Computer Graphics

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Contacts

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- **TA**

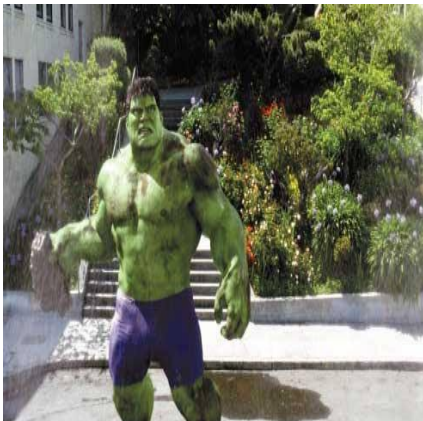 - Shen Chao-hui(沈超慧),

    shench04@gmail.com

- **Why we need graphics?**
- **Will graphics die?**

Movies

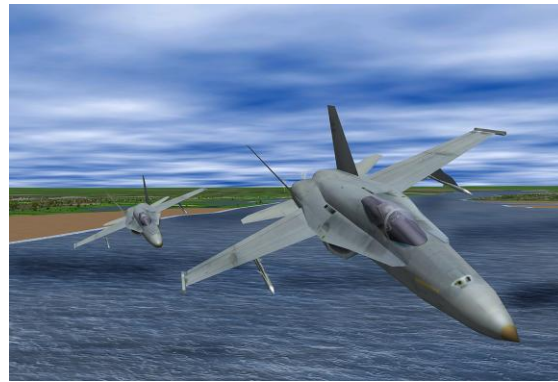- **CG has been widely used in movie industry.**

Games

- **Video game is a major driven of innovations in Computer Graphics**

Simulation

- *Next application of Graphics is Simulation, a key example is Flight Simulation (Evan& Sutherland)*
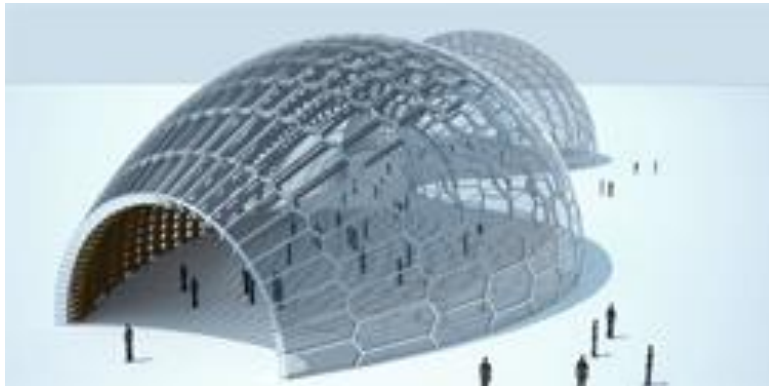
CAD/CAM/CAE

- **Design and analysis results have to be displayed by using Computer graphics**
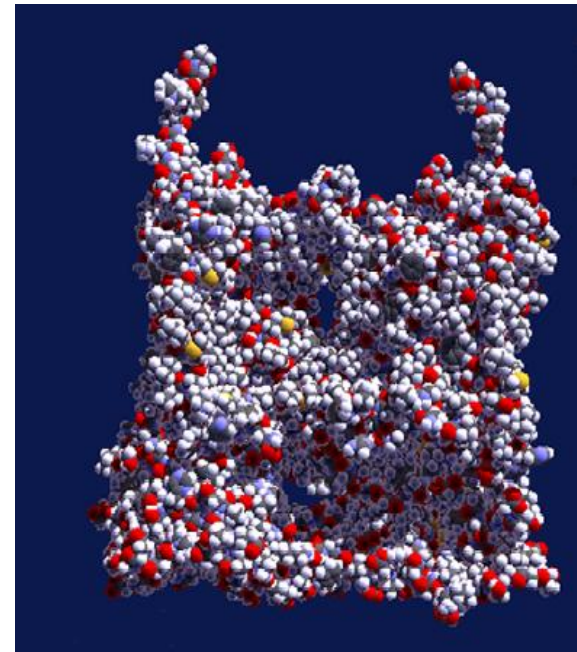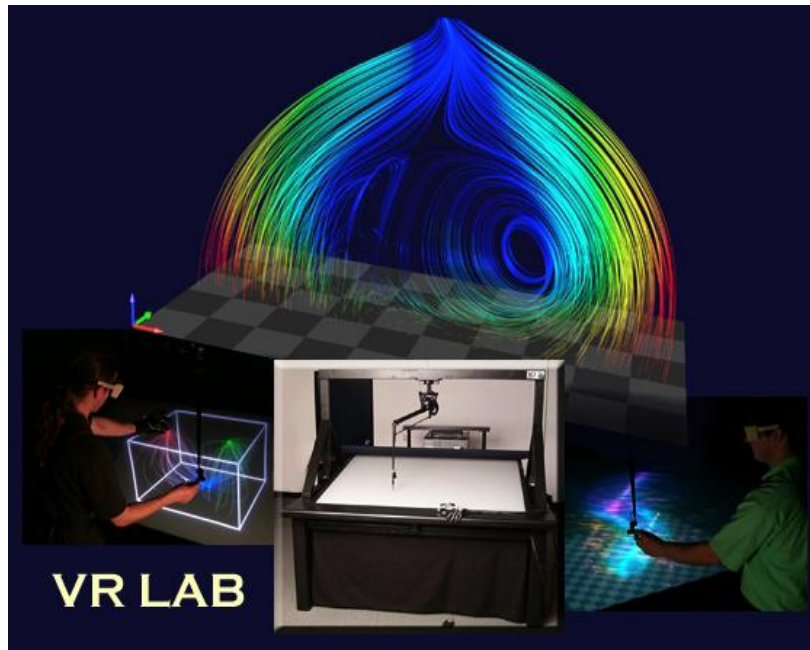
Architecture

