History & Applications of Computer Graphics

Teacher: Dr. Zhuo SU (苏卓)

E-mail: suzhuo3@mail.sysu.edu.cn

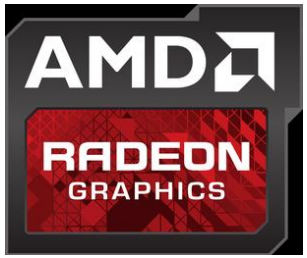
School of Data and Computer Science

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

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

Apple iPhone

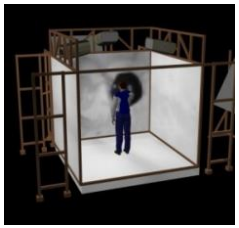
Android Phones

Tablets

Microsoft's first Surface

Apple Watch

Android Wear



Brown's old Cave

Microsoft Hololens

Oculus Rift

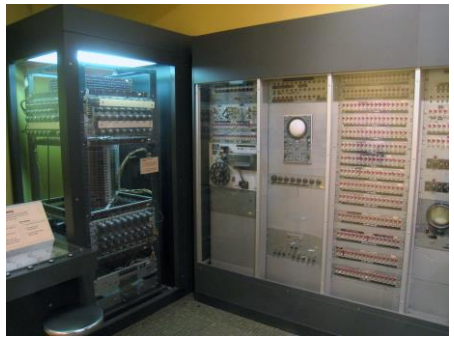
Google Cardboard

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!

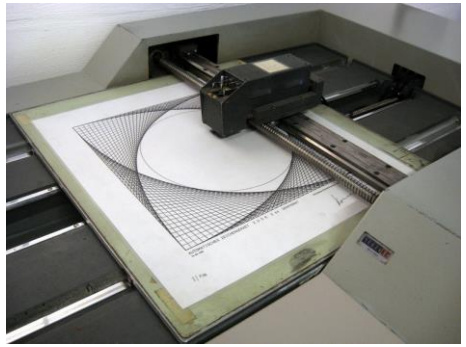
History of computer graphics

- 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

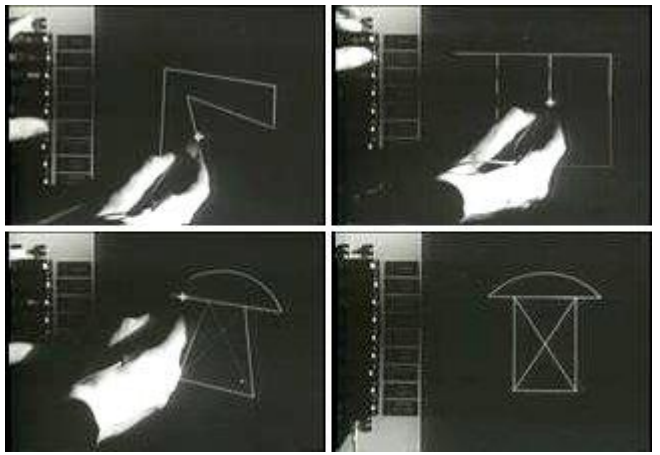
- The 1950's
  - In the late of 1950's, The whirlwind team became assimilated into the creation of SAGE air defense system (semiautomatic ground environment)
  - Emerge of interactive computer graphics

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

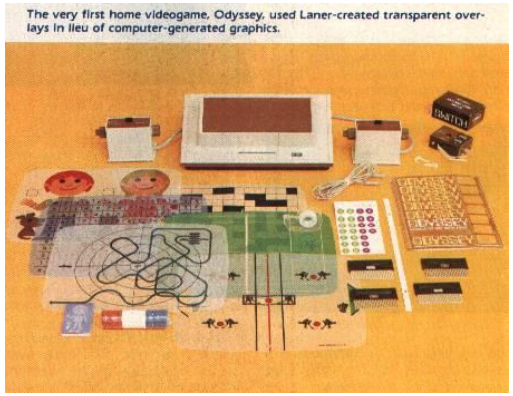
History of computer graphics

- 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.



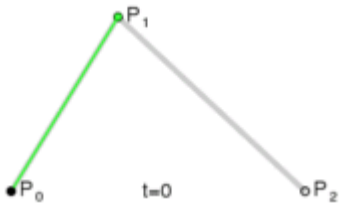
History of computer graphics

- 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.

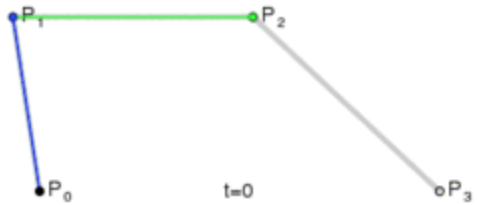


History of computer graphics

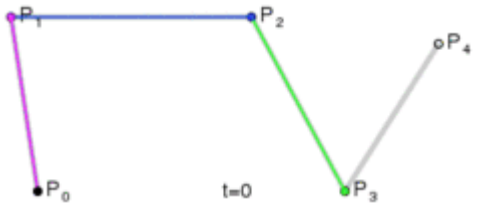
- The 1960's(CAD)
  - Professor Coons, the concept of "CAD" (Computer Aided Design) in 1958, Coons surface in 1964
  - In the late 1960's, a French engineer Pierre Bezier creates Bezier curves and Bezier surfaces that are now used in most CAD and computer graphics systems
  - UNISUR system for Car design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



Quadratic



Cubic

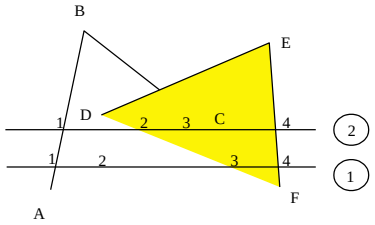


Quartic

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.

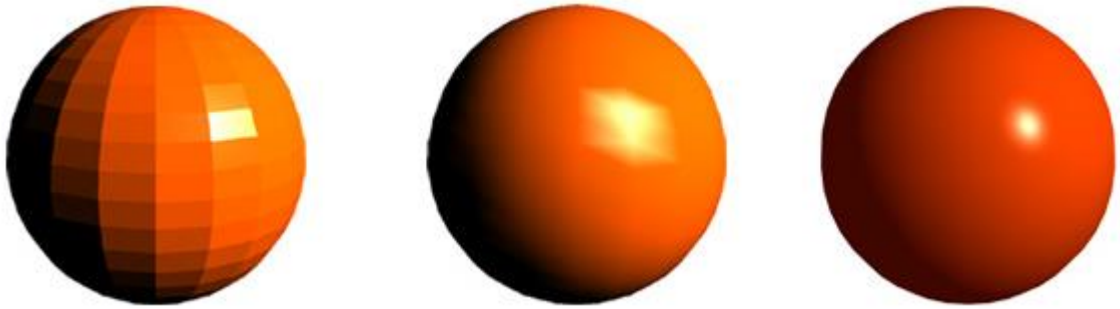


- Standardization
  - In 1974, ACM SIGGRAPH formed the Graphics Standard Committee.
    - Core Graphics System (核心图形系统).
  - ISO published CGI (Computer Graphics Interface), CGM, (Computer Graphics Metafile), GKS(Graphics Kernel system), PHIGS (Programmer's Hierarchical Interactive Graphics Standard).

