detail and survey Chapters 8-13

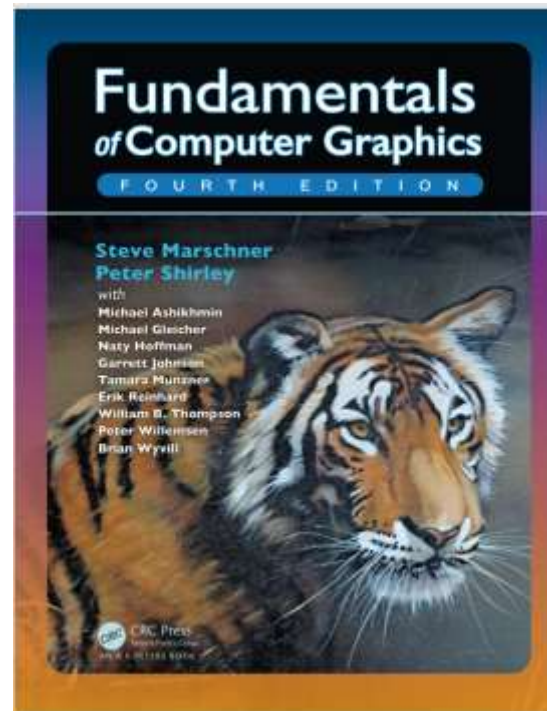
www.cs.unm.edu/~angel/



- [SIGGRAPH and SIGGRAPH Asia Materials](#)
- [SIGGRAPH13 OpenGL Course on YouTube from SIGGRAPH University](#)
- [SIGGRAPH14 WebGL Course on YouTube from SIGGRAPH University](#)
- [Book Support \(All Editions of Interactive Computer Graphics and the Open Primer\)](#)
- [Adoption List of Interactive Computer Graphics](#)

Reference Book 2

- **Fundamentals of Computer Graphics (Five Edition) Steve Marschner, Peter Shirley.**

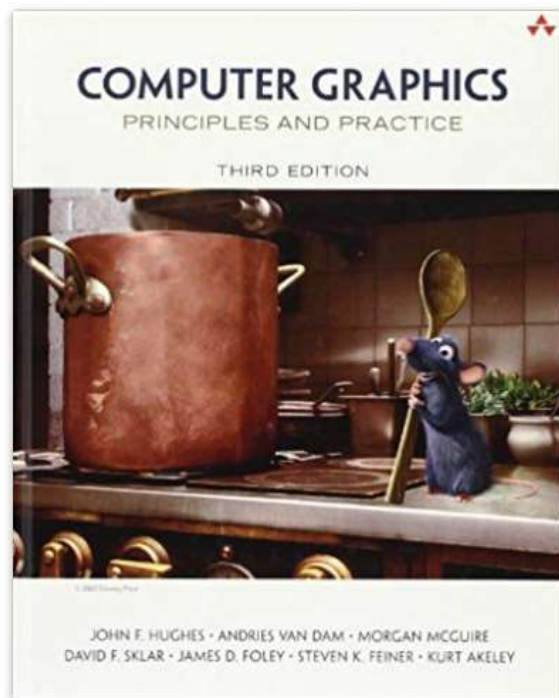


Reference Book 3

Computer Graphics: Principles and Practice, Third Edition,

- John F Hughes, Published by Perason Education, Inc, Copyright, 2014.