- **Graphics is also widely used in architecture design**

Visualization

- **Visualization can be regarded as extension of Computer Graphics**

History of computer graphics

- **Computer Graphics is a subject to investigate graphics representation, generation, processing and display by using Computers.**

- **Graphics is one of the most active branch in computer science**

History

- **Graphics and CAD**
  - **In 1962, MIT's Lincoln Lab, Ivan Sutherland's PhD Thesis**

    Sketchpad: A Man-Machined Graphical Communication System
  - **Professor Coons, the concept of "CAD" (Computer Aided Design) in 1958, Coons surface in 1964, Coons Award**

History

- **The 1950's**
    - **In 1950, the first visual display unit is designed for MIT's Whirlwind I Computer**
    - **In 1958, CalComp developed 565 drum plotter (滚筒绘图仪)**
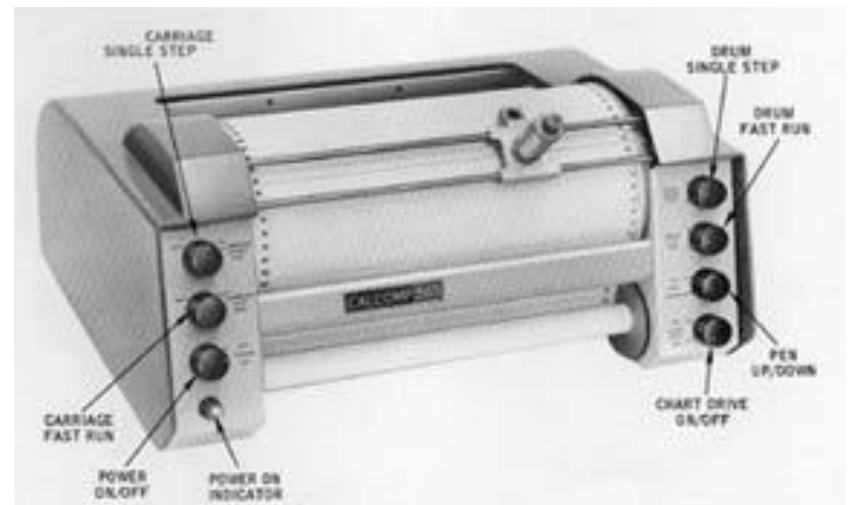
History

- **The 1950's**
  - **In 1958, Gerber Company developed the first flat plotter**
  - **In the late of 1950's, The whirwind team became assimilated into the creation of SAGE air defense system**

    (semiautomatic ground environment)

History

- **The 1960's**
  - **In 1962, Ivan Sutherland of Lincoln lab, Phd Thesis:** *Sketchpad: A Man-Machined Graphical Communication System,*
    - **"the father of computer graphics"**
    - **ACM Coons Award, 1983**
    - **Turing Award in 1988**
    - **Movie for PHD defense *"PPT"***

History

- **The 1960's**
  - **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**

History

- **The 1970's**
  - **Fast development of Rasterizing Graphics**
    - **The concept of scan conversion（扫描转化），clipping (裁减) and surface hidden removal （消影）and the corresponding algorithms**
  - **Standardization**
    - **In 1974, ACM SIGGRAPH formed the Graphics Standard Committee.**
      - **Core Graphics System**
   - **ISO published CGI, CGM, GKS, PHIGS**

History

- **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 lighting model. (one of the most important and influential lighting model).**
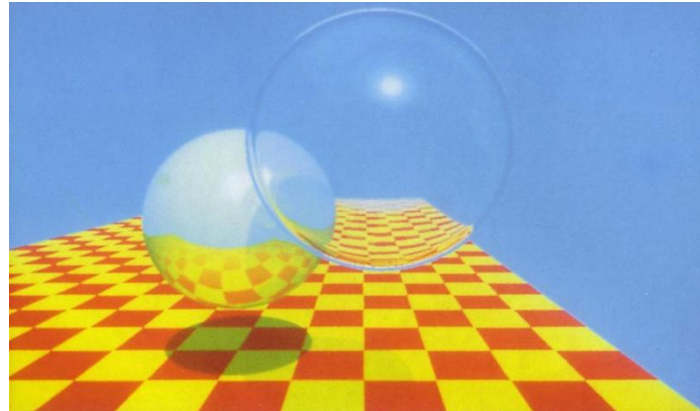
History

- **The 1970's (Geometry Modeling)**
    - **The "Build" System by the CAD group of University of Cambridge**
        - **A story on CAD group in Cambridge**
    - **The PADL-1 System, University of Rochester**
    - **…**
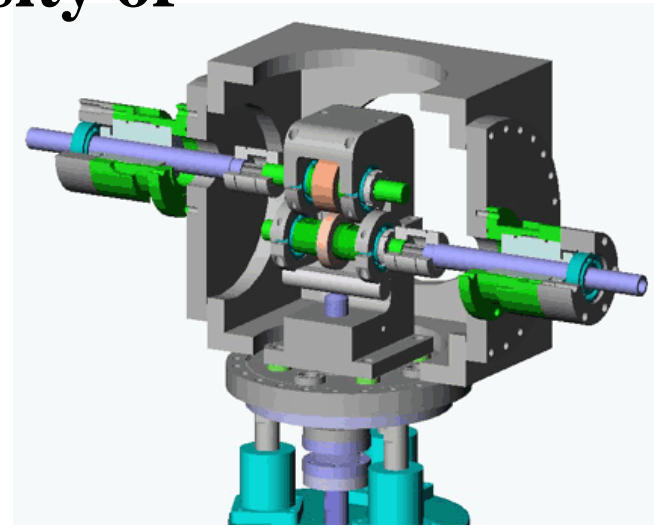
History