ACMSIGGRAPH

History of computer graphics

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

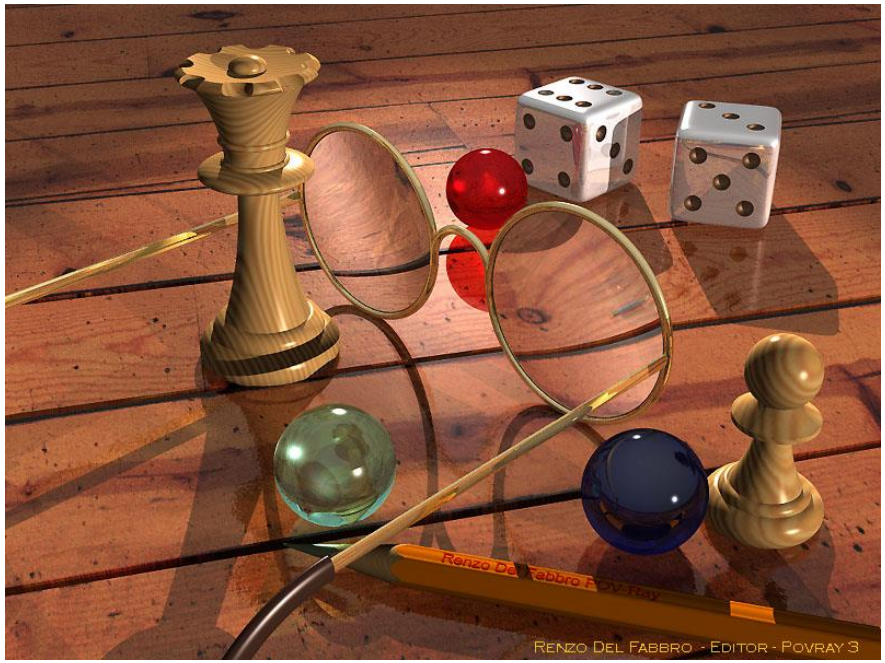


Flat shading　　Gourand shading　　Phong shading

History of computer graphics

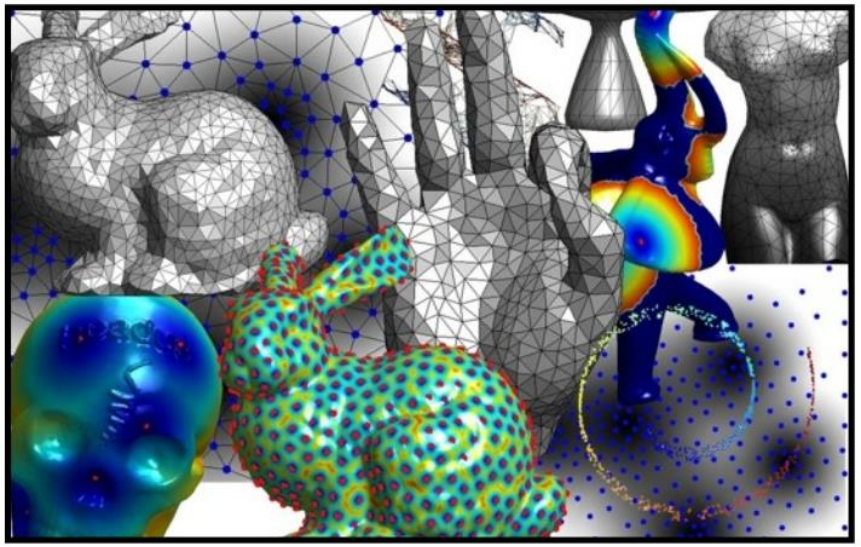
- The 1980's (Ray tracing 光线跟踪 and Radiosity 辐射度方法)
  - In 1980, Whitted proposed a ray tracing model, include light reflection (反射) and transmission (透射) effects.
  - A Milestone of CG.
  - Graphics Hardware

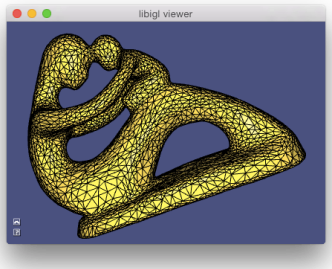
Graphics workstations such as these have been replaced with commodity hardware (CPU + GPU), e.g., MaxBuilts + Nvidia cards

