Computer Graphics

Introduction 2

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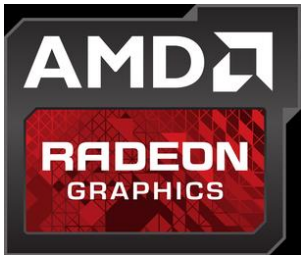
School of Data and Computer Science

Enabling Modern Computer Graphics

- Hardware revolution
  - **Moore's Law:** every 12-18 months, computer power improves by factor of 2 in price / performance as size shrinks
  - Newest CPUs are 64-bit with 2, 4, 6, 8, even up to 18 cores
  - Intel Skylake – consumer processor with 4 cores, 8 threads, and a fully featured graphics chip built in to the processor
  - Significant advances in commodity graphics chips every 6 months vs. several years for general purpose CPUs
    - NVIDIA GeForce GTX Titan X… 3072 cores, 12GB memory, and 7 teraflops of processing power in a single chip

Enabling Modern Computer Graphics

- Graphic subsystems
  - Offloads graphics processing from CPU to chip designed for doing graphics operations quickly
  - NVidia GeForce™, AMD Radeon™, and Intel HD and Iris Pro Graphics
  - GPUs originally designed to handle special-purpose graphics computations
  - Increasingly, GPUs used to parallelize other types of computation (known as **GPGPU**, or General-Purpose Computing on the Graphics Processing Unit)



Enabling Modern Computer Graphics

- High-end PCs with hot graphics cards (nVidia GeForce™, AMD Radeon™) have supplanted graphics workstations
- Such PCs are clustered together over high speed buses or LANs to provide “scalable graphics” to drive tiled PowerWalls, Caves, etc.
- Also build GPU-clusters as number crunchers, e.g., protein folding, weather prediction
- Now accessible to consumers via technologies like NVIDIA’s SLI (Scalable Link Interface) bridge

You can put multiple GPUs together in your computer using SLI.

Enabling Modern Computer Graphics

- Input Devices
  - Mouse, tablet & stylus, multi-touch, force feedback, and other game controllers (e.g., Wii), scanner, digital camera (images, computer vision), etc.
  - Body as interaction device (e.g. Kinect)

Xbox Kinect


Leap Motion


Nimble UX

Enabling Modern Computer Graphics

- Many form factors
  - Smartphones/laptops/desktops/tablets
  - Smart watches
  - Head-mounted displays (HMDs)
  - 3D immersive virtual reality spaces

Apple iPhone

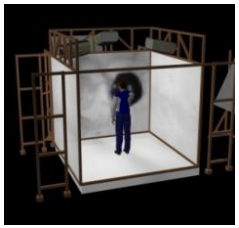
Android Phones

Tablets

Microsoft's first Surface

Apple Watch

Android Wear



Brown's old Cave

Microsoft Hololens

Oculus Rift

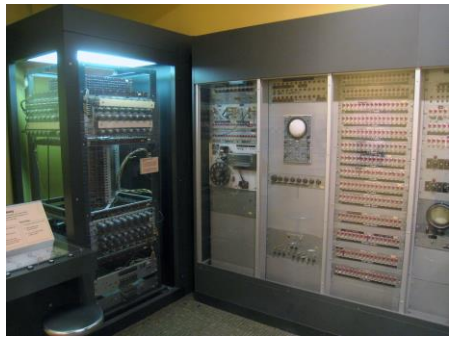
Google Cardboard

Enabling Modern Computer Graphics

- Software Improvements
  - Algorithms and data structures
    - Modeling of materials
    - Rendering of natural phenomena
    - “Acceleration data structures” for ray tracing and other renderers
  - Parallelization
    - Most operations are embarrassingly parallel: changing value of one pixel is often independent of other pixels
  - Distributed and Cloud computing
    - Send operations into ‘cloud’, get back results, don’t care how
    - Rendering even available as internet service!

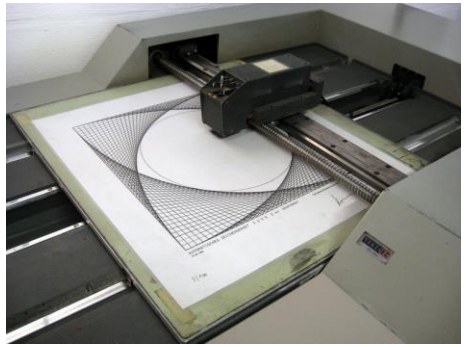
History of computer graphics

- The 1950's
  - In 1950, the first visual display unit is designed for MIT's Whirlwind I Computer（旋风一号）



  - In 1958, CalComp developed 565 drum plotter (滚筒绘图仪)

  - In 1958, Gerber Company developed the first flat plotter (平板绘图仪)



History of computer graphics

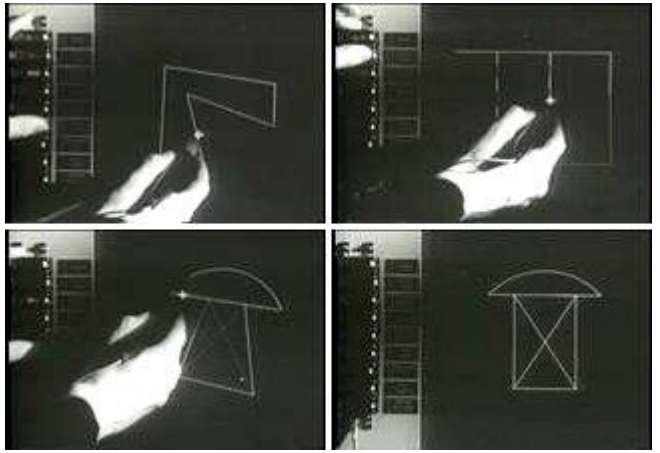
- The 1950’s
  - In the late of 1950’s, The whirlwind team became assimilated into the creation of SAGE air defense system (semiautomatic ground environment)
  - Emerge of interactive computer graphics