- **The 1980's (Ray tracing and Radiosity)**

  - **In 1980, Whitted proposed a ray tracing model, include light reflection(反射) and transmission（透射） effects.**
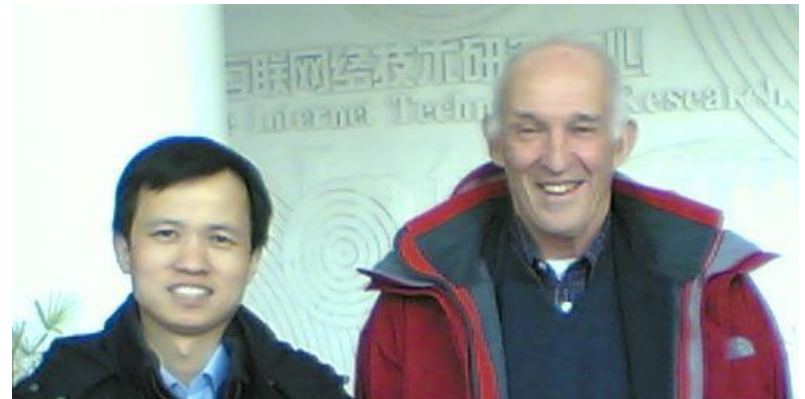
  - **A Milestone of CG.**

– **In 1984, the researchers of Cornell University and Hiroshima University introduced the concept and methods of radiosity in the field of heat radiation to computer graphics**

  • **Greenberg @ Cornell**

  • **Nishita @ Hiroshima**

Greenberg @ Tsinghua

December, 2006

Conferences and Journals

- **Conferences**

    ACM **Siggraph, Eurograph, Pacific Graphics**

    Computer Graphics International, CASA,

    Graphics Interface, Rendering workshop, SGP,

- **Journals**

    ACM Transaction on Graphics

    IEEE Computer Graphics and Application

    IEEE Visualization and Computer Graphics

    CAD, CAGD, Computer Graphics Forum

    Graphical Models

    The Visual Computer

- **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**
  - **http://www.siggraph.org**

Overview of the course in this Semester

- **Geometry (Modeling)**

  Geometrical Modeling describes the shape of an object.

- **Rendering**

  Rendering converts a model into an image either by simulating light transport to get physically-based photorealistic images, or by applying some kind of style as in non-photorealistic rendering

Geometry

- **Topics for Geometry included:**
  - **View, Transformation of Models (模型的投影和变换)**
  - **Bezier Curves**
  - **B-Spline Curves**
  - **Triangle Mesh（三角网）**
  - **Deformation （变形）**

View, Transformation of Model
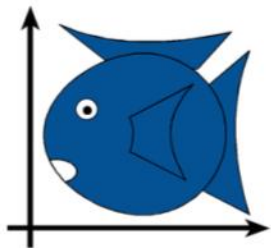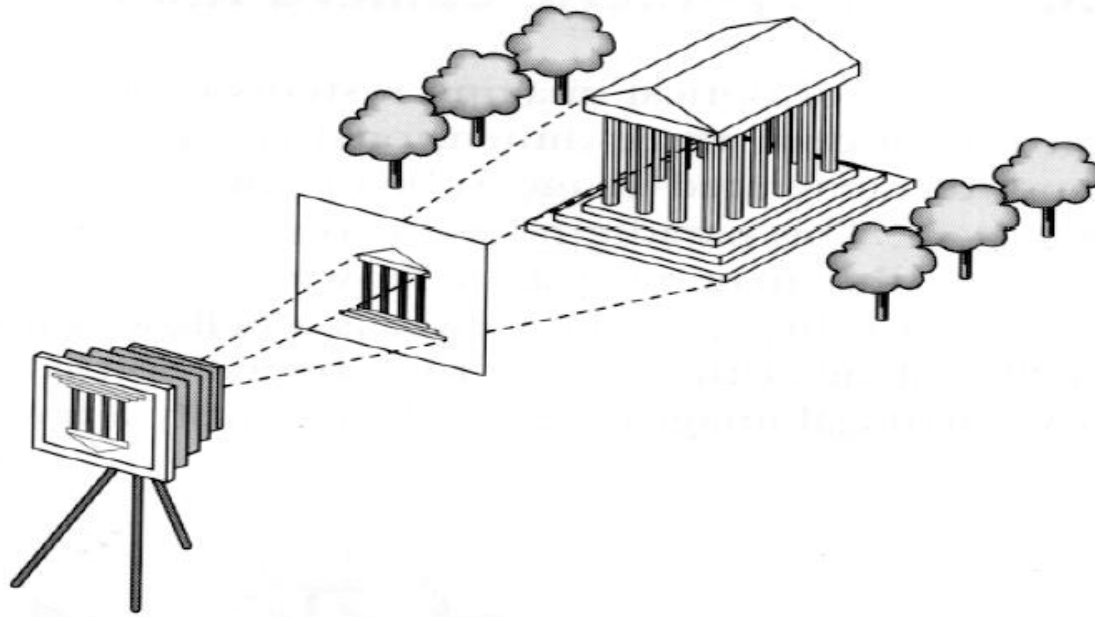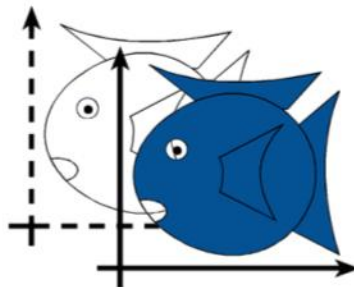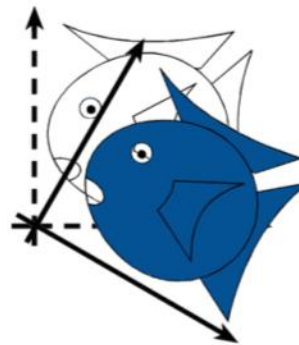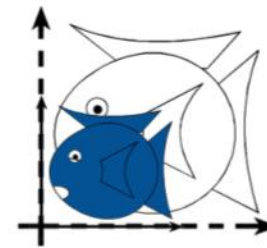
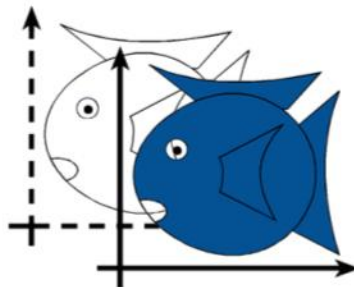Identity   Translation   Rotation   Isotropic (Uniform) Scaling
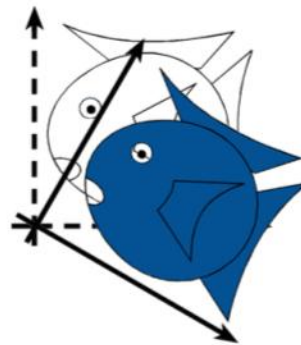
View, Transformation of Model
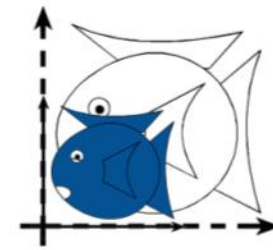