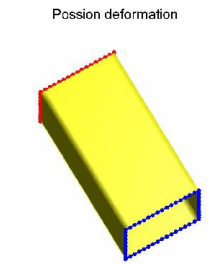


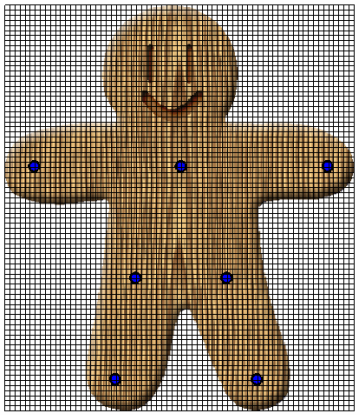
History of computer graphics

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



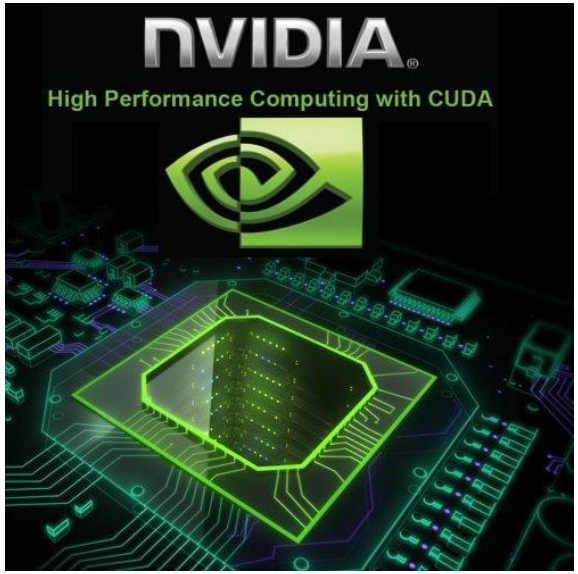


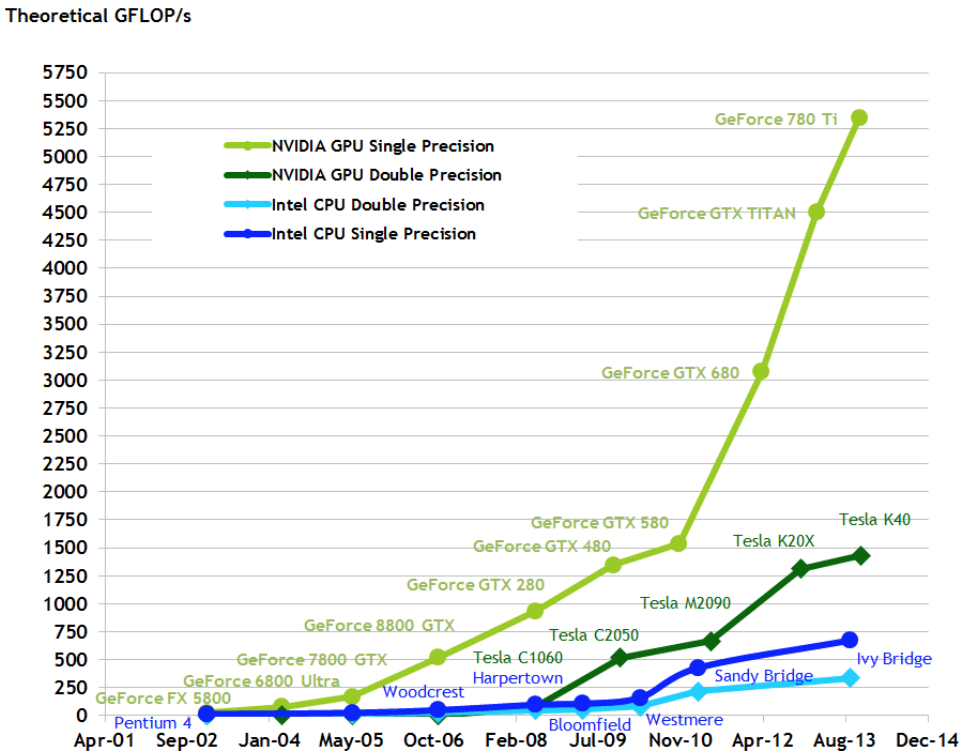




History of computer graphics

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



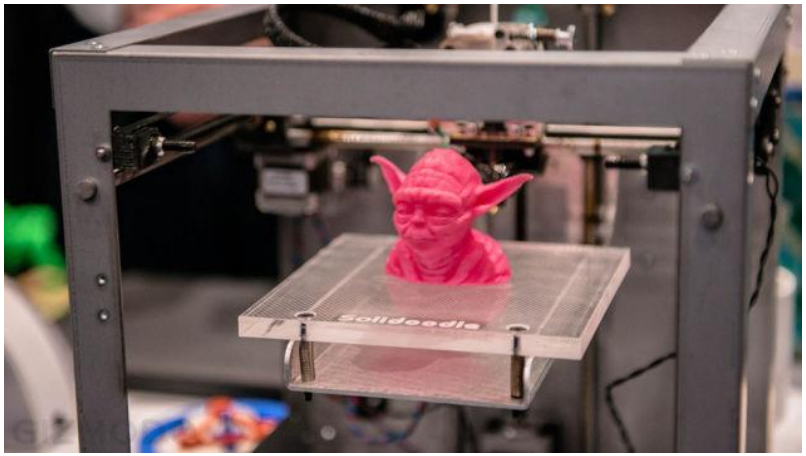


New trends

- Microsoft Kinects

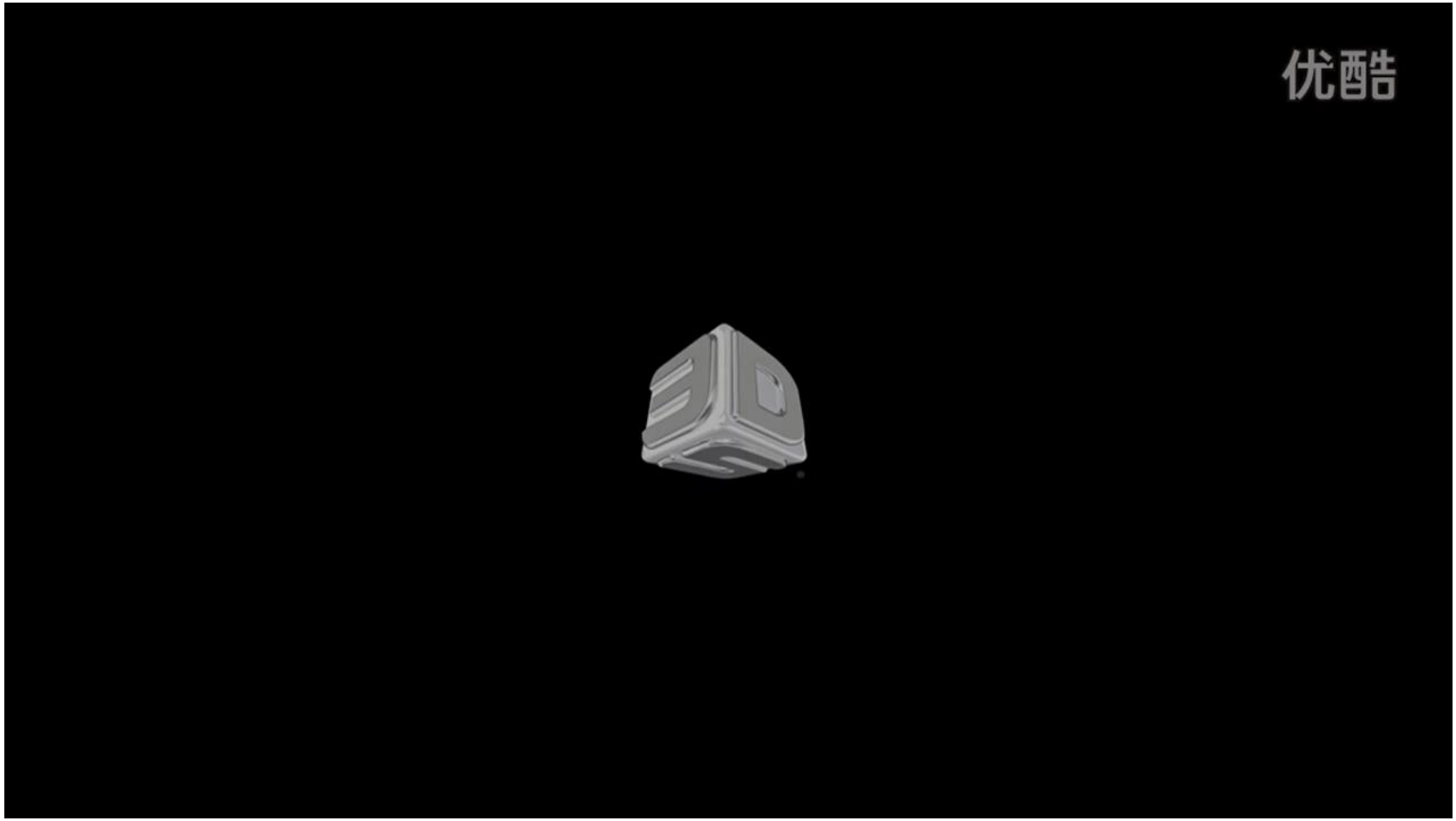
New trends

- 3D Printing



New trends

- 3D Printing



New trends

- Leap Motion

New trends

- Virtual Reality - Cyberith Virtualizer

What is CG used for?

