



Introduction

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School of Data and Computer Science



What is the class about?

- Fundamental Algorithm of Computer Graphics
- 3D Geometry Processing
- Photorealistic Rendering
- OpenGL
- Programming
- Hot Topic of Computer Graphics

We will **not** learn how to use
animation or rendering
software to create animations.

Our goal is to learn the basics
that are necessary to develop
such software.



课程内容

- 13 Topics + 2 Projects

- Introduction
- Rendering Pipeline
- OpenGL Programming
- Rasterization
- Transformation
- Viewing in 2D & 3D
- Curve and Surface Modeling
- Mesh Processing
- Geometry-Driven Image Processing
- Lighting & Shading
- Texture Mapping
- Shape Analysis
- VR, AR & MR
- Project 1: Advanced Computer Graphics Topics
- Project 2: CG Programming

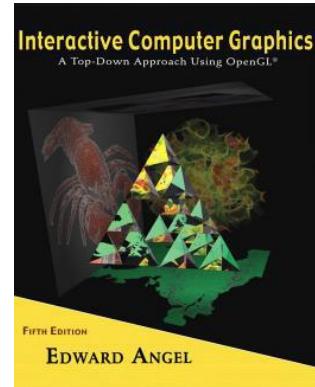
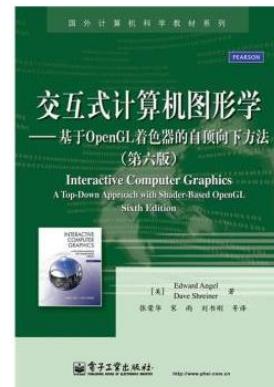


Optional Textbooks

- E. Angel, Interactive Computer Graphics — A top-down approach using OpenGL™, 6th ed., 2011. (国内有影印版)



计算机图形学 (第4版)
“Computer Graphics with OpenGL, Fourth Edition”

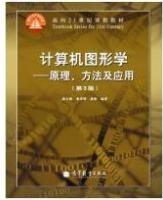


OpenGL 编程指南 (原书第8版)
“OpenGL Programming Guide”



Related Textbooks

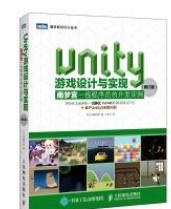
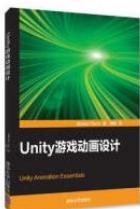
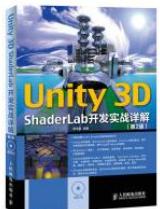
- Theory



- Programming Guideline



- Game & Animation



Exciting cartoons

- Brave (勇敢传说) , 2012 , Pixar



Exciting cartoons

- Thinking:

Which graphics technologies are included in the cartoon product?



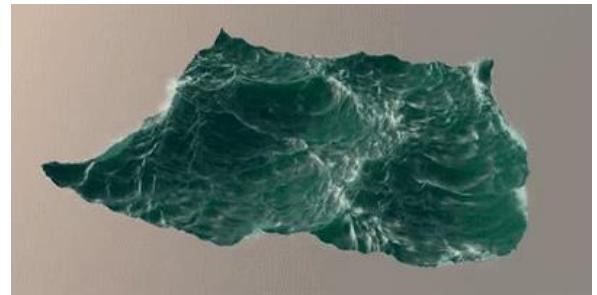
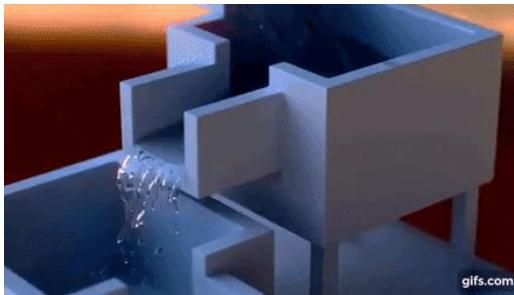
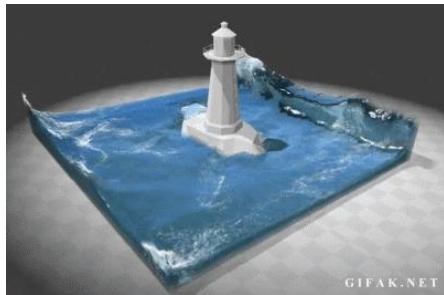
Exciting cartoons

- Hair Modeling



Exciting cartoons

- Fluid simulation & illumination



Exciting movies



Exciting movies



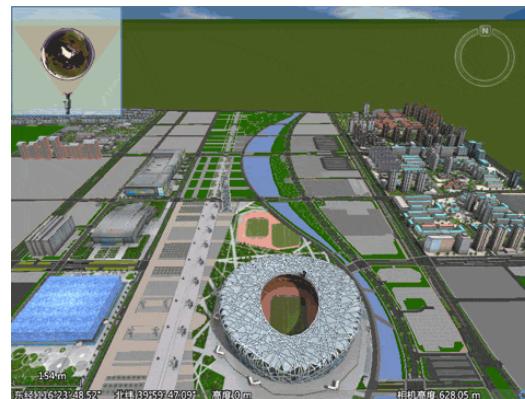
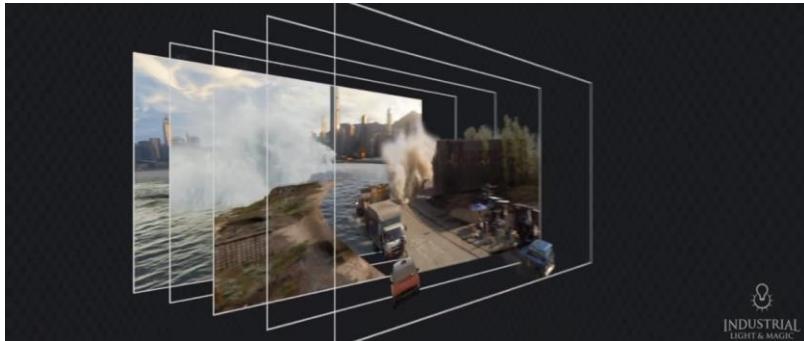
A movie poster featuring the title "TRANSFORMERS" in large, metallic, reflective letters. The letters have a strong perspective, appearing to recede into the distance. The background is a dark, textured surface, possibly a city skyline at night.