Modeling

Viewing
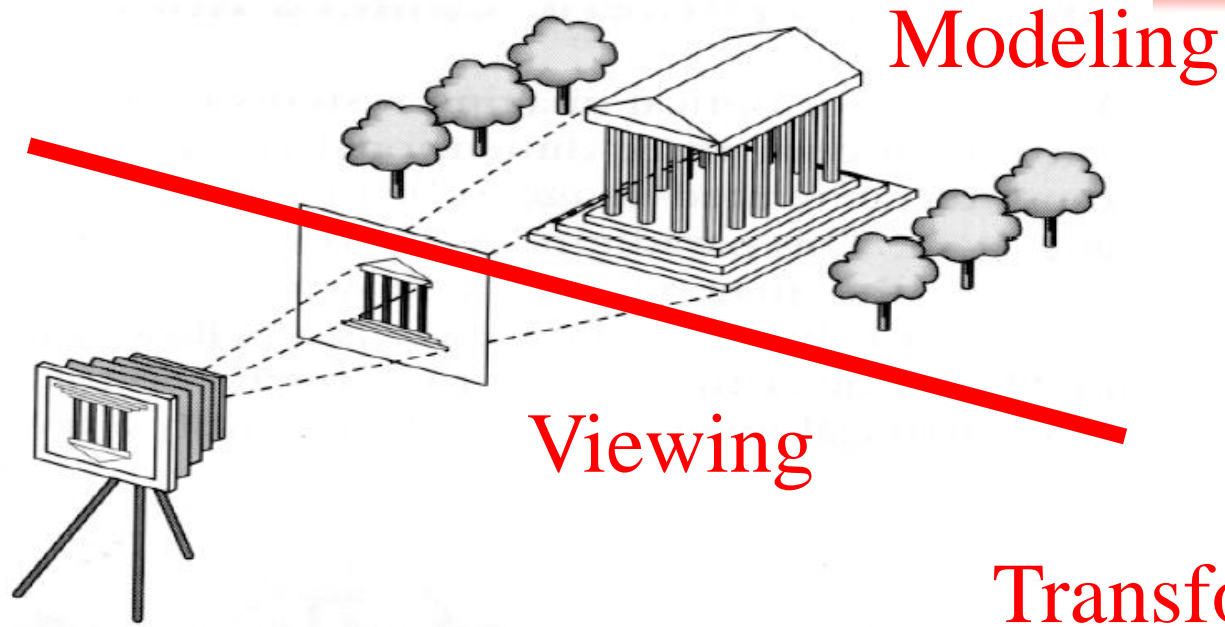
Transformation
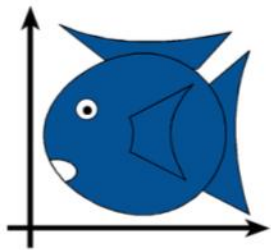
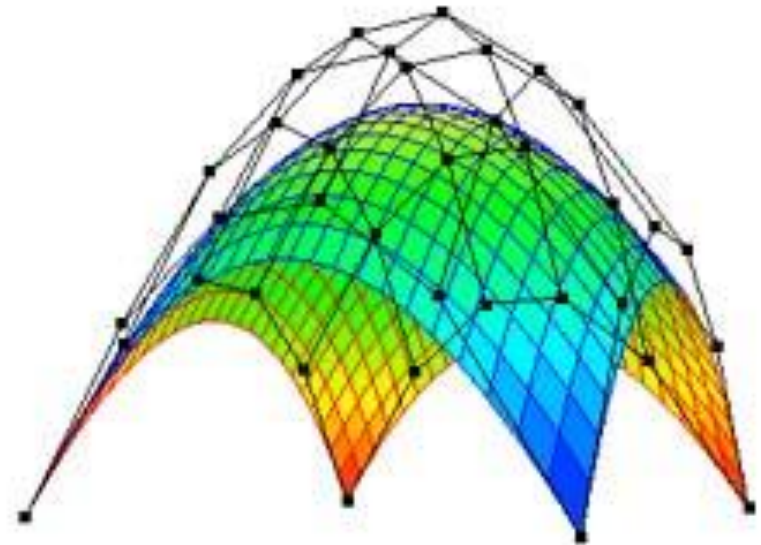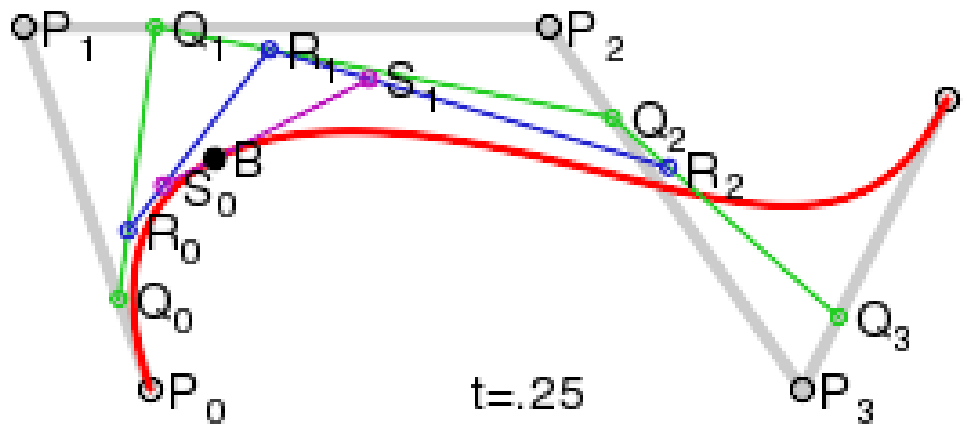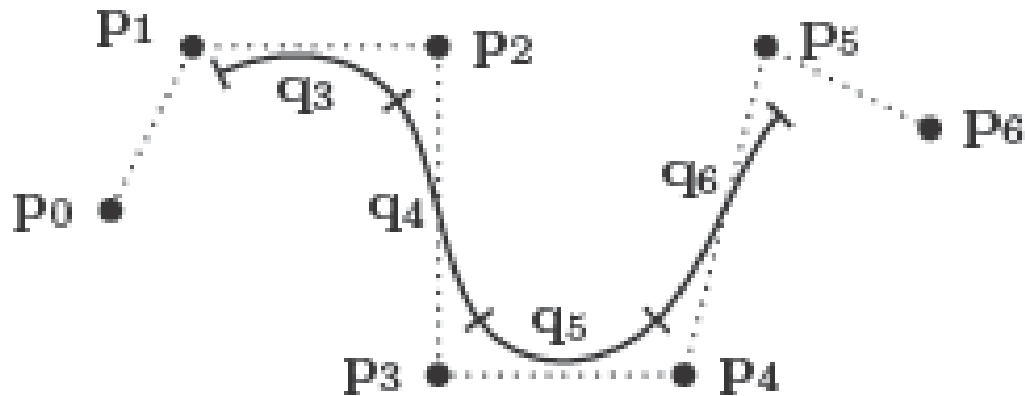Identity   Translation   Rotation   Isotropic (Uniform) Scaling