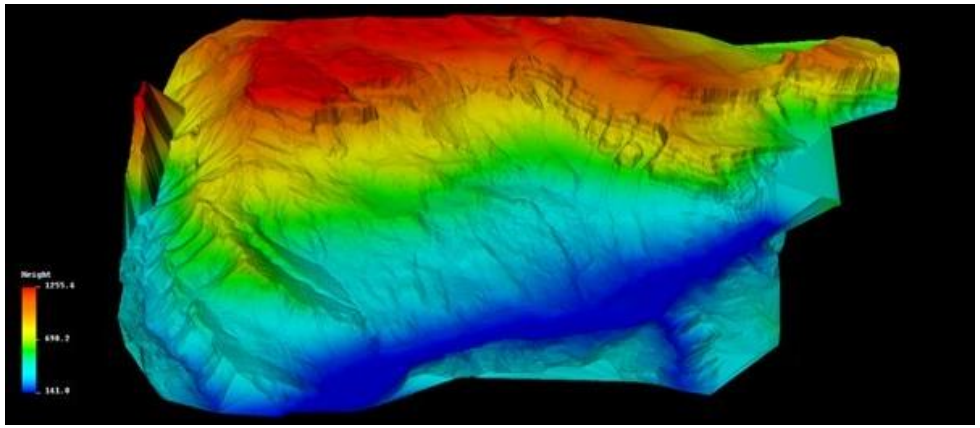
- Movies
  - animation
  - special effects

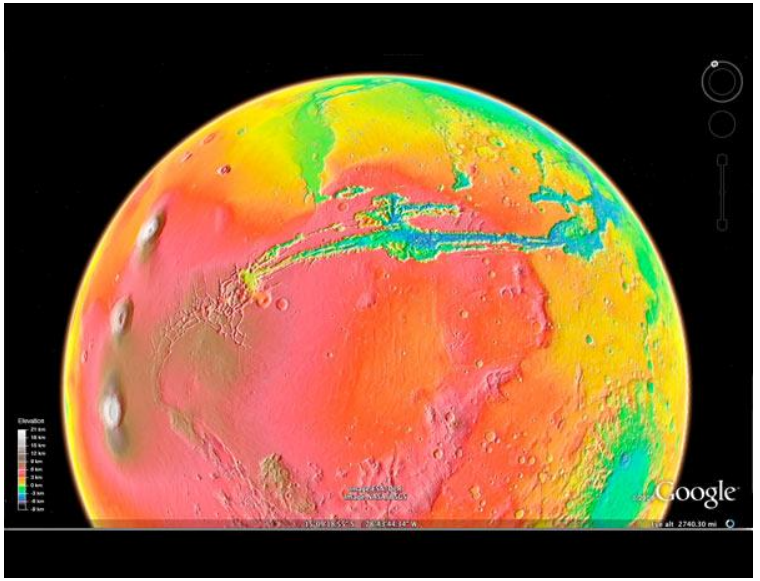
What is CG used for?

- Movies
  - performance capture

What is CG used for?

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





What is CG used for?

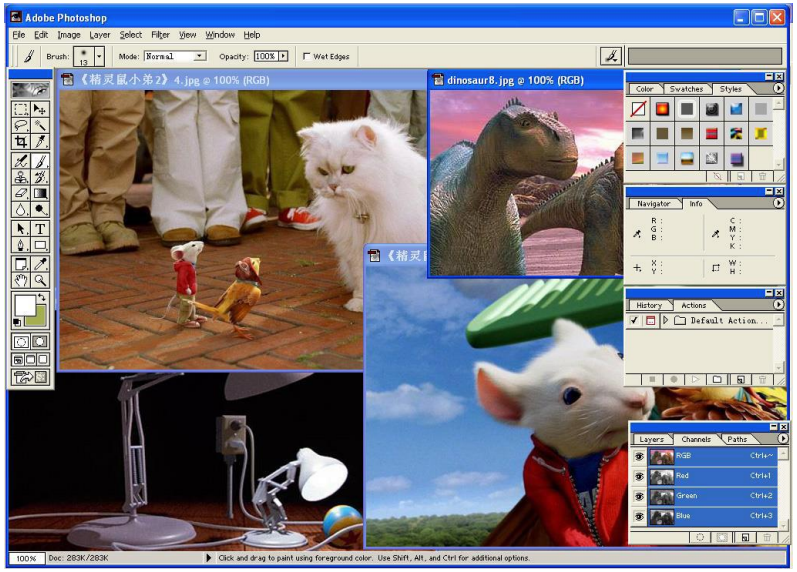
- Computer games

What is CG used for?

- images
  - advertising
  - design
  - art

What is CG used for?

- UI Design



What is CG used for?