TRANSFORMERS



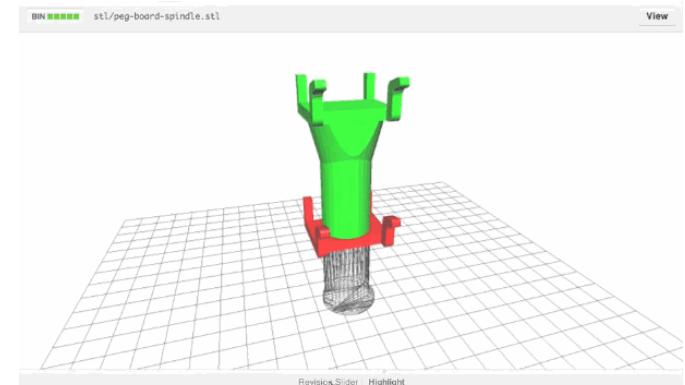
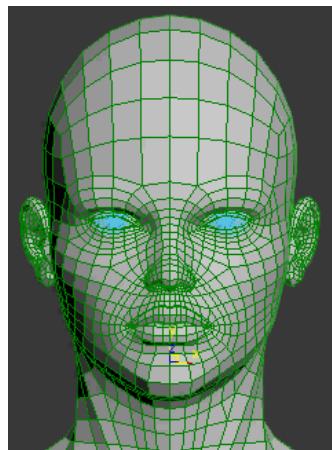
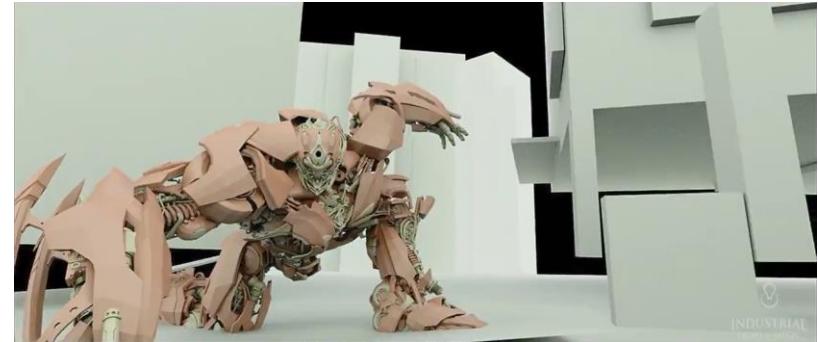
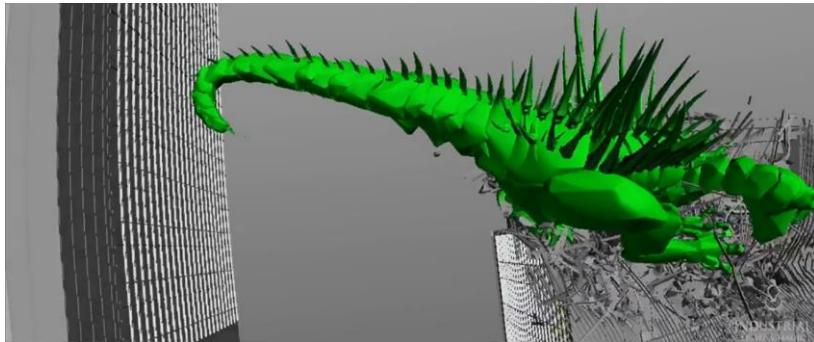
Exciting movies

- Scene modeling



Exciting movies

- Object modeling



Exiting games



What is Computer Graphics?

- Computer graphics generally means creation, storage and manipulation of models and images
- Such models come from diverse and expanding set of fields including physical, biological, mathematical, artistic, and conceptual/abstract structures
- 计算机图形学(简称CG)是一种使用数学算法将二维或三维图形转化为计算机显示器的栅格形式的科学。简单地说，计算机图形学的主要研究内容就是研究如何在计算机中表示图形、以及利用计算机进行图形的计算、处理和显示的相关原理与算法。

Frame from animation by William Latham, shown at **SIGGRAPH 1992**. Latham creates his artwork using rules that govern patterns of natural forms.



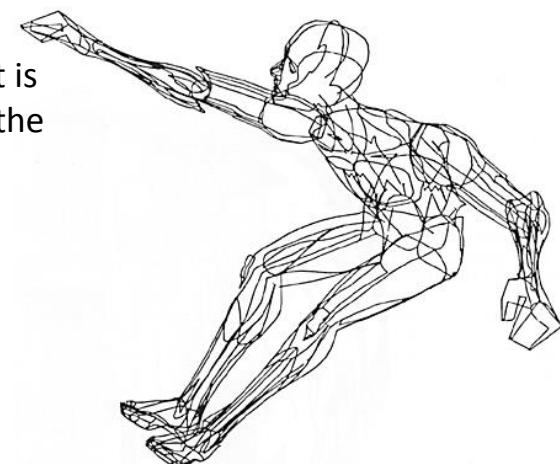
What is Computer Graphics?

- William Fetter coined term “computer graphics” in 1960 to describe new design methods he was pursuing at Boeing for cockpit ergonomics (飞机座舱工效学).
- Created a series of widely reproduced images on “pen plotter” exploring cockpit design, using 3D model of human body.

“Perhaps the best way to define computer graphics is to find out what it is not. It is not a machine. It is not a computer, nor a group of computer programs. It is not the know-how of a graphic designer, a programmer, a writer, a motion picture specialist, or a reproduction specialist.

Computer graphics is all these – a consciously managed and documented technology directed toward **communicating information** accurately and descriptively.”

Computer Graphics, by William A. Fetter, 1966



What is Interactive Computer Graphics?