Bezier Curve/Surface

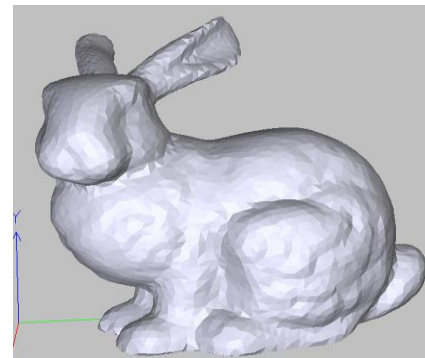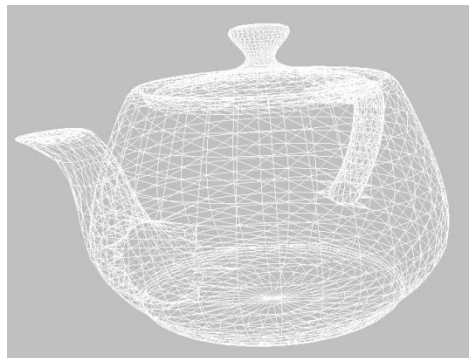- **Definition and algorithms for Bezier Curves and Surfaces**

B-Spline Curves

- **Definition and algorithms for B-spline Curves and Surfaces**

Triangle Mesh

- **Triangle mesh** is a representation for 3D models in computer graphics , which is mostly used current days.

- It comprises a set of triangles (typically in three dimensions) that are connected by their common edges.