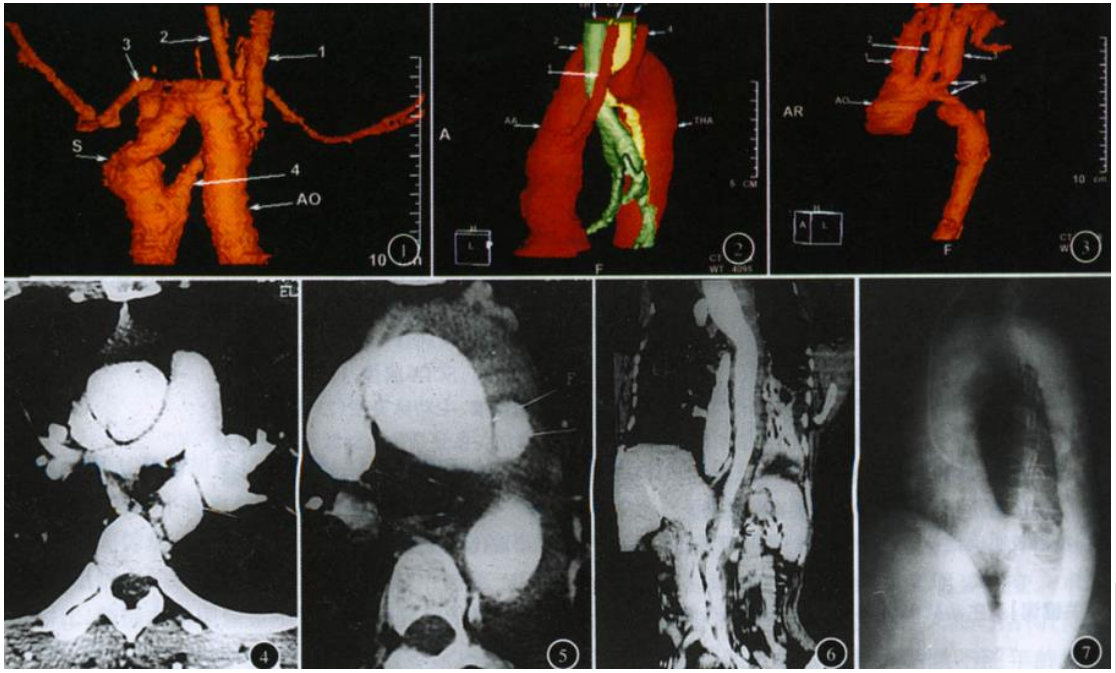
- Training & simulation

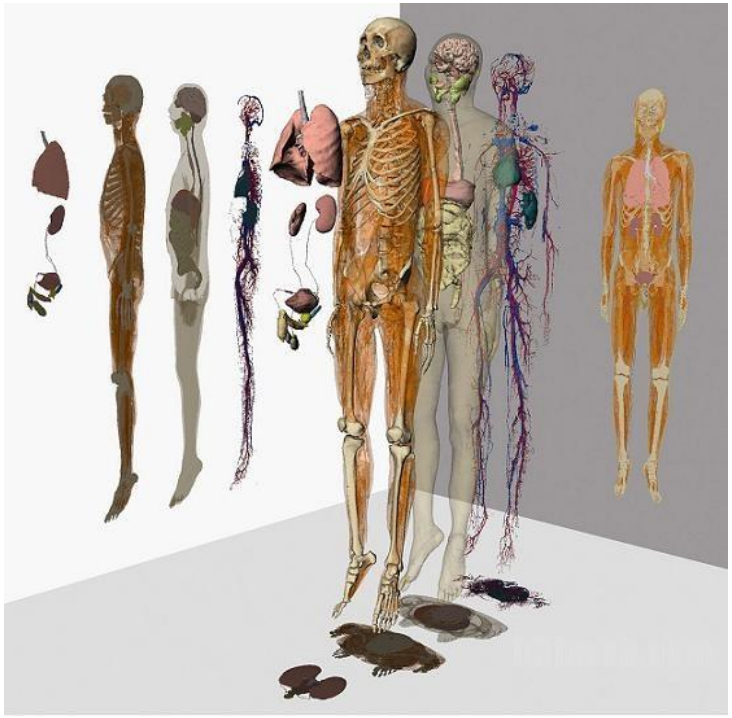
Army Research Lab—IES

NASA/Ames—ACFS

What is CG used for?

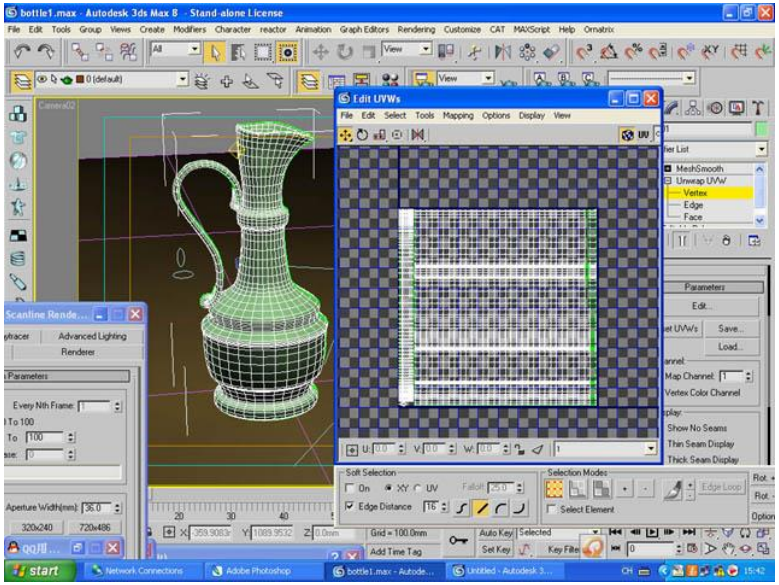
- Medical Imaging

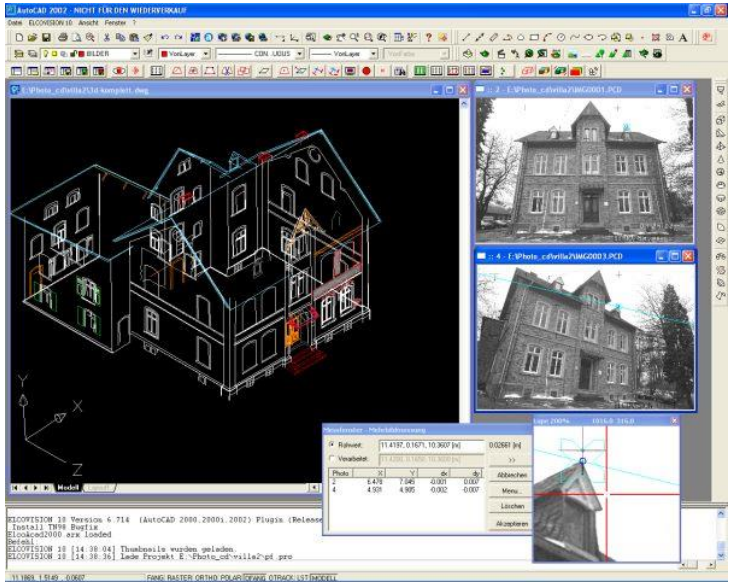


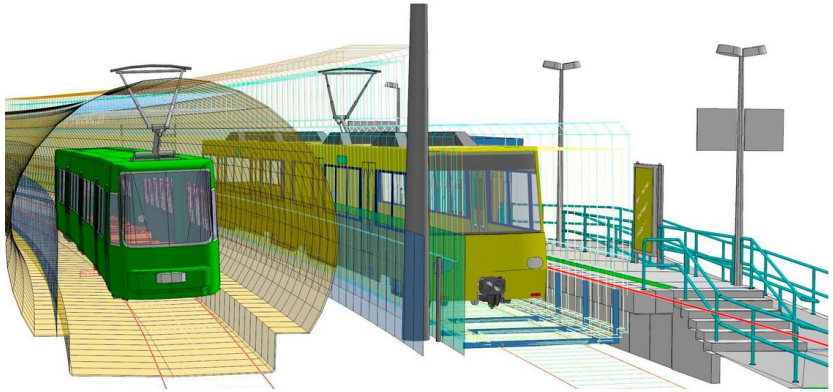


What is CG used for?