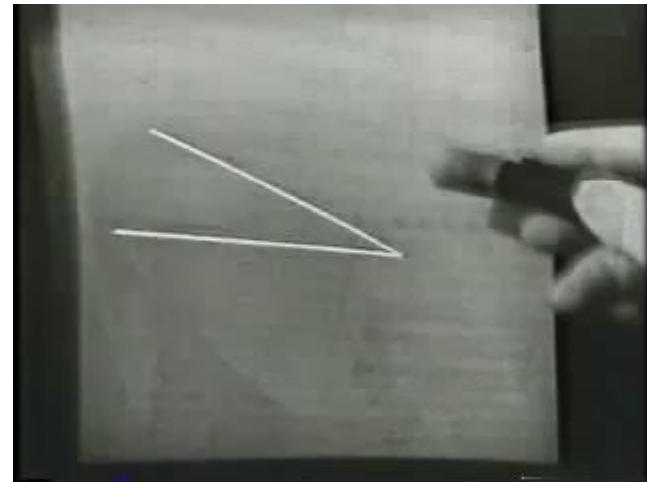
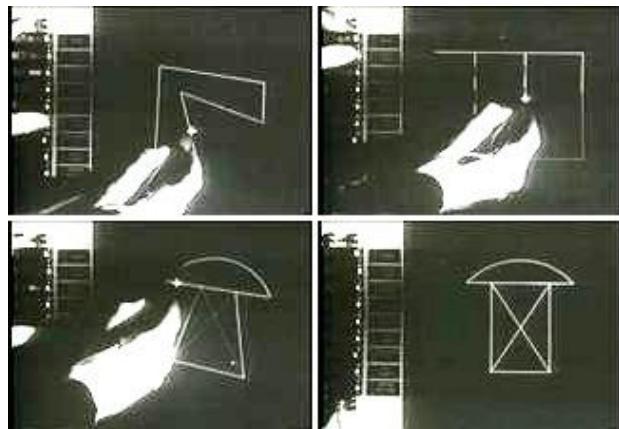
- User controls content, structure, and appearance of objects and their displayed images via rapid visual feedback
- Basic components of an interactive graphics system
 - input (e.g., mouse, stylus, multi-touch, in-air fingers...)
 - processing (and storage of the underlying representation/model)
 - display/output (e.g., screen, paper-based printer, video recorder...)
- First truly interactive graphics system,
Sketchpad, pioneered by Ivan Sutherland (伊凡·苏泽兰) 1963 Ph.D. thesis
Sketchpad, A Man-Machine Graphical Communication System
- Used TX-2 transistorized “mainframe” at MIT Lincoln Lab



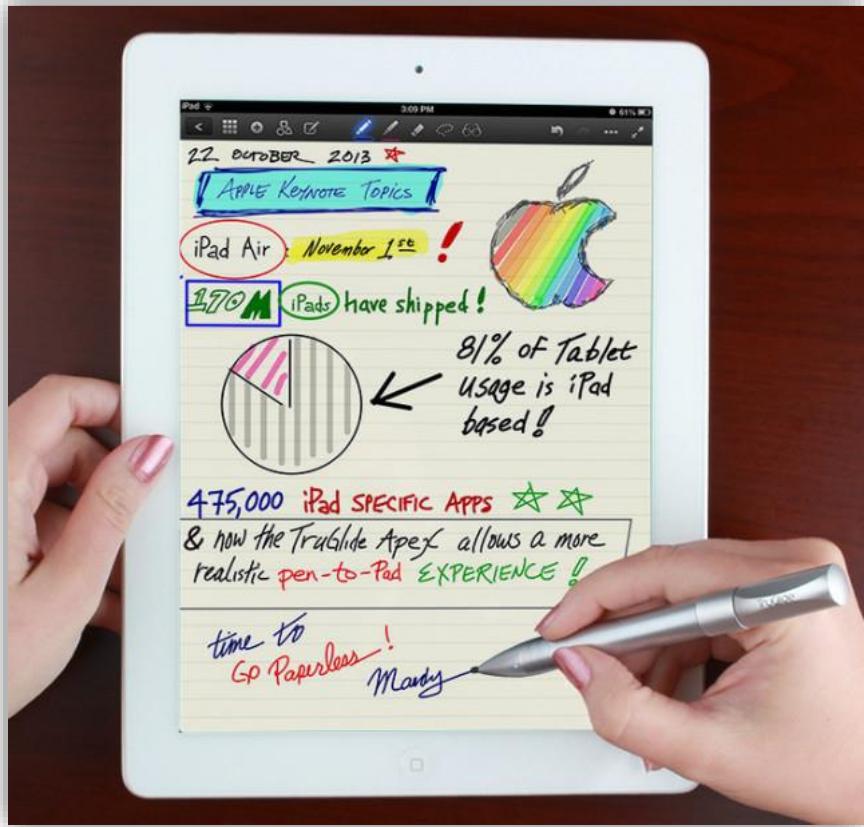
What is Interactive Computer Graphics?

- Almost all key elements of interactive graphics system are expressed in first paragraph of Sutherland's 1963 Ph.D. thesis.

*The Sketchpad system uses drawing as a novel communication medium for a computer. The system contains **input**, **output**, and computation programs which enable it to **interpret information** drawn directly on a computer display. Sketchpad has shown the most usefulness as an aid to the understanding of processes, such as the motion of linkages, which can be described with pictures. Sketchpad also makes it **easy** to draw **highly repetitive** or **highly accurate drawings** and to **change** drawings previously drawn with it...*



What is Interactive Computer Graphics?



What is Interactive Computer Graphics?

- Autodesk 3Ds Max 2016 - Overview

The logo for Autodesk 3ds Max 2016, featuring the company name "Autodesk" in a stylized font with a registered trademark symbol, followed by "3ds Max" and "2016" in a larger, bold font.

Autodesk® 3ds Max® 2016



What is Batch Computer Graphics?

- Today, still use non-interactive batch mode for final production-quality video and film (special effects – FX). Rendering a single frame of Monsters University (a 24 fps movie) averaged 29 hours on a 24,000-core render farm!



Still from Monsters University



Render farm

What is Batch Computer Graphics?

- Exposure the cloud rendering technology in “Little Door Gods (小门神, 2016)”