Deformation

- **Deformation is referred to as deforming from one 3D model to another one**
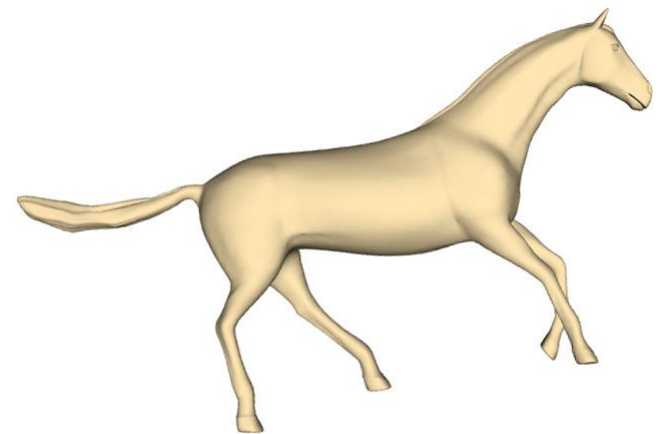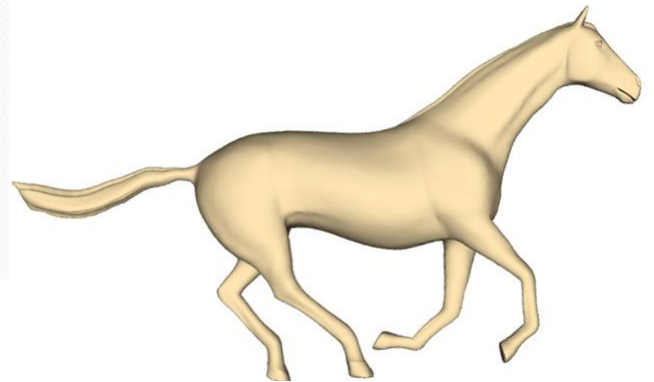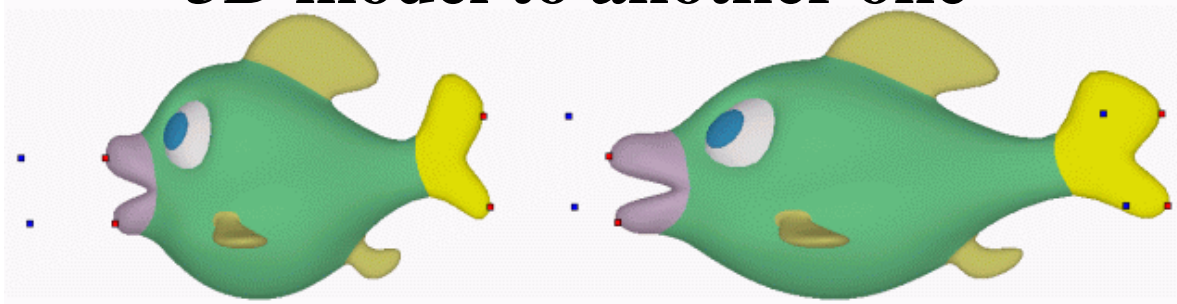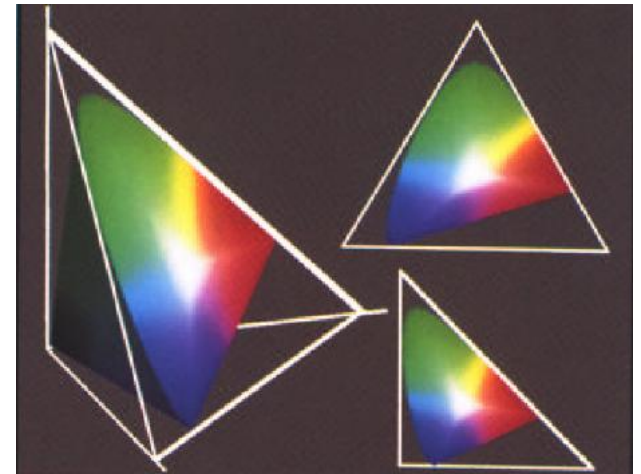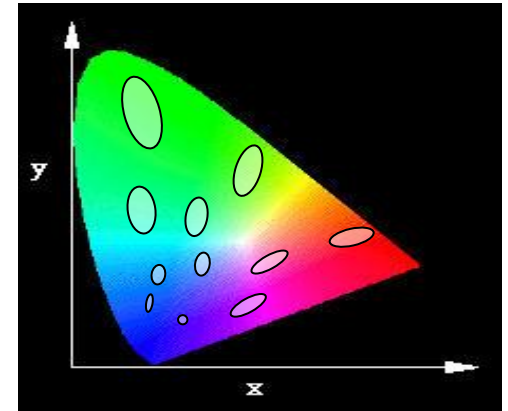
Rendering

- **Topics on rendering included:**
  - **Basic Concepts, OpenGL**
  - **Lighting** （光照）
  - **Ray Tracing** （光线跟踪）
  - **Acceleration of Ray Tracing** （光线跟踪加速）
  - **Texture** （纹理）
  - **Shadow** （阴影）
  - **Radiosity** （辐射度）

Color, OpenGL

- **Color perception and color representation**
- **Open GL** Library
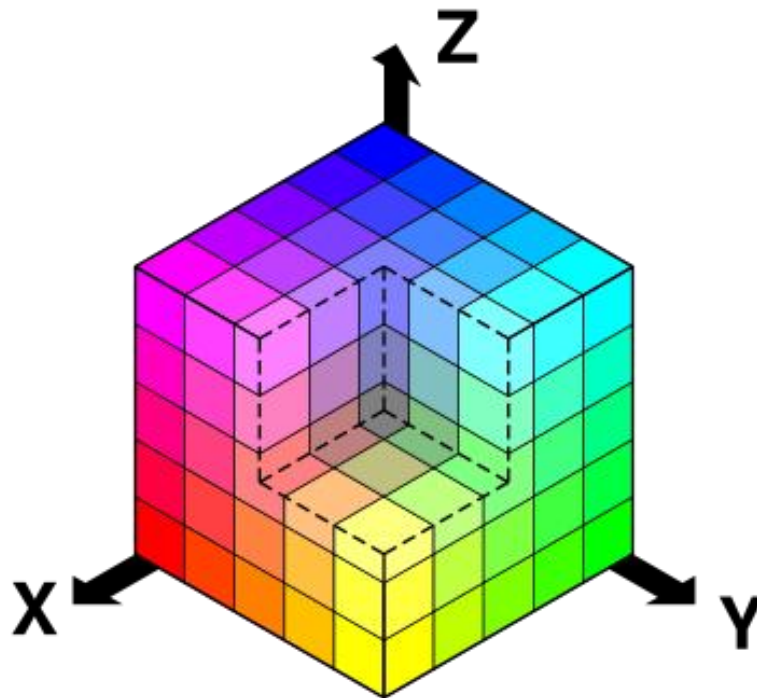
Lighting