History of computer graphics

- The 1960’s
  - Spacewar (stylized "Spacewar! 星际飞行") is one of the earliest digital computer video games. It is a two-player game, with each player taking control of a starship and attempting to destroy the other.
  - Steve Russell, MIT for PDP-1

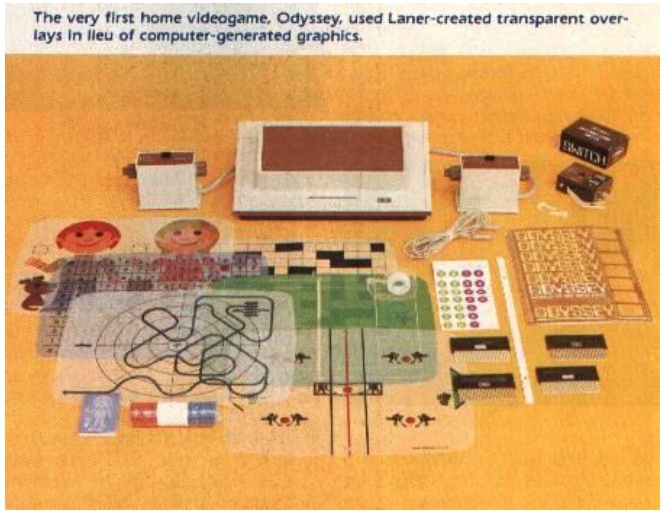
History of computer graphics

- The 1960's
  - Sketchpad (aka Robot Draftsman) was a revolutionary computer program written by Ivan Sutherland in 1963 in the course of his PhD thesis, for which he received the Turing Award in 1988.



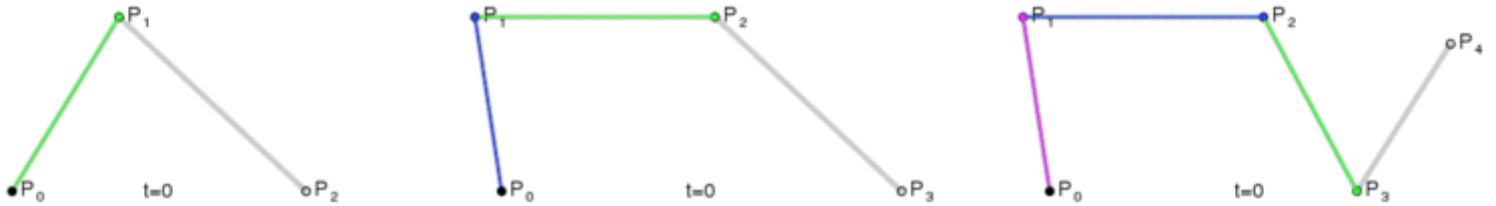
History of computer graphics

- The 1960’s
  - The Magnavox Odyssey (奥德赛) is the first commercial home video game console.
  - The Odyssey was designed by Ralph H. Baer, assisted by engineers William Harrison and William Rusch. They began around 1966 and had a working prototype finished by 1968.



History of computer graphics

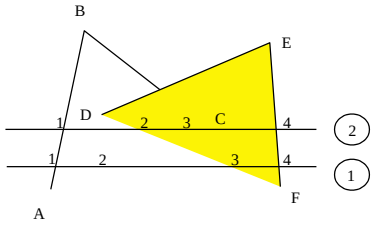
- The 1960's(CAD)
  - Professor Coons, the concept of "CAD" (Computer Aided Design) in 1958, Coons surface in 1964
  - In the late 1960's, a French engineer Pierre Bezier creates Bezier curves and Bezier surfaces that are now used in most CAD and computer graphics systems
  - UNISUR system for Car design in Renault
  - ACM Coons' award in 1985
  - Bezier and de Casteljau
  - Bezier and Forrest



Quadratic Cubic Quartic

Bezier Curve

History of computer graphics

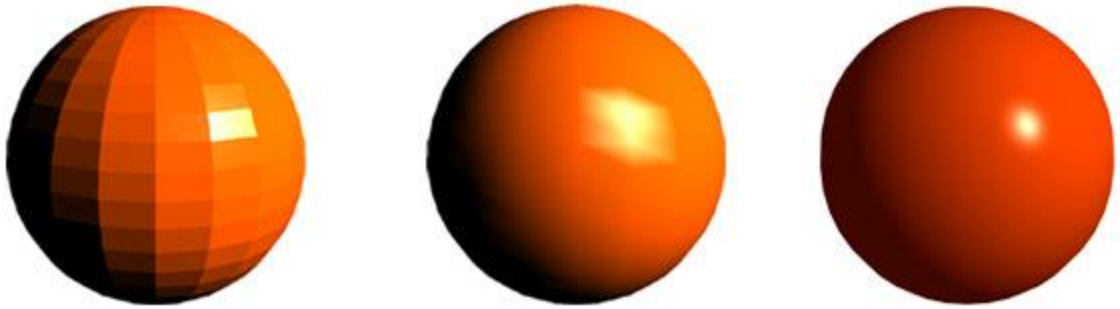


- The 1970's
- Fast development of Rasterizing Graphics
  - The concept of scan conversion(扫描转化), clipping (裁减) and surface hidden removal (消隐) and the corresponding algorithms.
- Standardization
  - In 1974, ACM SIGGRAPH formed the Graphics Standard Committee.
    - Core Graphics System (核心图形系统).
  - ISO published CGI (Computer Graphics Interface), CGM, (Computer Graphics Metafile), GKS(Graphics Kernel system), PHIGS (Programmer's Hierarchical Interactive Graphics Standard).