The Basic Content of Computer Graphics

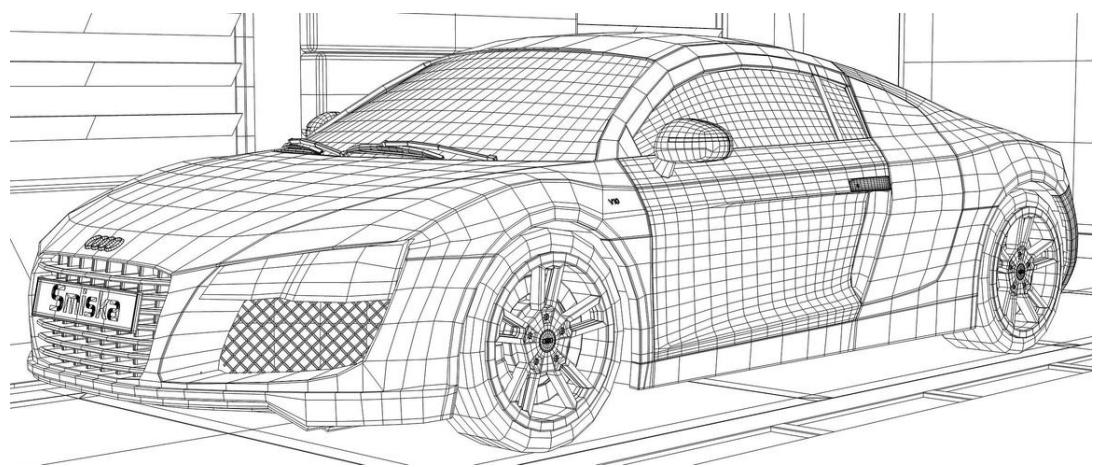
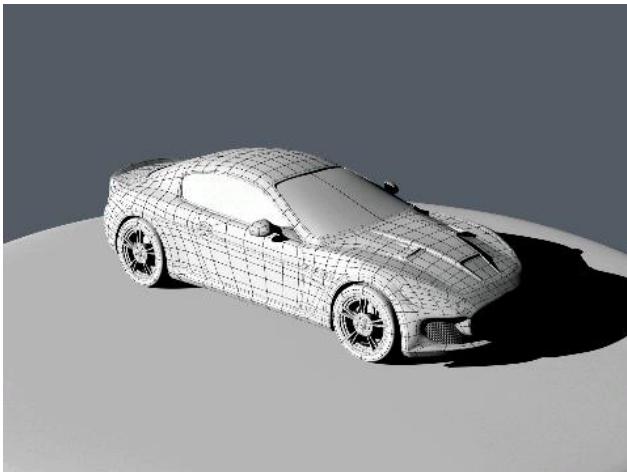
- Modeling (shape): **creating** and **representing** the **geometry** of objects in the 3D world.
- Rendering (displaying): is a term inherited from art and deals with the **creation** of **2D shaded images** from 3D computer models.
- Animation (simulating): describing how objects **change in time**.



Modeling

How do we represent objects/environments?

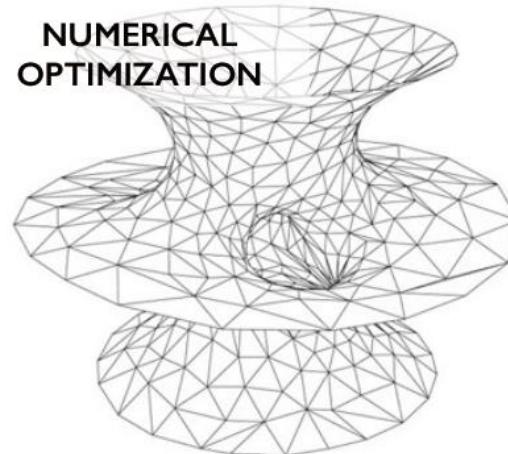
- shape — the geometry of the object
- appearance — emission, reflection, and transmission of light



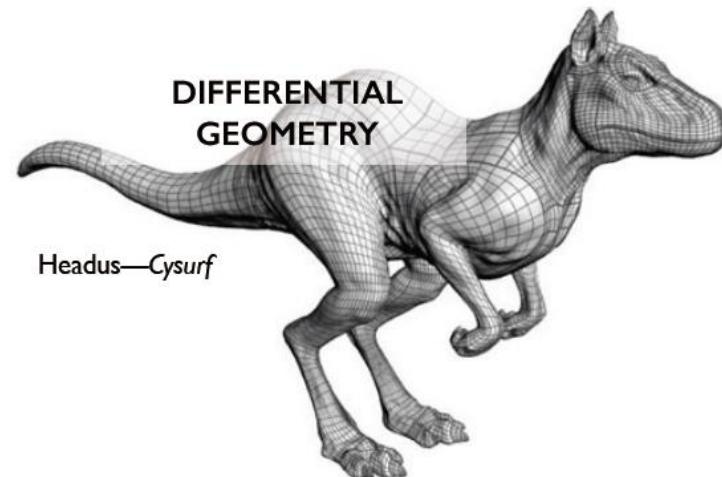
Modeling

How do we construct these models?

- manual description (e.g., write down a formula)
- interactive manipulation
- procedurally — write a generating program (e.g., fractals)
- scan a real object (laser scanners, computer vision, ...)

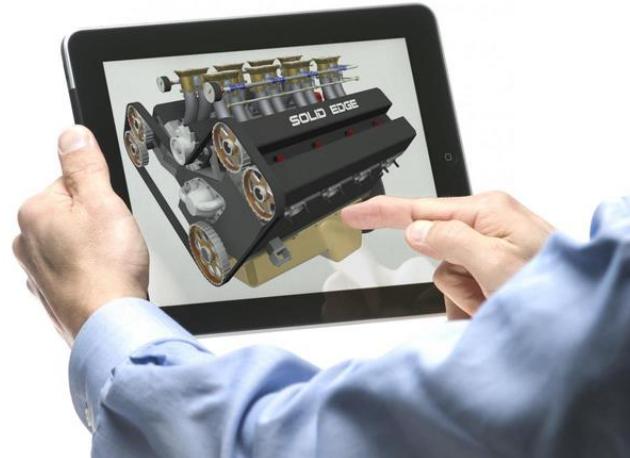
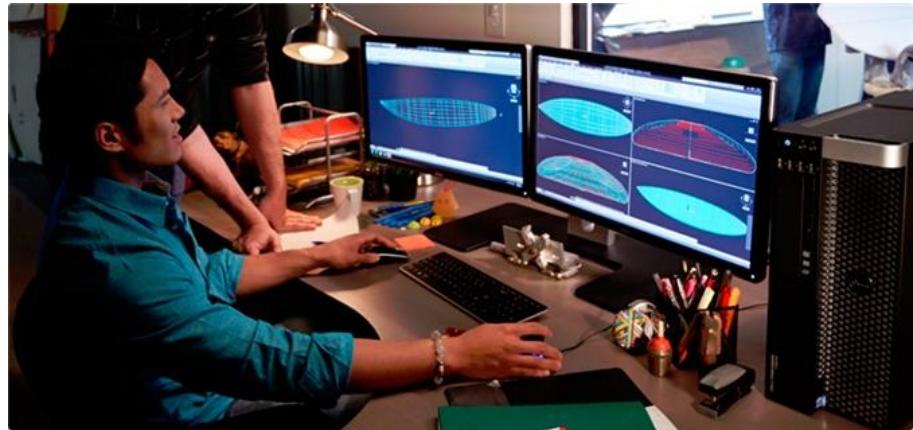


[Hoppe et al. 1993]