.计算机图形学原理及实践（原书第3版）（基础篇），John F Hughes（约翰.F.休斯）中译本，彭群生等译，机械工业出版社，2018.10

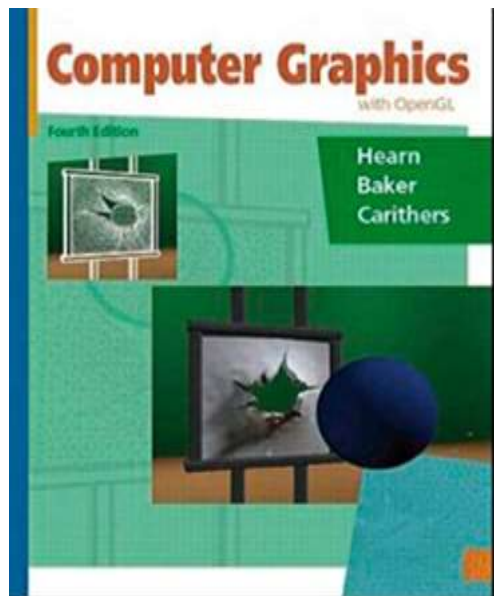


Reference Book 4

Computer Graphics with OpenGL(fourth version) ,

- Donald Hearn M.Pauline Baker , Publishing house of electronics industry

计算机图形学（第四版） , *Donald Hearn M. Pauline Baker* 蔡士杰译, 电子工业出版社 2014.11



Reference Book 5

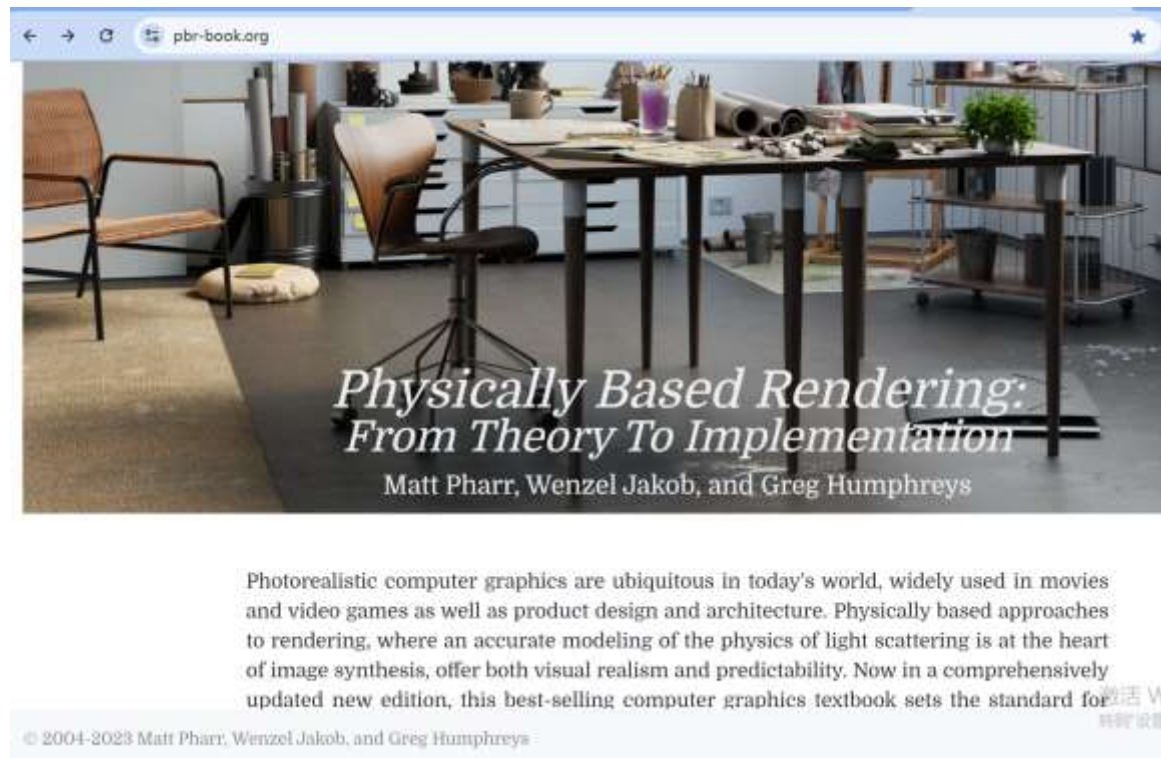
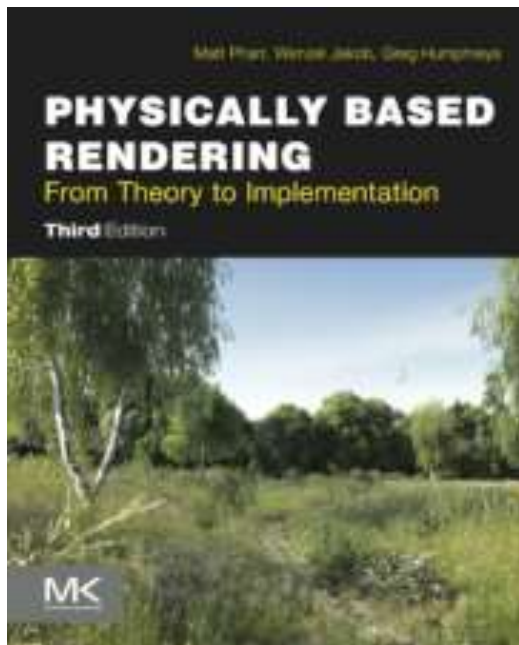
Real-Time Rendering (4th Edition)

- Tomas Akenine-Möller , Eric Haines , Naty Hoffman



Reference Book 6

- **Physically Based Rendering: From Theory to Implementation**
 - Matt Pharr, Wenzel Jakob, and Greg Humphreys
- <https://pbr-book.org/>



Online Course 1

- **GAMES101:** <https://games-cn.org/gamescoursescollection/>

GAMES 101



现代计算机图形学入门



闫令琪

加州大学圣芭芭拉分校(UCSB)

2020年2月11日起 | 北京时间每周二周五上午10:00-11:00 | WEBINAR.GAMES-CN.ORG

GAMES101: 现代计算机图形学入门



Online Course 2

- <https://www.icourse163.org/> 华中科技大学 万琳 计算机图形学

The screenshot shows the course page for '计算机图形学' (Computer Graphics) on the '中国大学MOOC' (China University MOOC) platform. The page features a navigation bar with links to '课程' (Courses), '学校' (Schools), '慕课堂' (MooK), and '下载APP' (Download APP), along with a search bar. The course is listed under '首页 > 计算机' (Home > Computer). The main content area includes a video player with a thumbnail of Professor Wan Lin, a list of 14 topics, and course details such as '第5次开课' (5th session), '开课时间: 2021年10月11日 ~ 2022年03月24日' (Start time: October 11, 2021 ~ March 24, 2022), and '学时安排: 每周3小时' (Credit arrangement: 3 hours per week). A message at the bottom states '老师已关闭该学期, 无法查看' (Teacher has closed this semester, cannot view).