ACMSIGGRAPH

History of computer graphics

- The 1970's (Rendering)
  - In 1970, Bouknight proposed the first lighting reflection model (**flat shading**)
  - In 1971, Gourand proposed "diffuse reflection + interpolation ", which is called as **Gourand shading**
  - In 1975, Phong proposed a local lighting model – **Phong shading**. (one of the most important and influential lighting model).

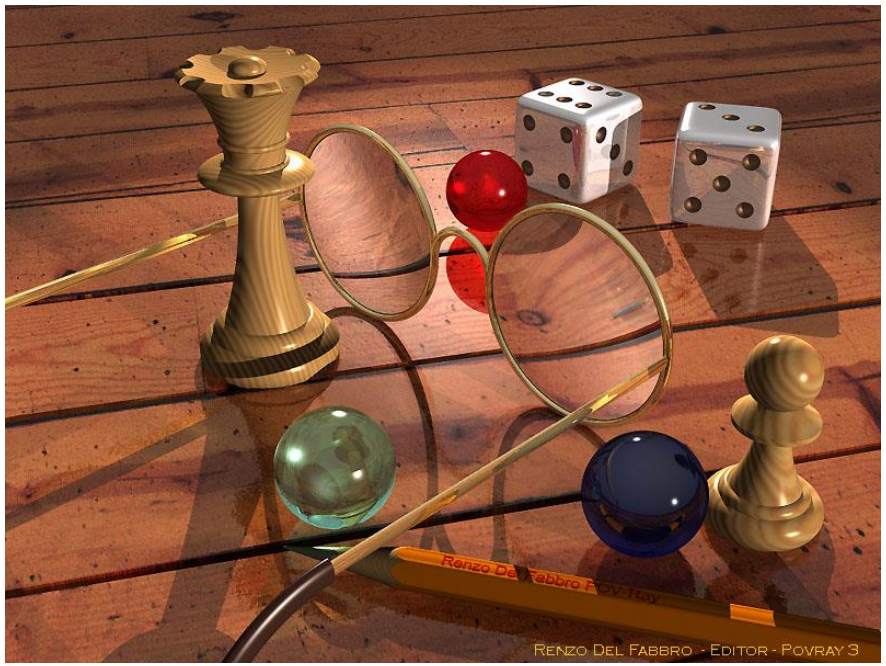


Flat shading Gourand shading Phong shading

History of computer graphics

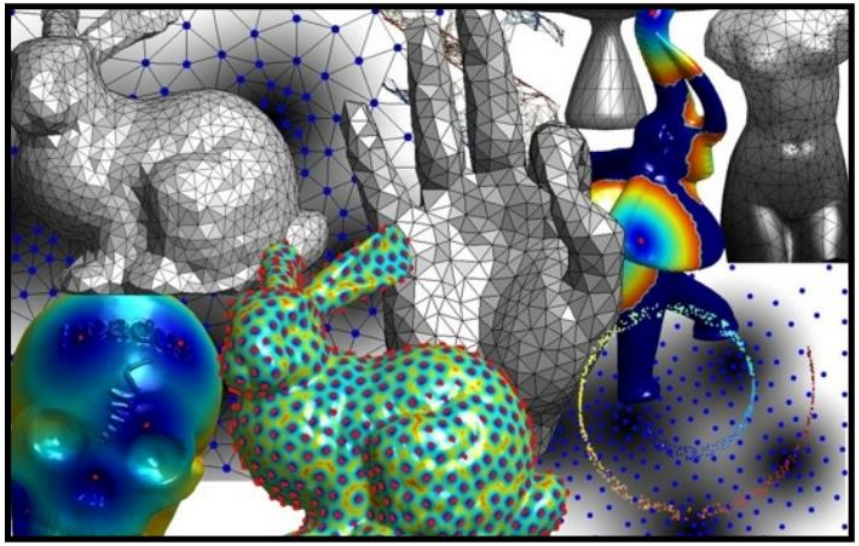
- The 1980's (Ray tracing 光线跟踪 and Radiosity 辐射度方法)
  - In 1980, Whitted proposed a ray tracing model, include light reflection (反射) and transmission (透射) effects.
  - A Milestone of CG.
  - Graphics Hardware

Graphics workstations such as these have been replaced with commodity hardware (CPU + GPU), e.g., MaxBuilts + Nvidia cards