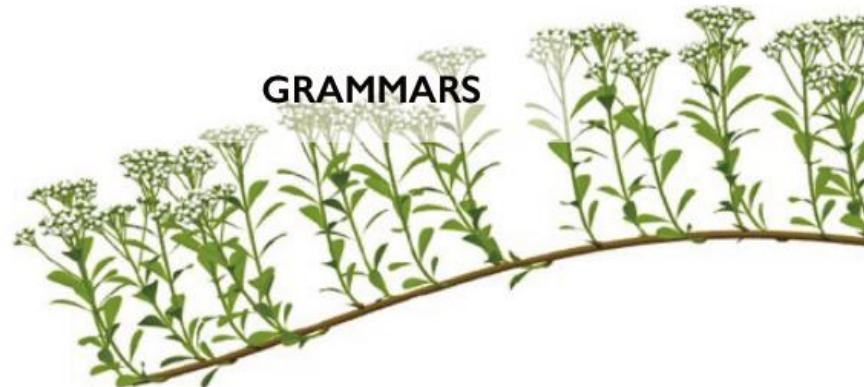
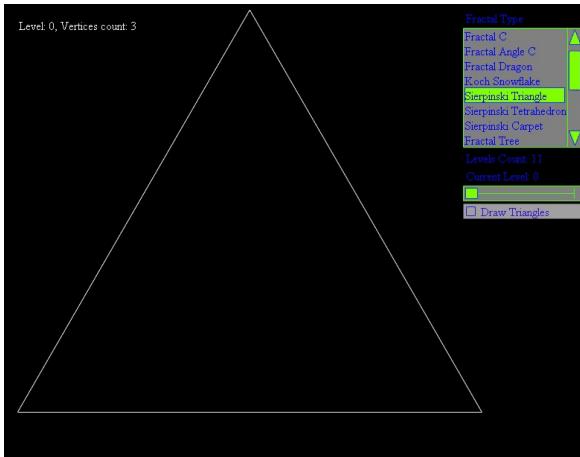
Modeling

- Interactive manipulation



Modeling

- Procedurally generation

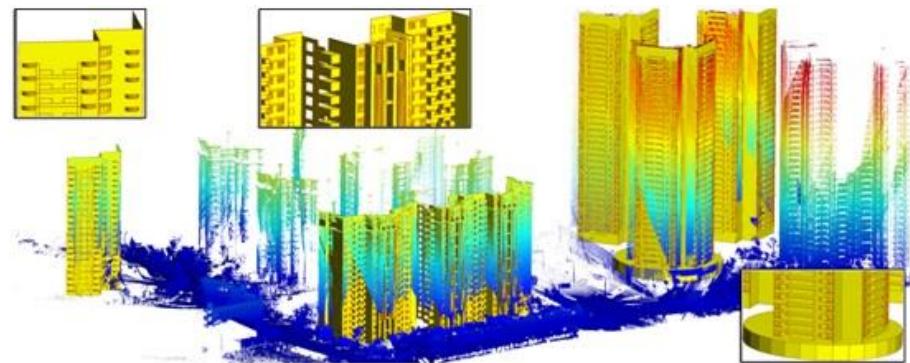


[Prusinkiewicz et al. 2001]



Modeling

- Scan a real object



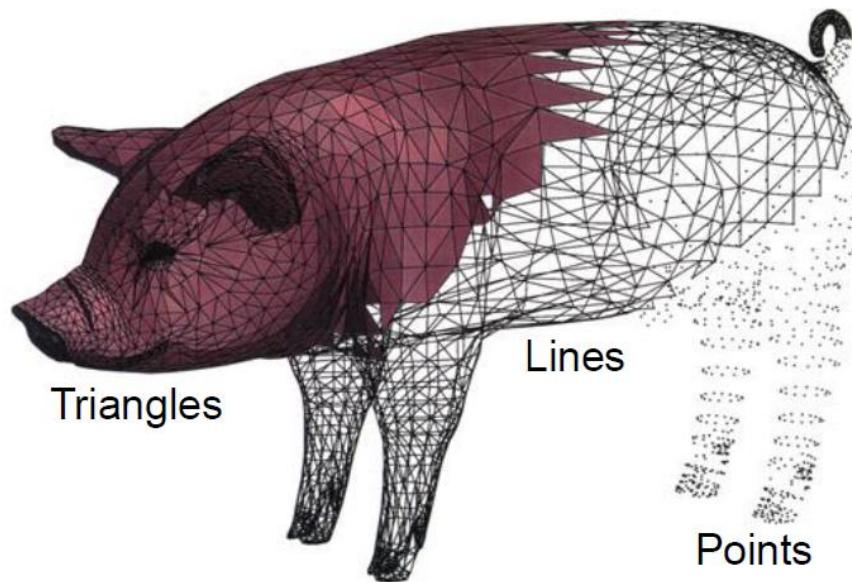
Modeling

- Urban Reconstruction



Discrete Geometry: Points & Meshes

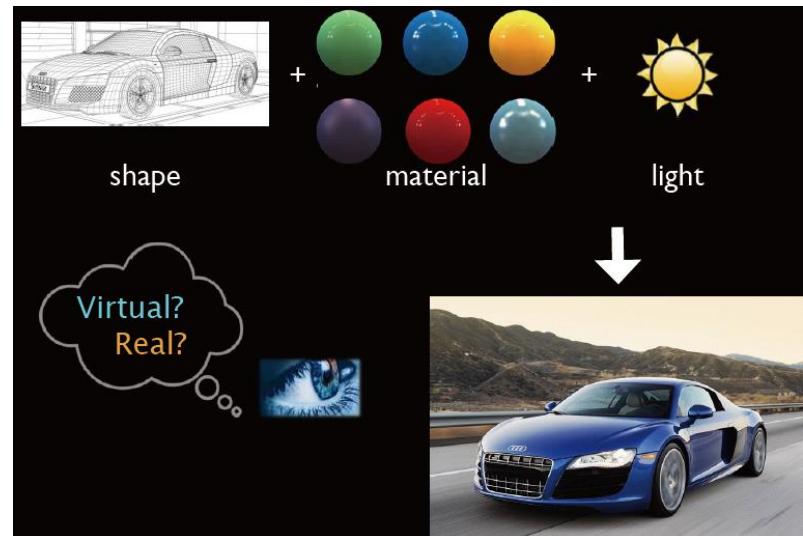
- Digitized 3D objects
 - Computerized modeling of 3D geometry
- Triangular meshes
 - Piecewise linear approximation to surfaces



Rendering

- Generation of 2D images from a 3D Models.
 - I/O of Computer Graphics
 - Input : graphics : object (shape, material,...)
 - Output : image : array of pixels (RGB)