- CAD-CAM & Design

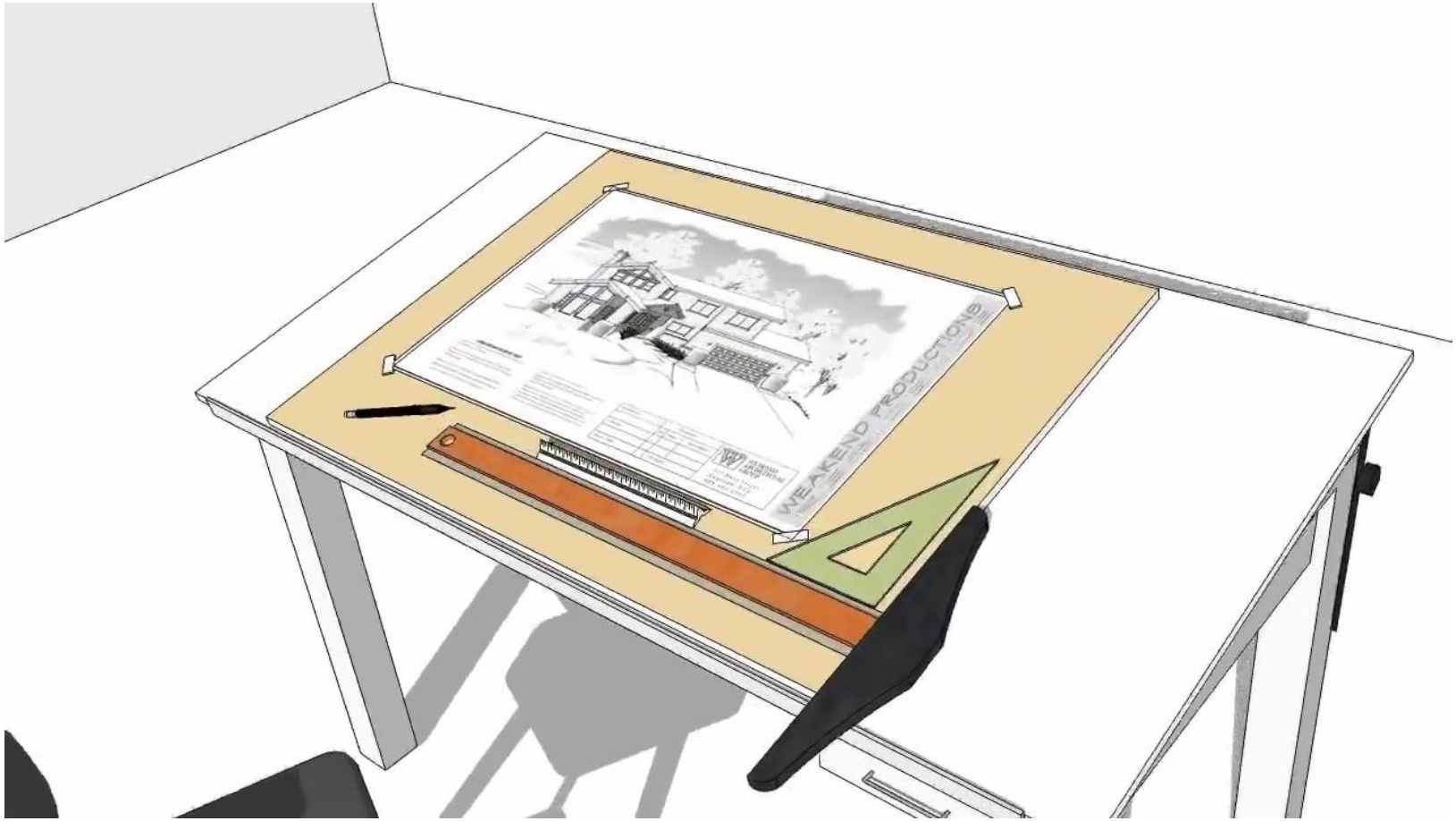






What is CG used for?

- CAD-CAM & Design



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
- Programming
- 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
  - ……

Course Mailbox

- Lecture Slides
  - **cgcourse_sysu@qq.com**
  - **Password: cgcourse2018**
- Homework submission
  - **cgcourse_homework@qq.com**

Cutting-Edge of CG

- International Conferences
  - ACM SIGGRAPH & ACM SIGGRAPH (Asia)
  - 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

https://s2018.siggraph.org/

https://sa2018.siggraph.org/en/

Cutting-Edge of CG

- ACM SIGGRAPH Asia 2017：Technical Papers Trailer

Cutting-Edge of CG

- ACM SIGGRAPH Asia 2017：Emerging Technologies Trailer

Cutting-Edge of CG

Eurographics
EUROPEAN ASSOCIATION FOR COMPUTER GRAPHICS

- Eurographics
  - Eurographics Symposium on Geometry Processing (SGP)
  - Eurographics Symposium on Rendering (EGSR)
  - Eurographics Symposium on Computer Animation (SCA)

Cutting-Edge of CG

- Pacific Graphics
  - PG 2018
  - Hong Kong
  - http://sweb.cityu.edu.hk/pg2018/
  - Deadline: 2018.06.12
- Chinagraphics
  - Chinagraphics 2018
  - Guangzhou
  - http://www2.scut.edu.cn/chinagraph2018/
  - Deadline: 2018.05.30

Cutting-Edge of CG

- How to find the cutting-edge papers?
- http://kesen.realtimerendering.com/

Ke-Sen Huang's Home Page

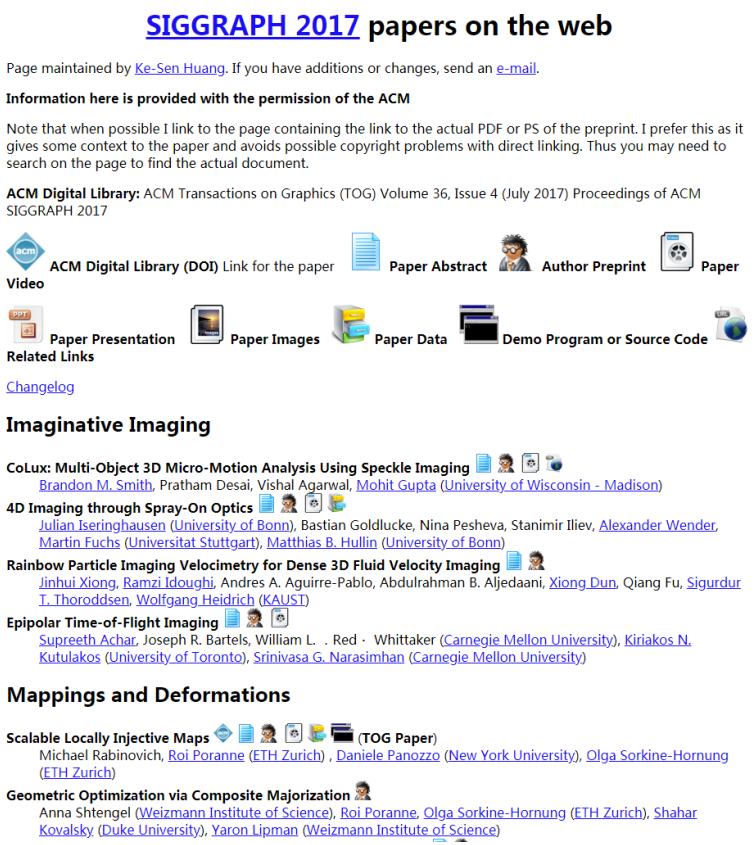
- I got my Ph. D from the Department of Computer Science of National Tsing-Hua University, Taiwan.
- My research interests include: animation synthesis, animation summarization, and motion retrieval.
- My Web Changelog

Paper Collection / Resources

- Open Access to ACM SIGGRAPH-Sponsored Content: For both SIGGRAPH and SIGGRAPH Asia, conference content is freely accessible in the ACM Digital Library for a one-month period that begins two weeks before each conference, and ends a week after it concludes.
- Journal of Computer Graphics Techniques
- Point-based Graphics Papers
- Physics-Based Animation Resources (Maintained by Christopher Batty)
- Real-Time Rendering Resources (Maintained by Tomas Akenine-Möller, Eric Haines, and Naty Hoffman)
- Visualization Paper Collection (IEEE VisWeek papers / EuroVis papers / IEEE Pacific Vis papers) (Maintained by ZJU-VAG)

Computer Graphics Conference and Special Issue Calendar

- CFP - The Springer Encyclopedia of Computer Graphics and Games (ECGG) (PDF)
- 2013, 2012, 2011, 2010, 2009, 2008



SIGGRAPH 2017 papers on the web

Page maintained by Ke-Sen Huang. If you have additions or changes, send an e-mail.

Information here is provided with the permission of the ACM

Note that when possible I link to the page containing the link to the actual PDF or PS of the preprint. I prefer this as it gives some context to the paper and avoids possible copyright problems with direct linking. Thus you may need to search on the page to find the actual document.