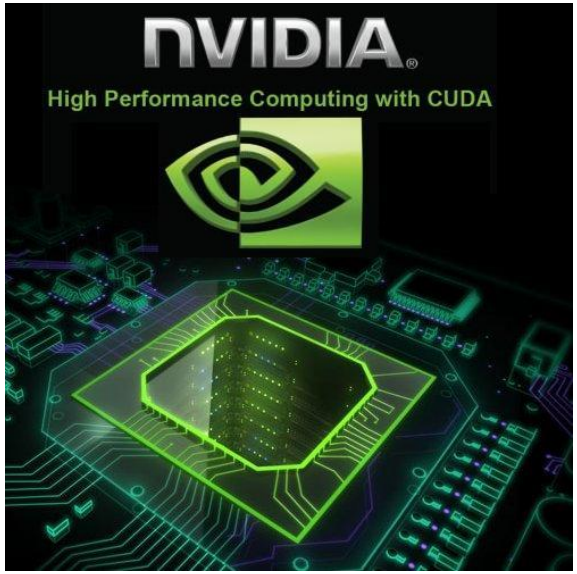
History of computer graphics

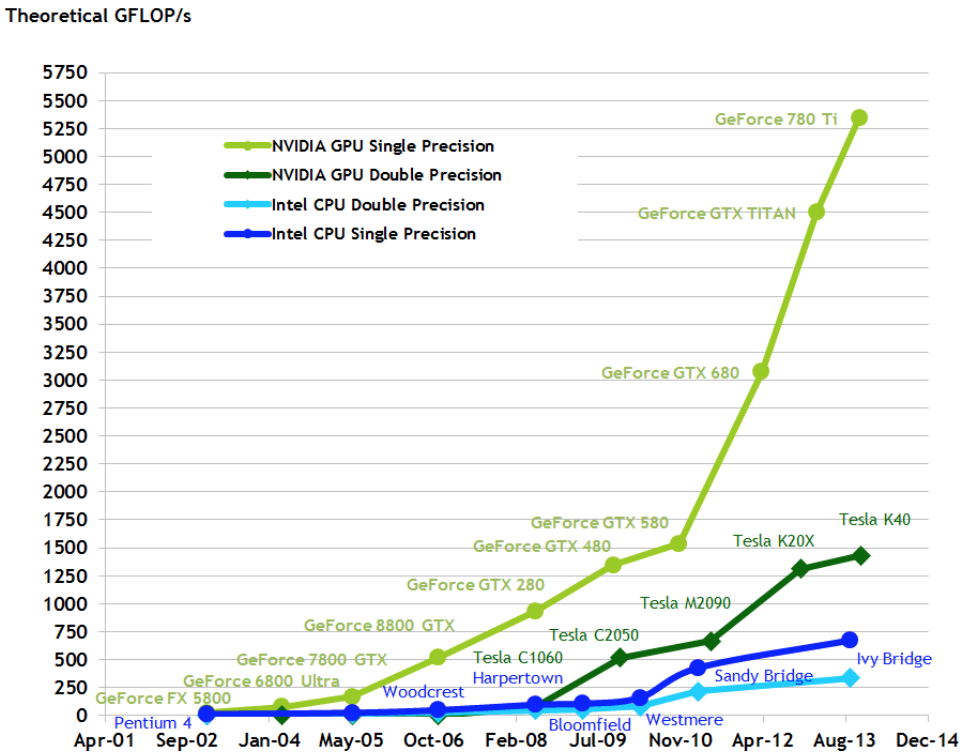
- The 1990's…
- Geometric Modeling:
  - Meshes,
  - Subdivision,
  - Implicit Surface,
  - Procedural,
  - Multi-resolution
- Rendering:
  - Volume Rendering,
  - Image-Based rendering,
  - Point-Based Rendering
- …



History of computer graphics

- The 2000's…
  - 3D Scan Technology
  - Graphics Hardware
  - GPU Parallel Computing