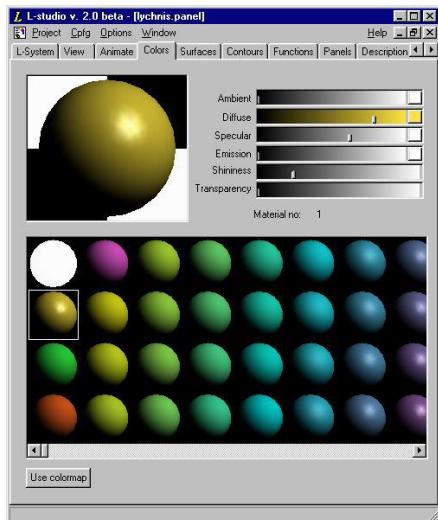
3D object → Image
Display or Rendering



Rendering

- Different objectives
 - Photorealistic
 - Interactive
 - Artistic

Materials



Dark



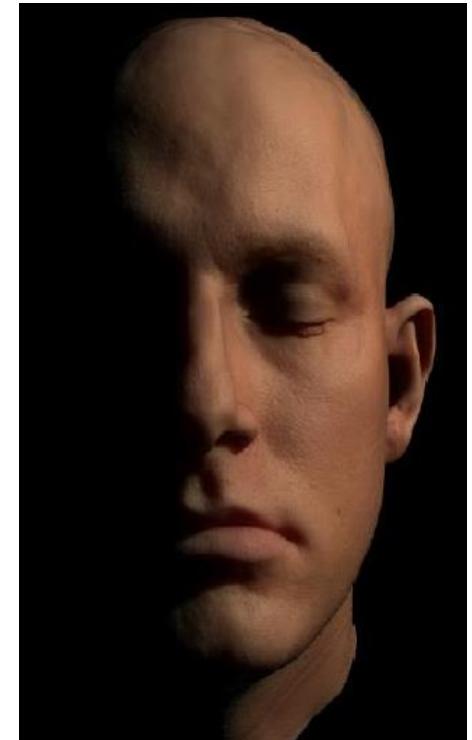
Lights



Bright

Photorealistic rendering

- Photorealistic rendering
 - Physically-based simulation of light, camera
 - Shadows, realistic illumination, multiple light bounces
 - Special effects, movies



Photorealistic rendering

- GODZILLA - Visual Effects Breakdown



Godzilla
VFX Breakdown



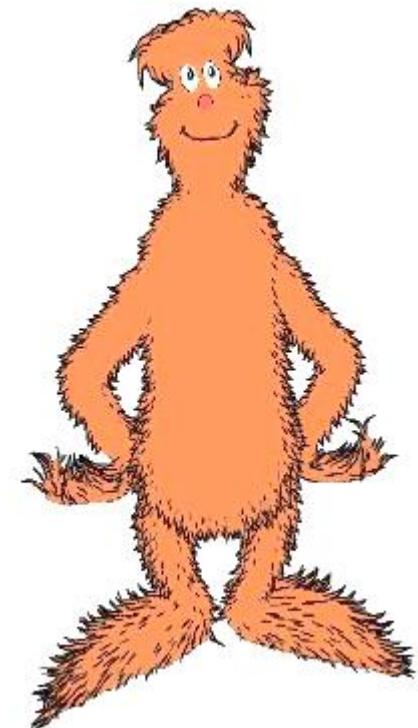
Interactive rendering

- Produce images within milliseconds
- Using specialized hardware, graphics processing units (GPUs)
- Standardized APIs (OpenGL, DirectX)
- Often “as photorealistic as possible”
- Hard shadows, fake soft shadows, only single bounce of light
- Games