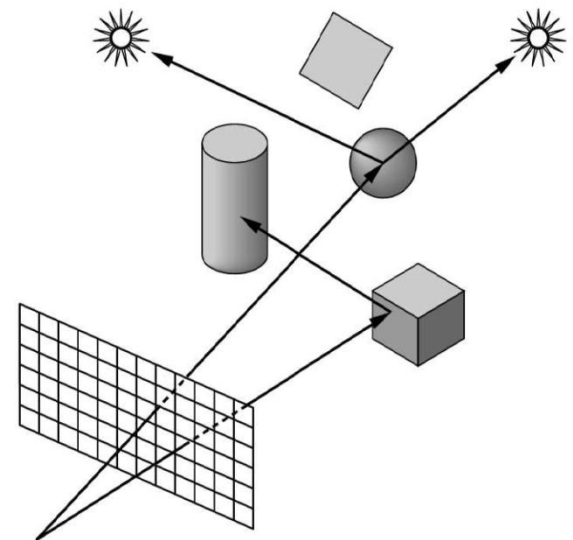- Lighting and shading are important tools for making graphics images appear more realistic and more understandable.

Ray Tracing

- Ray tracing is a technique that performs, by a single unified technique, global calculations of lighting and shading, hidden surface elimination, reflection and transmission of light, casting of shadows, and other effects.
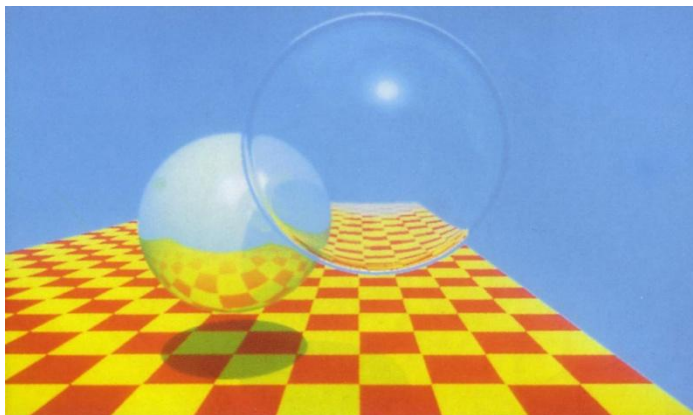
Ray Tracing

By a student in 1998?
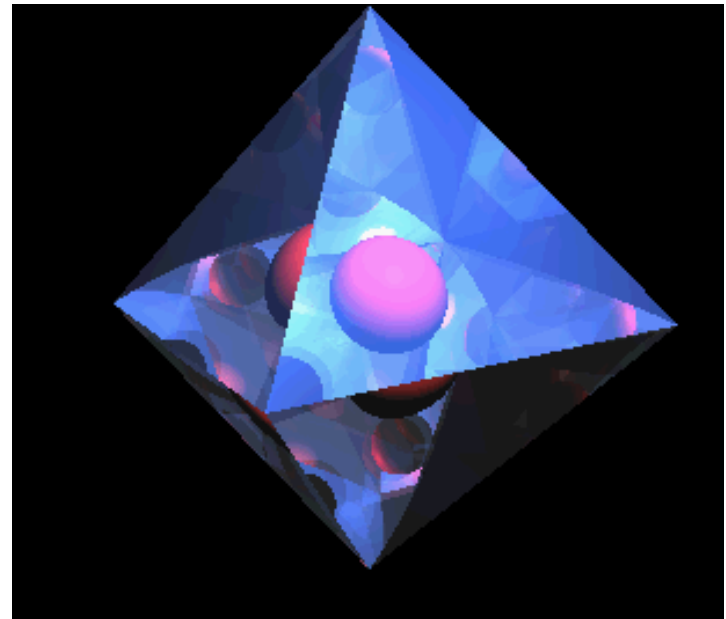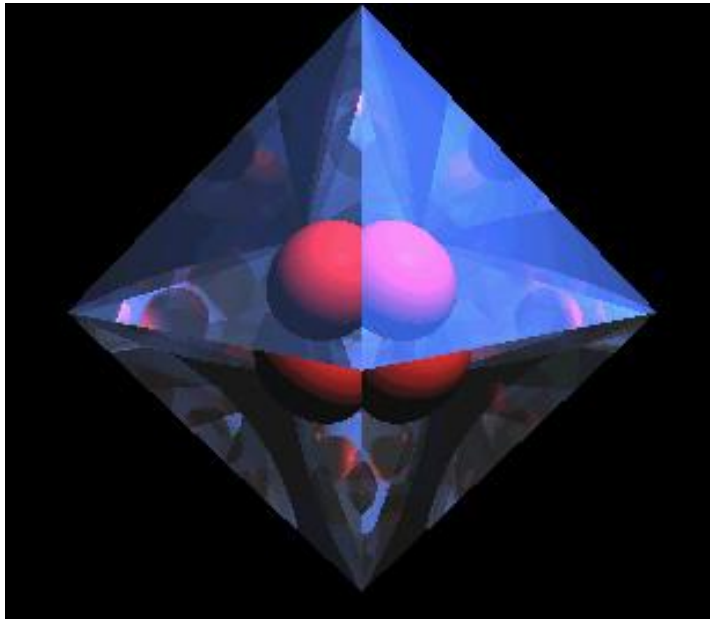
Acceleration of Ray Tracing