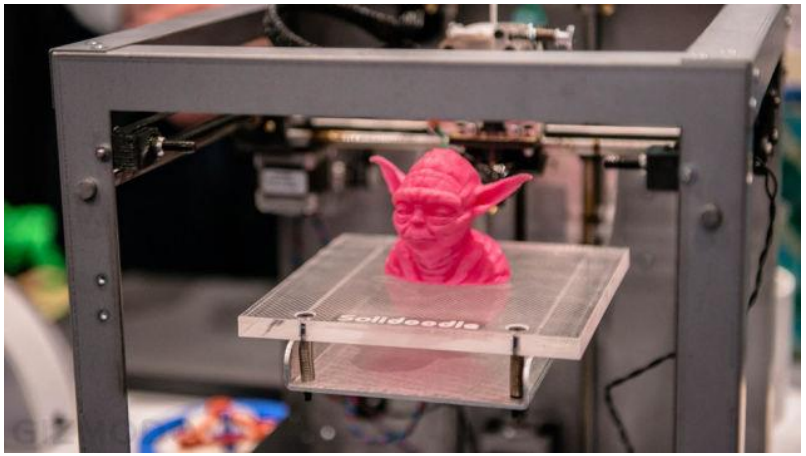


New trends

- Microsoft Kinects

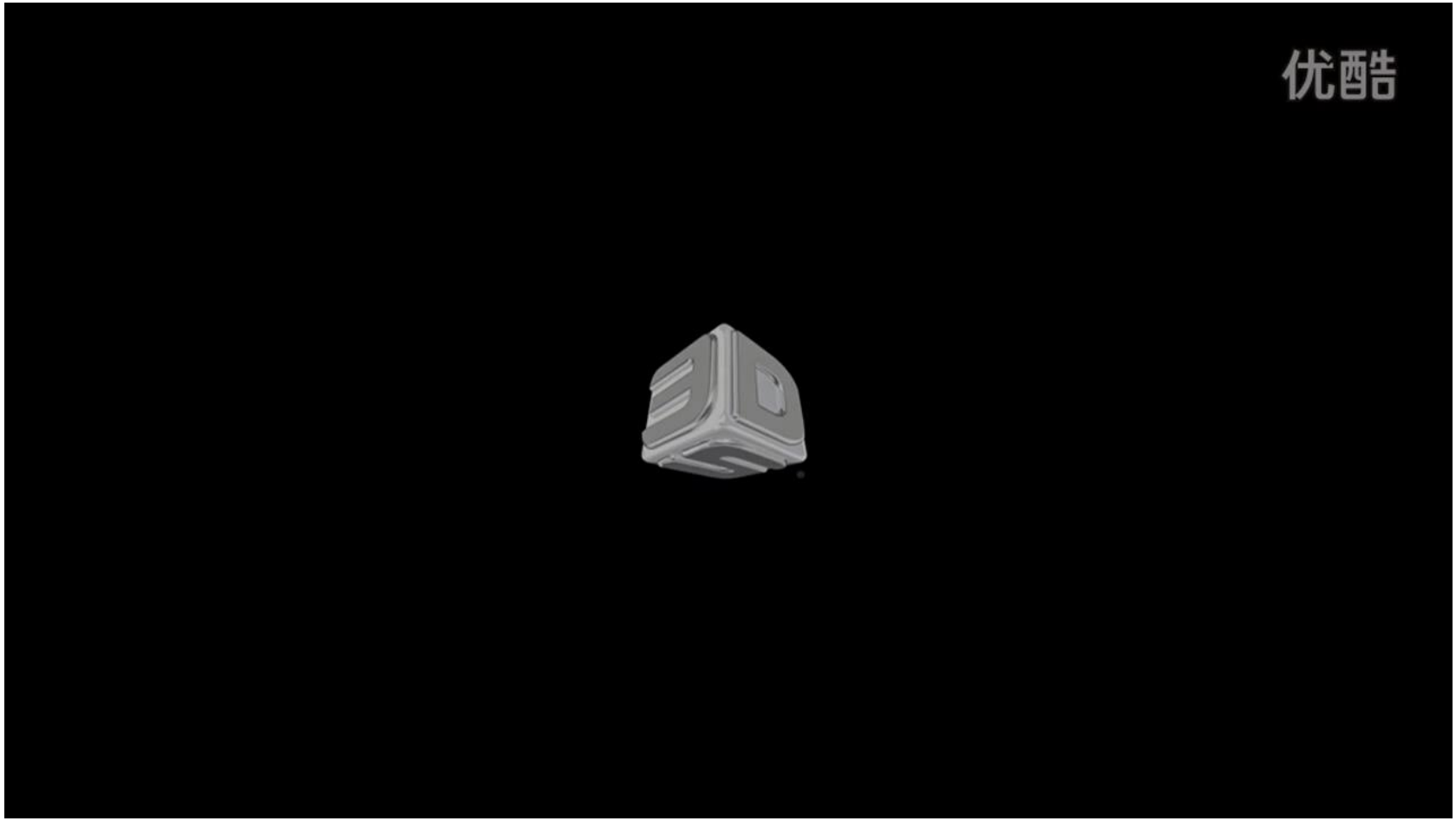
New trends

- 3D Printing



New trends

- 3D Printing



New trends

- Leap Motion

New trends

- Virtual Reality - Cyberith Virtualizer

What is CG used for?

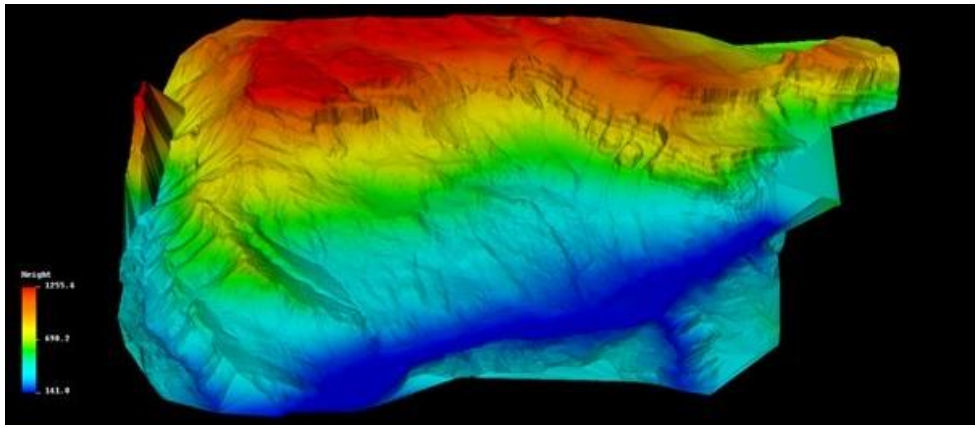
- Movies
  - animation
  - special effects