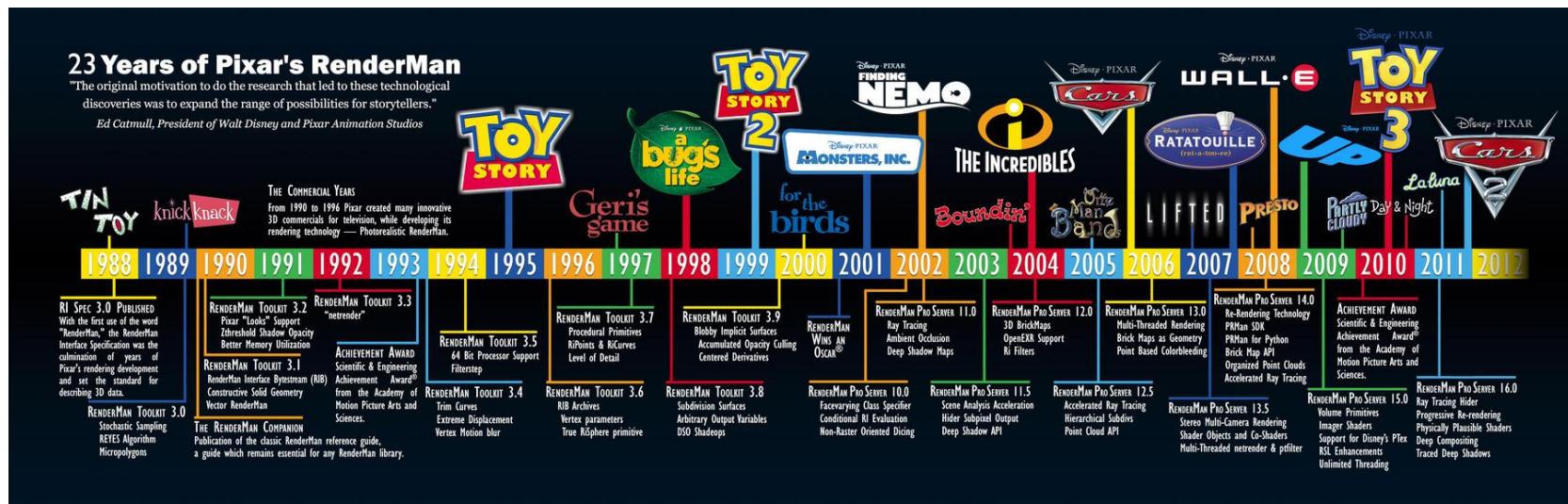


Non-Photorealistic (Artistic) Rendering

- Stylized
- Artwork, illustrations



Pixar's RenderMan



Pixar's RenderMan



Animation

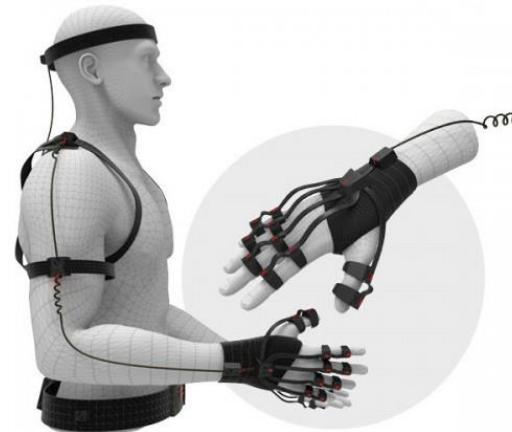
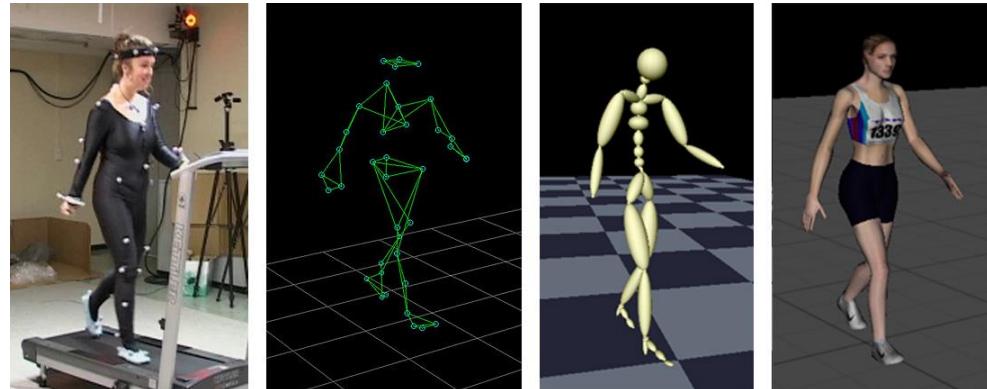
- Making geometric models move and deform

How do we represent the motion of objects?

- positions, angles, etc. as functions of time

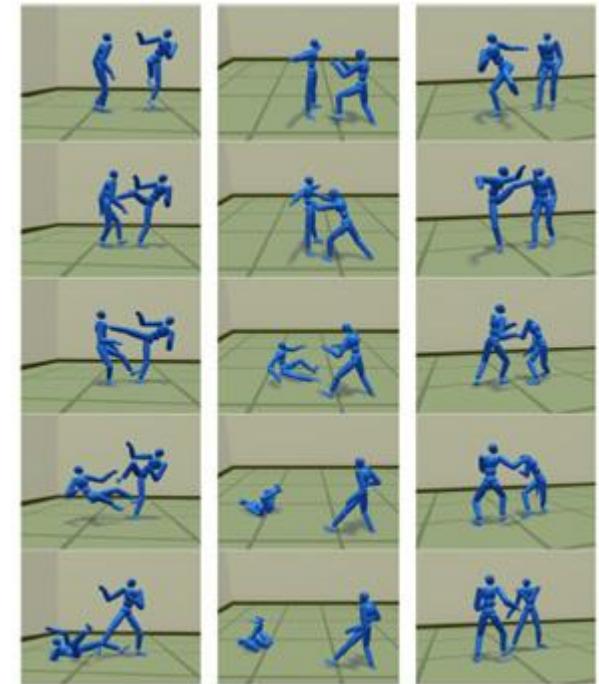
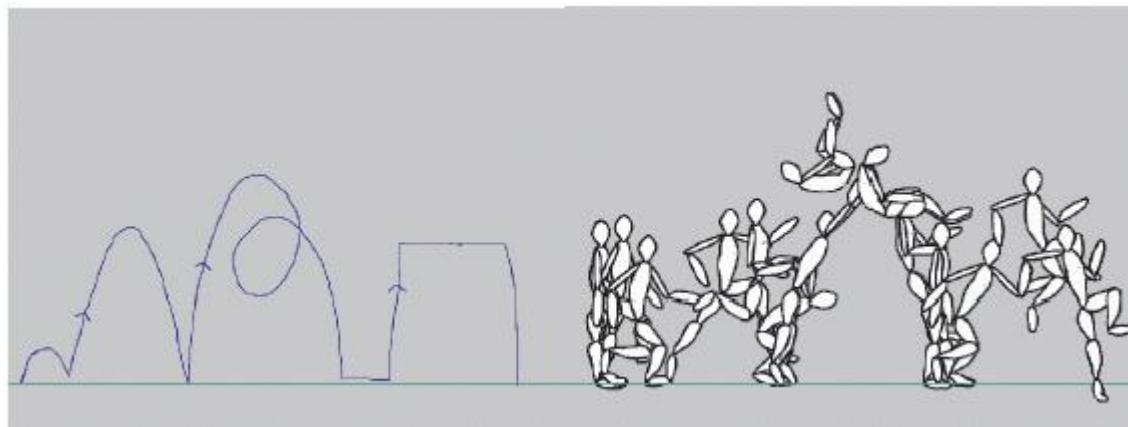
How do we control/specify this motion?

- generate poses by hand, fill in with keyframing
- behavioral simulation
(program little “brains” for objects)
- physical simulation
- motion capture