中国大学MOOC

课程 学校 慕课堂 下载APP

搜索感兴趣的课程

首页 > 计算机

计算机图形学

从造型到渲染的完整理论体系

1. 中点生成算法
2. 有序边表算法
3. 种子填充
4. 分形几何
5. 颜色模型
6. Phong模型
7. Blinn-Phong模型
8. Whitted模型
9. 光线追踪算法
10. 法线贴图
11. 阴影计算
12. 基于物理的渲染
13. 延迟渲染
14. 层次细节

第5次开课

开课时间: 2021年10月11日 ~ 2022年03月24日

学时安排: 每周3小时

当前开课已结束

老师已关闭该学期, 无法查看

International Conference

– SIGGRAPH <https://www.siggraph.org/>

· 全称 “the Special Interest Group on Computer Graphics and Interactive Techniques”

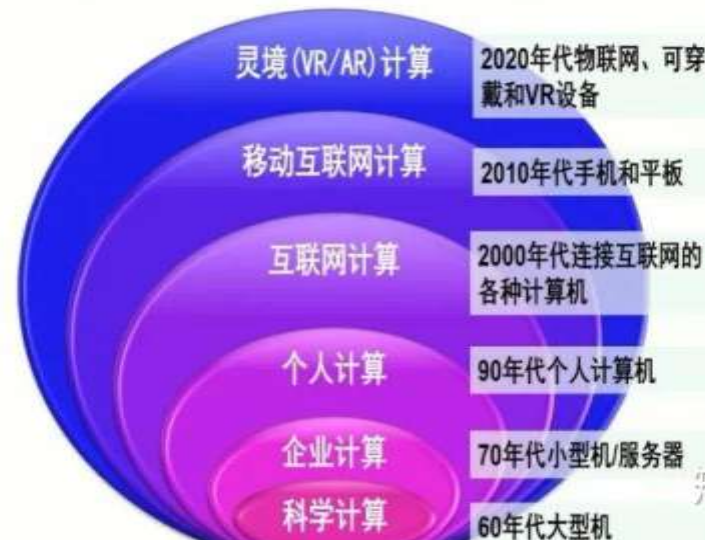
siggraph2024: 黄仁勋和马克·扎克伯格探讨AI 和下一代计算平台

https://www.bilibili.com/video/BV1Fx4y147dC/?spm_id_from=333.337.search-card.all.click



计算改变人类文明进程

- 计算技术与系统每10—15年发生一次重大变革



知乎 @晒科网

Domestic Periodical & Conference

- 中国图形图像学报



2023年 | 第28卷 | 第8期

刊 号: ISSN1006-8961/CN11-3758/TB
CODEN ZTTXFZ
主管单位: 中国科学院
主办单位: 中国科学院空天信息创新研究院,
中国图形图像学学会, 北京应用物
理与计算数学研究所

- 计算机辅助设计与图形学学报



1989年创刊, 月刊

主管: 中国科学技术协会

主办: 中国计算机学会

北京中科期刊出版有限公司
(科学出版社)

ISSN 1003-9775

CN 11-2925/TP

Engineering Village Scopus CSCD

1. 教学管理工具

1) 课程QQ群

- 重要通知,
- 课件发布, 文件共享,
- 答疑

2) 互动平台：雨课堂智慧平台

四川大学雨课堂智慧平台：<https://scu.yuketang.cn/>

- 首先进行“身份绑定”：微信公众号“雨课堂”->更多->“身份绑定”
- 平台使用参考QQ群文件：雨课堂使用手册**5.2**（学生），雨课堂学生网页版听课说明**(1)**

2.教学考核方式（暂定）*

总成绩=平时过程60%+期末报告40%

平时过程70%：雨课堂智慧平台（课堂30%，课后练习30%，编程作业 40%）

期末报告30%：设计实现一个基于可编程渲染管线的3D图形程序

Project : 3D scene modeling ,rendering and interaction

Requirements:

- ✓ Rendering: Display result(image) on screen
 - ✓ Local illumination model and color model must be realized in this project.
 - ✓ Texture mapping must be realized in this project.
- ✓ Interaction and Animation: Change images on screen
 - ✓ Apply keyboard and mouse to control the position and orientation of the camera and the 3D object parts.
 - ✓ Generate Smooth Animation Images
- ✓ Geometry: Modeling objects of the scene
 - ✓ Describe object in mesh surface

3.学习方法说明

- “三阶段”：预习，听课，练习
- 课前：预习线上相关章节视频内容
- 课中：考勤，重点知识听讲，课堂交互活动，提问答疑等
- 课后：课后平台上完成练习，每月完成1次编程练习

“知行合一”：想清楚，做明白！

通过课后客观题作业，掌握基本理论知识点；

通过课后编程作业，深入理解知识点及算法，达到融会贯通。