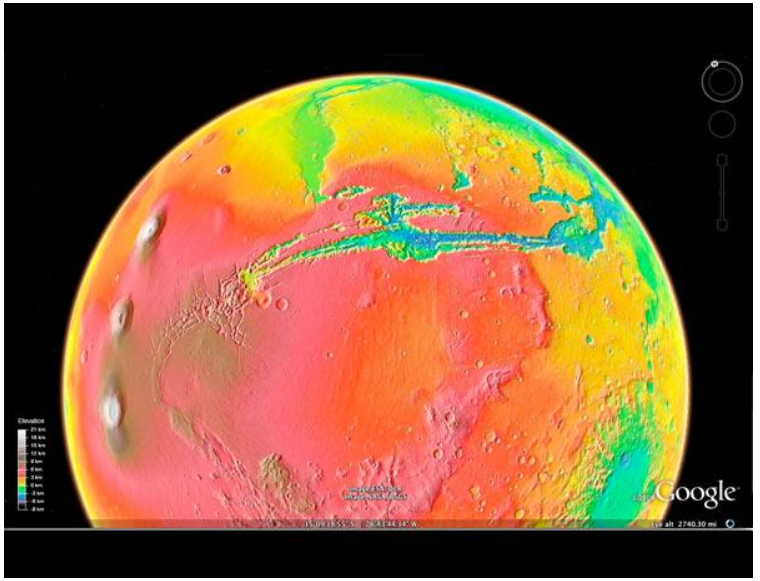
What is CG used for?

- Movies
  - performance capture

What is CG used for?

- Geography
  - Geometric Registration Technique / Digital Earth & Digital City





What is CG used for?

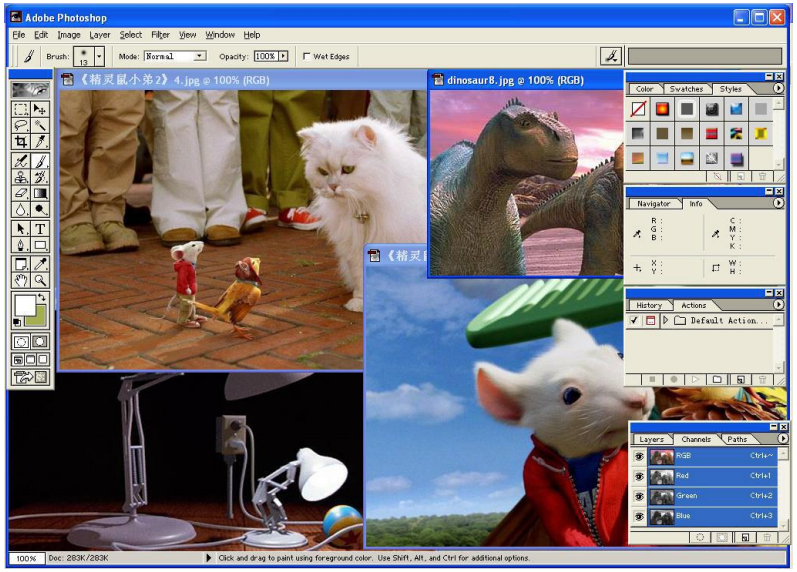
- Computer games

What is CG used for?

- images
  - advertising
  - design
  - art

What is CG used for?

- UI Design



What is CG used for?