ACM Digital Library: ACM Transactions on Graphics (TOG) Volume 36, Issue 4 (July 2017) Proceedings of ACM SIGGRAPH 2017

ACM Digital Library (DOI) Link for the paper **Paper Abstract** **Author Preprint** **Paper Video**

Paper Presentation **Paper Images** **Paper Data** **Demo Program or Source Code** **Related Links**

Changelog

Imaginative Imaging

CoLux: Multi-Object 3D Micro-Motion Analysis Using Speckle Imaging
Brandon M. Smith, Pratham Desai, Vishal Agarwal, Mohit Gupta (University of Wisconsin - Madison)

4D Imaging through Spray-On Optics
Julian Iseringhausen (University of Bonn), Bastian Goldlucke, Nina Pesheva, Stanimir Iliev, Alexander Wender, Martin Fuchs (Universitat Stuttgart), Matthias B. Hullin (University of Bonn)

Rainbow Particle Imaging Velocimetry for Dense 3D Fluid Velocity Imaging
Jinhui Xiong, Ramzi Idoughi, Andres A. Aguirre-Pablo, Abdulrahman B. Aljedaani, Xiong Dun, Qiang Fu, Sigurdur T. Thoroddsen, Wolfgang Heidrich (KAUST)

Epipolar Time-of-Flight Imaging
Supreeth Achar, Joseph R. Bartels, William L. . Red · Whittaker (Carnegie Mellon University), Kiriakos N. Kutulakos (University of Toronto), Srinivasa G. Narasimhan (Carnegie Mellon University)

Mappings and Deformations

Scalable Locally Injective Maps **(TOG Paper)**
Michael Rabinovich, Roi Poranne (ETH Zurich) , Daniele Panozzo (New York University), Olga Sorkine-Hornung (ETH Zurich)

Geometric Optimization via Composite Majorization
Anna Shtengel (Weizmann Institute of Science), Roi Poranne, Olga Sorkine-Hornung (ETH Zurich), Shahar Kovalsky (Duke University), Yaron Lipman (Weizmann Institute of Science)

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

- **Proceedings**

  Siggraph

  Siggraph Asia

  Eurographics

  Pacific Graphics

  Symposium on Geometry Processing

  Shape Modeling International

  Chinagraph

  ….

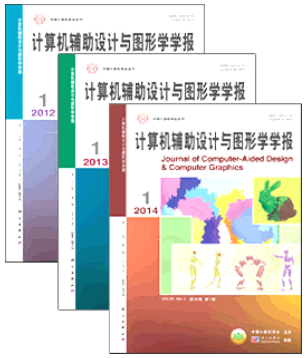
- **Journals (Domestic)**

  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



Industrial CG Resources

- **NVIDIA GameWorks™ Samples Overview**

  https://developer.nvidia.com/gameworks-samples-overview

NVIDIA GameWorks™ OpenGL Samples

Get the documentation or download the NVIDIA GameWorks™ OpenGL samples here:

Download ›

New Browse or Clone Source from GitHub:

GitHub ›

New samples in 2.0:

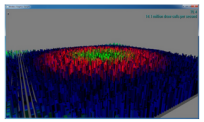
- Blended Antialiasing Sample
- Cascaded Shadow Mapping Sample
- Conservative Rasterization Sample
- Normal-Blended Decal Sample
- Weighted, Blended, Order-independent Transparency Sample

Bindless Graphics Sample

- Category: **Performance**

This sample demonstrates the large performance increase in OpenGL that is made possible by 'Bindless Graphics'. These extensions allow applications to draw large numbers of objects with only a few setup calls, rather than a few calls per object, thus reducing the driver overhead necessary to render highly populated scenery.

Docs ›

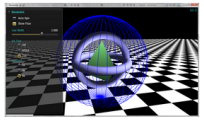


★NEW:Blended AA

- Category: **Performance, Visuals**

This sample implements a two-pass additive blending anti-aliasing technique using Target-Independent Rasterization (TIR), which should give comparable results to MSAA with a reduced memory footprint.

Docs ›

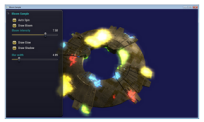


Bloom Sample

- Category: **Visuals**

This sample demonstrates creating a glow effect by post-processing the main scene. It heavily leverages FBO render targets across multiple steps/passes with custom effects processing shaders. It also integrates shadow mapping to demonstrate self-illumination cutting through the shadow effects.

Docs ›



NVIDIA GameWorks™ DirectX Samples

Get the documentation or download the NVIDIA GameWorks™ Direct3D samples here.

Download ›

New Browse or Clone Source from GitHub:

GitHub ›

New samples in 1.2:

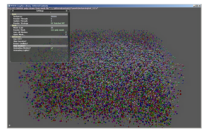
- Antialiased Deferred Rendering
- Motion Blur D3D Advanced Sample

D3D Deferred Contexts Sample

- Category: **Performance**

This sample shows how to use D3D11 Deferred Rendering contexts to lower the CPU overhead and improve performance when rendering large numbers of objects per frame, in situations where instancing is not feasible.

Docs ›

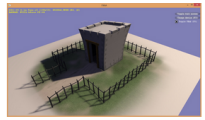


FXAA 3.11 Sample

- Category: **Performance**,**Visuals**

This sample presents a high performance and high quality screen-space software approximation to anti-aliasing called FXAA.

Docs ›

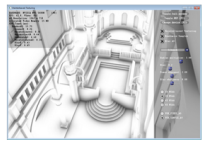


Deinterleaved Texturing Sample

- Category: **Performance**,**Visuals**

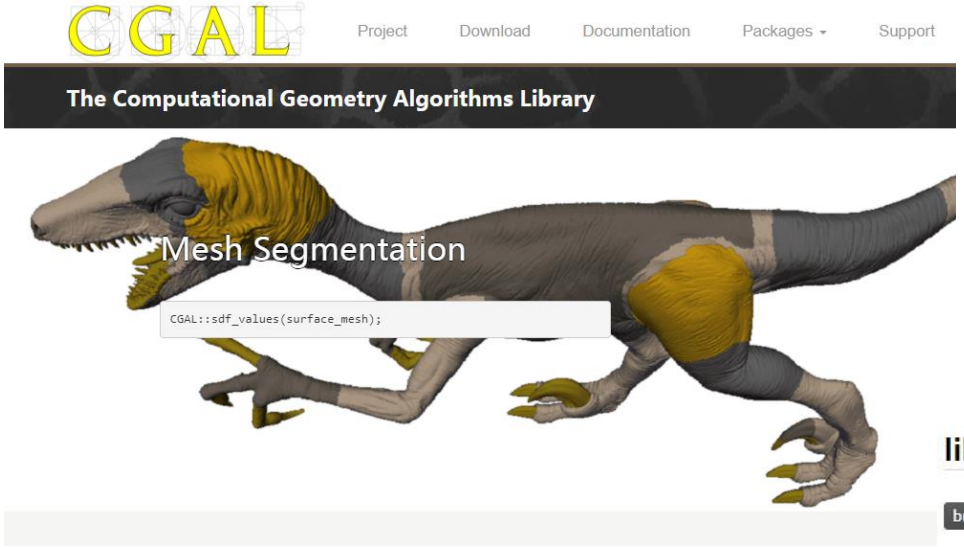
This sample demonstrates how a large, sparse and jittered post-processing filter (here a SSAO pass with a 4x4 random texture) can be made more cache-efficient by using a Deinterleaved Texturing approach.