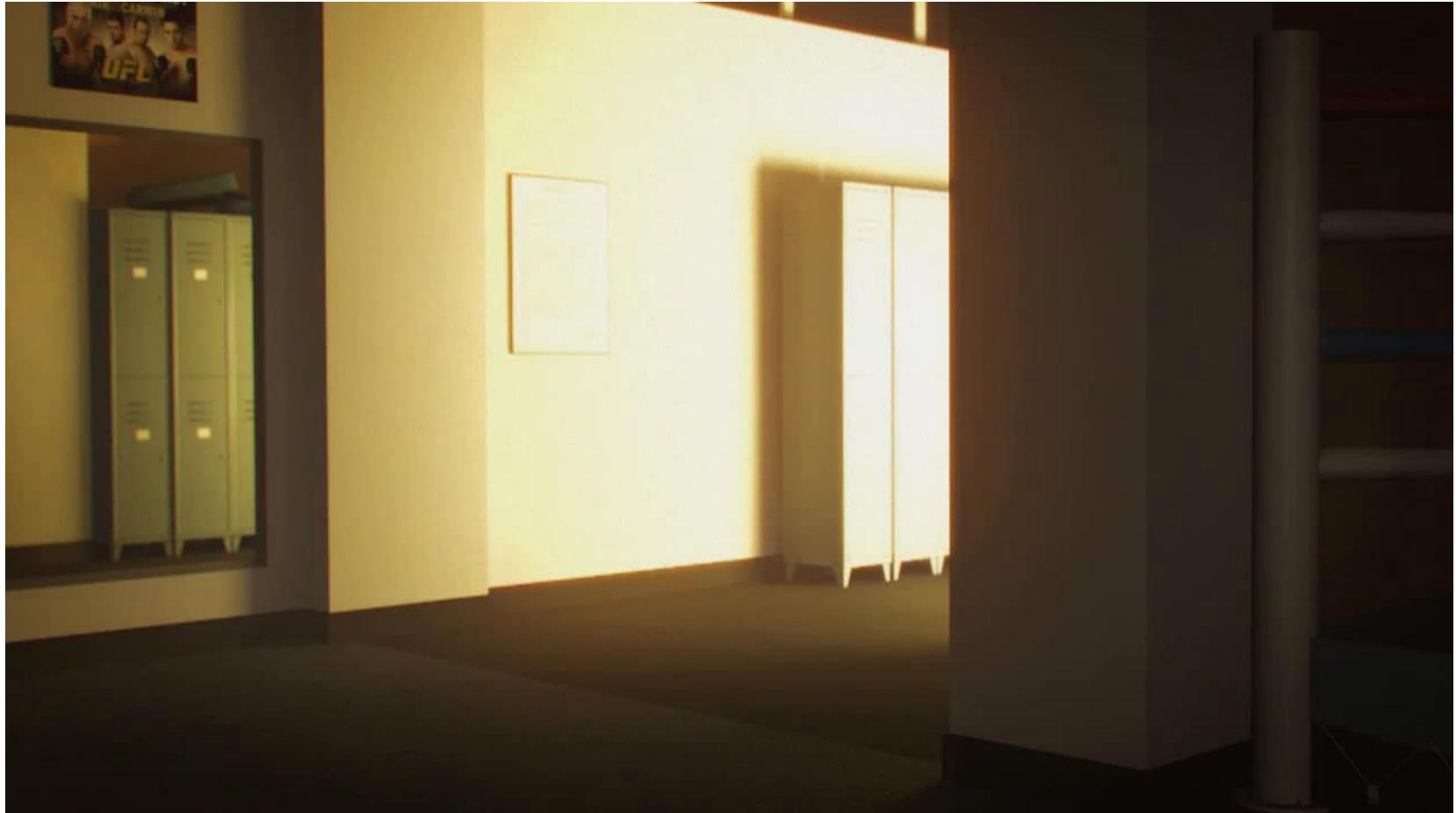
Animation

- **Generating motion**
 - interpolating between frames, states



Animation

- A Warrior's Dream – from SIGGRAPH Asia 2014

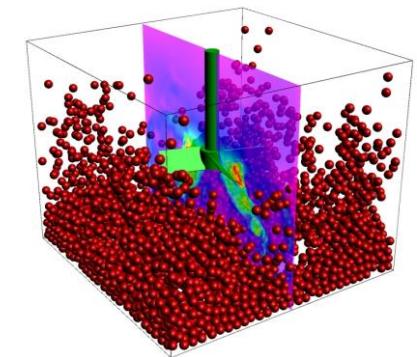
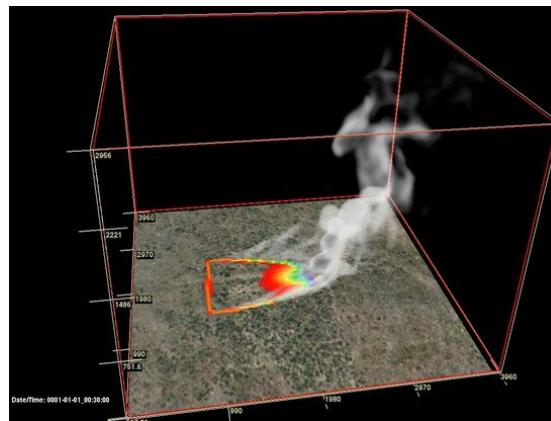
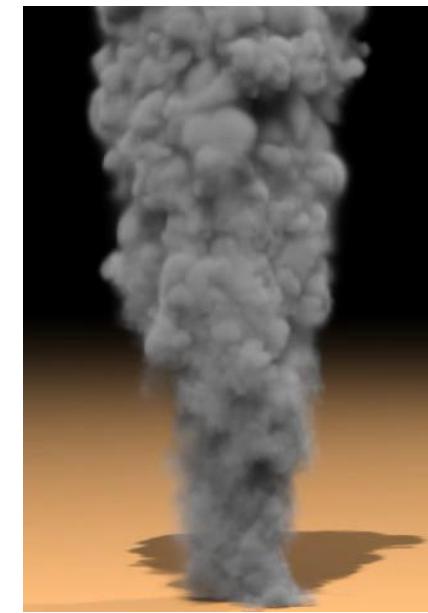
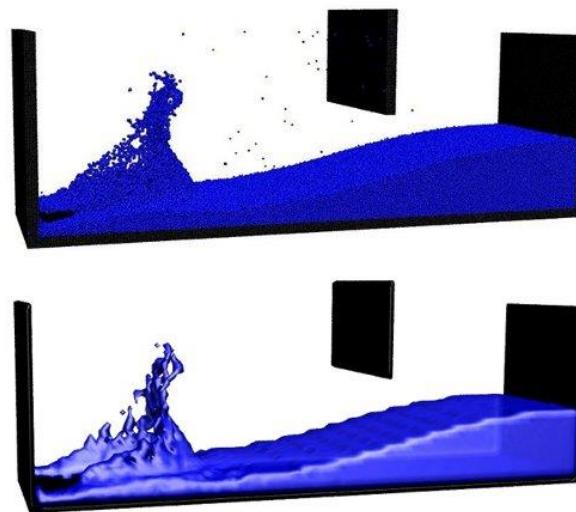


Animation

- Deforming or editing the geometry
- Change over time
- Faces, articulate characters,



Physics simulation



Physics simulation

- Iron Man 3



Summary

- 简单地说，计算机图形学的主要研究内容就是研究如何在计算机中表示图形、以及利用计算机进行图形的计算、处理和显示的相关原理与算法。
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Acknowledgement

- USTC Computer Graphics (Spring 2018), Prof. Ligang Liu
 - http://staff.ustc.edu.cn/~lgliu/Courses/ComputerGraphics_2018_spring-summer/default.htm
- ZJU CAD Computer Graphics 2017, Dr. Hongxin Zhang
 - <http://www.cad.zju.edu.cn/home/zhx/CG/2017/doku.php>
- XMU Digital Geometry Processing, Dr. Zhonggui Chen
 - <http://graphics.xmu.edu.cn/courses/dgp/index.html>
- Tsinghua Computer Graphics, Prof. Shimin Hu
 - <http://cg.cs.tsinghua.edu.cn/course/>