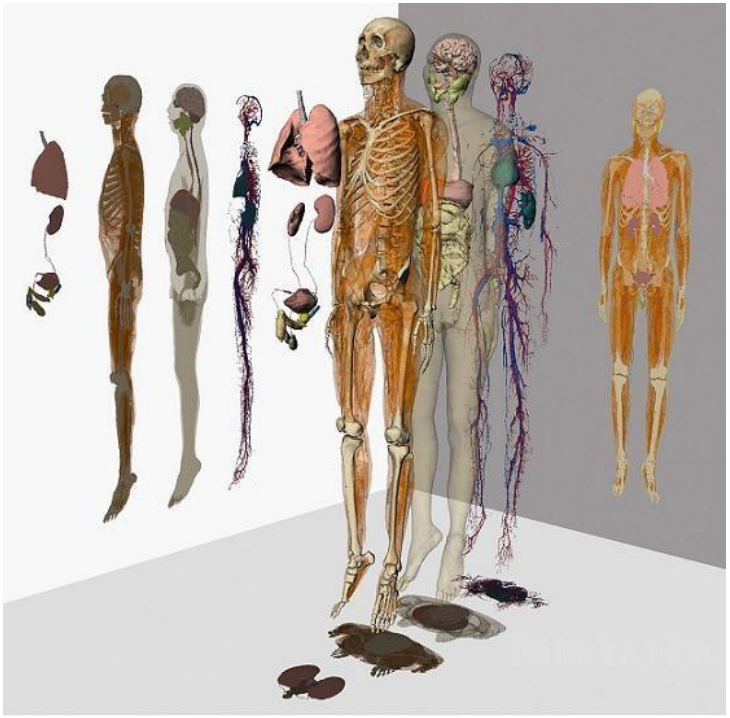
- Training & simulation

Army Research Lab—IES

NASA/Ames—ACFS

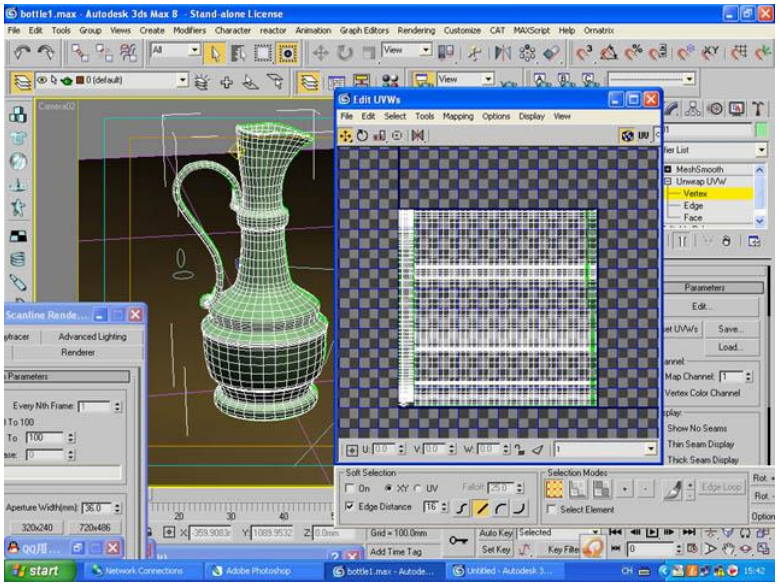
What is CG used for?

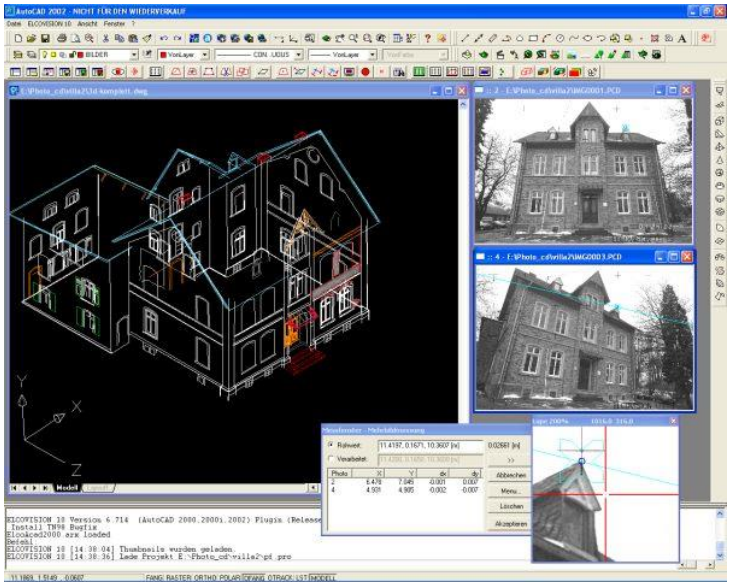
- Medical Imaging

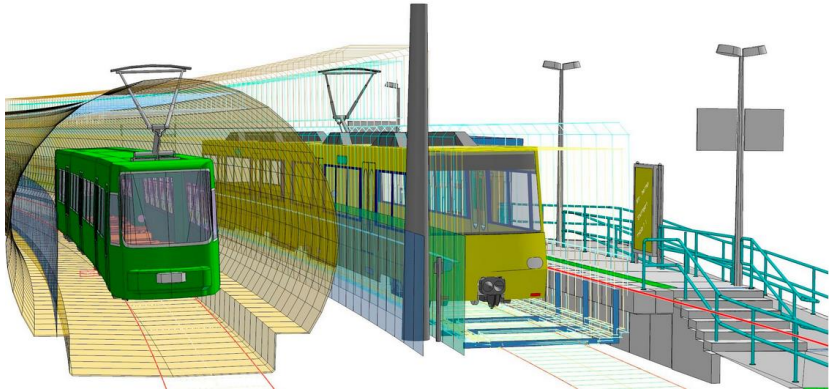


What is CG used for?