Docs ›

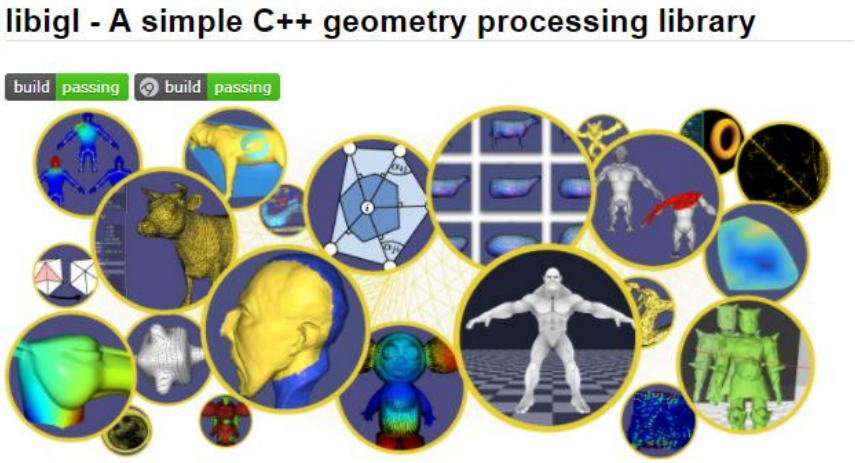


Industrial CG Resources: Geometry Processing

- CGAL
  - https://www.cgal.org/index.html

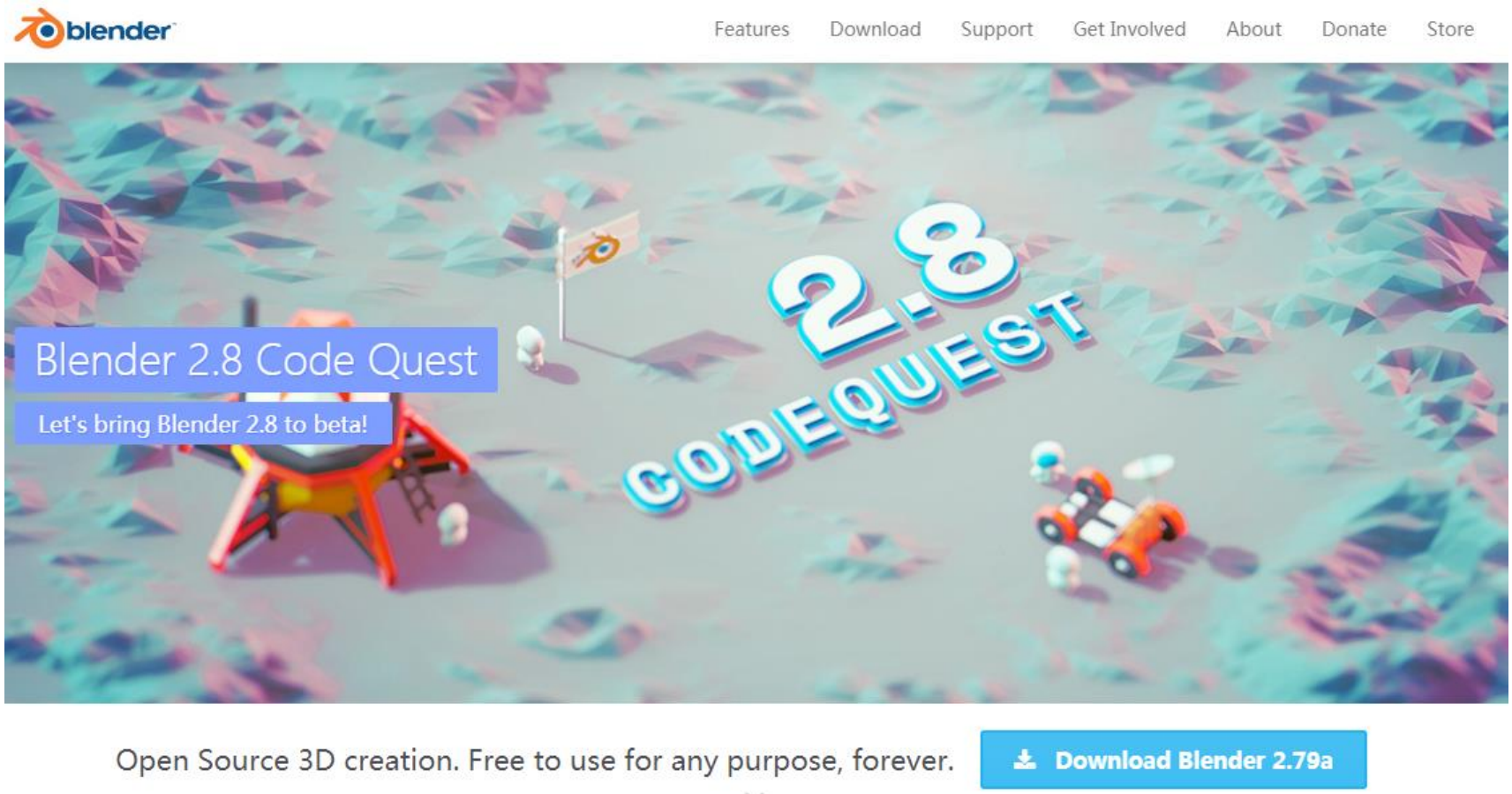


- Libigl
  - http://libigl.github.io/libigl/



Industrial CG Resources: Blender

- https://www.blender.org/

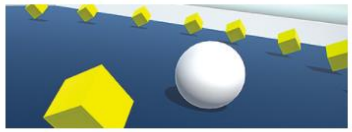


Industrial CG Resources: Unity 3D

- https://unity3d.com/cn

项目

Interactive Tutorials (4)
Get Started with Unity.



Roll-a-ball tutorial (9)
Build your first simple game and Learn to code in C#

2D Game Kit (38)
Explore the ancient and mysterious alien planet where our Principal Engineer, Ellen has crash landed.

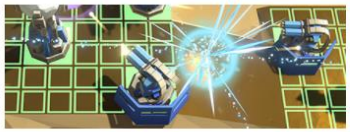
Space Shooter tutorial (19)
Blast some Asteroids!

Survival Shooter tutorial (12)
They mostly come at night..

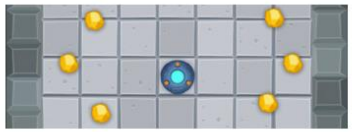
Tanks tutorial (8)
2-players, 1 keyboard, Tank vs Tank.

Adventure Game Tutorial (7)
Learn to create the systems used to develop an adventure game in this intermediate level project.

2D Roguelike tutorial (14)
Procedural level Survive-em-up!



Tower Defense Template (10)
Learn how to create your own Tower Defense game



2D UFO Tutorial (9)
New? Want to make 2D games? Start here.

Procedural Cave Generation tutorial (9)
Let's get spelunking.

Creating Believable Visuals (9)
In this article we look at the fundamentals of setting up good baselines for believable visuals.

Summary

- Enabling Modern Computer Graphics
- History of Computer Graphics
- Applications of Computer Graphics
- Cutting-Edge of Computer Graphics
- Research on Computer Graphics

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/