- CAD-CAM & Design







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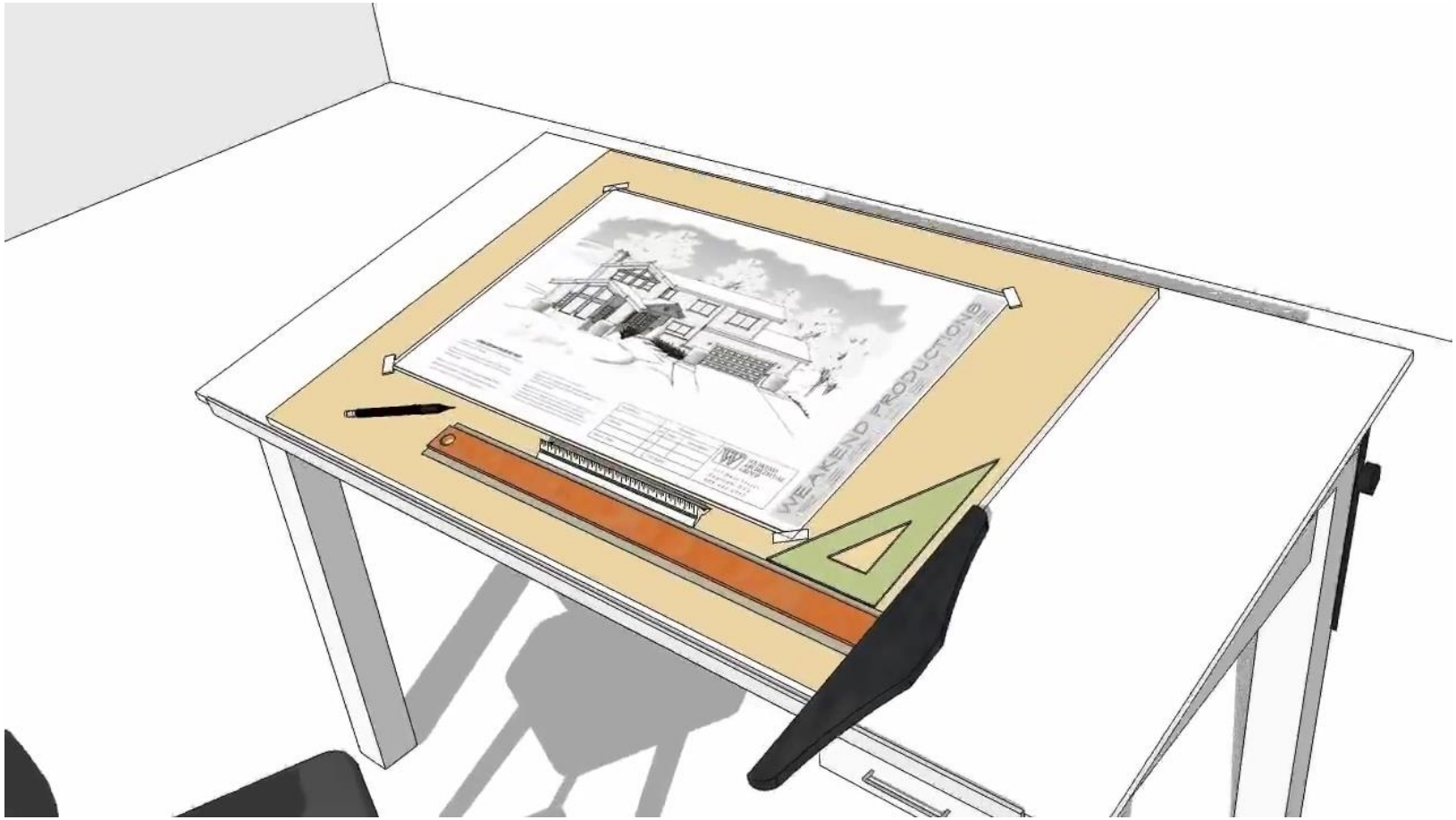


Why Study Computer Graphics?

- Wide Range of Applications
- Huge Market
  - Game
  - Movie
  - Education
- It is fun: create visually appealing results
- Fond of Science and Technology
- Opens doors to lots of job opportunities

Computer Graphics is Funny

- Interdisciplinary
  - mathematics, physics, computer, art…
- Understand the Law of Real World
  - illumination, motion
- You can ‘see’ what are your imaginary
- Virtual results may deceive your eyes
- Apply their knowledge to industry application

How to Study CG?

- Curiosity
  - Strong curiosity to unknown world
  - Desire and pursuit to technology
- Creative
  - constantly thinking and trying
- Practice
  - Master kinds of technical ability during practice

What is the class about?

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

- This is a programming class(OpenGL).
  - It is about algorithms that are created computer graphics images.
- Learning by doing!

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.

Prerequisites

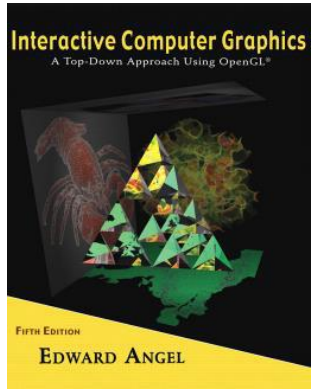
- **Good programming is very essential**
  - Good working knowledge of C++ is assumed.
  - The programming load is high.
- **Math**
  - Elementary geometry and linear algebra
  - Differential equation
  - The numerical method and calculated
  - Statistics

How much Math?

- Lots of simple linear algebra
  - Get it right, it will help you a lot!
- Some more advanced concepts
  - Homogeneous coordinates
  - Quaternions for interpolating rotations/orientations
  - Ordinary differential equations (ODEs) and their numerical solution
  - ……

Optional Textbook

- 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”

Course Assessment

- Project Assignments
  - OpenGL Programming (20%)
  - Graphics Developments (20%)
- Final Examination in 18th Week (40%)
- Homework (10%)
- Attendance (10%)

Course Mailbox

- Lecture Slides
  - **cgcourse_sysu@qq.com**
  - **Password: cgcourse2016**
- Homework submission
  - **cgcourse_homework@qq.com**

Further Reading

- **Journals (International)**

  ACM Transactions on Graphics

  IEEE Transactions on Graphics and Visualization

  Computer Graphics Forum

  Computer Aided Geometric Design

  Computer-aided Design

  The Visual Computer

  Graphical Models

  Computer & Graphics

  Computer Graphics & Applications

- **Journals (Domestic)**

  软件学报

  计算机学报

  计算机辅助设计与图形学学报

  中国图象图形学报

- **Proceedings**

  Siggraph

  Siggraph Asia

  Eurographics

  Pacific Graphics

  Symposium on Geometry Processing

  Shape Modeling International

  Chinagraph

  ….

Lots of CG papers can be found here:

http://kesen.realtimerendering.com/

ACM SIGGRAPH

- Full: “the Special Interest Group on Computer Graphics and Interactive Techniques”
  - In 1967, professor van Dam at Brown Unversity and Sam Masta of IBM Corporation co-founded SIGGRAPH
  - In 1974, the first SIGGRAPH annual conference was held in University of Colorado (科罗拉多大学)
  - http://www.siggraph.org