- **The biggest disadvantage of ray tracing is that it is too slow, so need Acceleration by techniques like Hierarchical Structure**
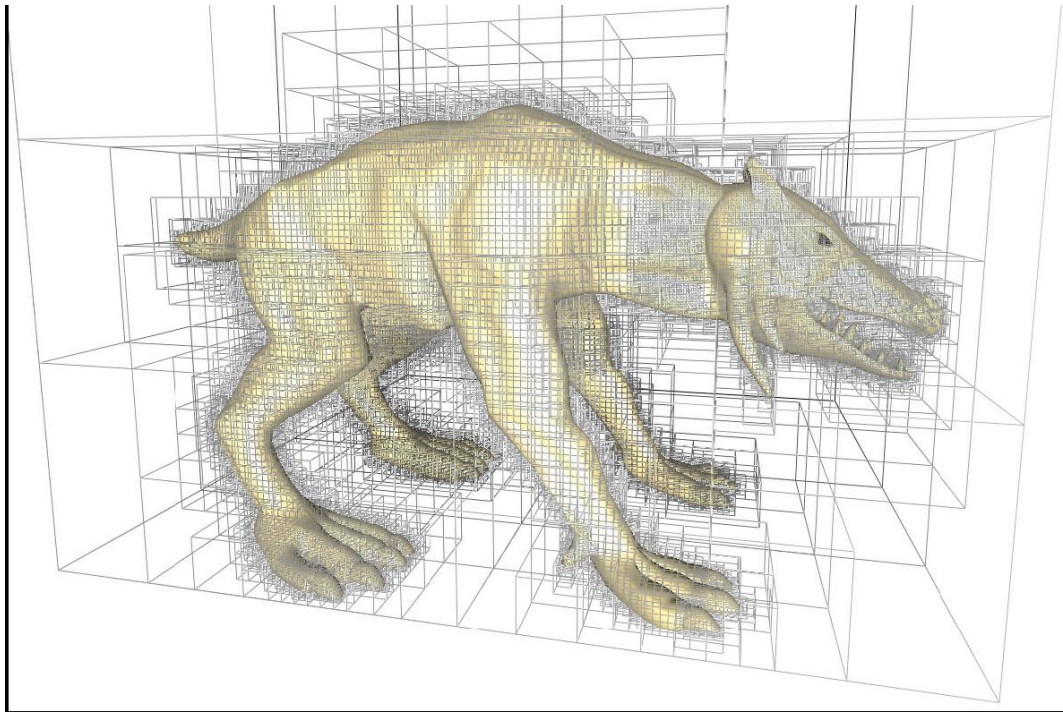
Texture

- **Texture exhibits great realistics in rendering.**

Shadow

- **Shadows are important in creating realistic images and in providing the user with visual cures about object placement.**

Radiosity

- **Radiosity is a global lighting method that tracks the spread of diffuse light around a scene**
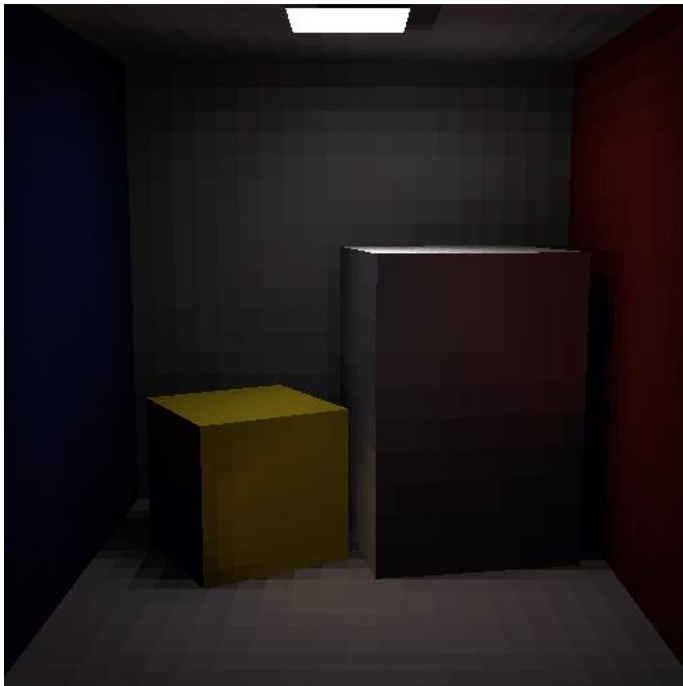
Research Hot Topics

- **Rendering**

- **Computer Animation**

- **Geometry**

- **Video-based rendering**

Rendering : Mesh Simplification

Wu 2001

Figure 11: *Comparison with QEM. The left model is the original with 5,804 faces. The middle and right models are both simplified to 2,000 faces using our scheme and QEM respectively.*

Wei 2009
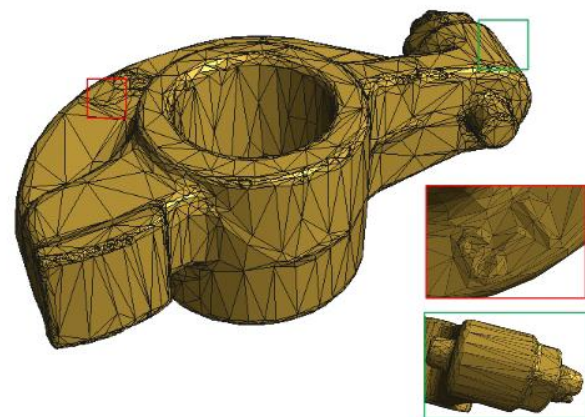
Image/Video based rendering

- glTIP(画中游)   Video from HKUST:

  http://www.cs.ust.hk/~cpegnel/glTIP/intro.html

Natural Scene Simulation

- 清华山水1999

- Simulation of Snow

- Tree generated by Xfrog3.0

- Tree Bark (Siggraph03)

  – **VDM**

- **GDM**

  Play Video

- Physical based rendering of Gemstones
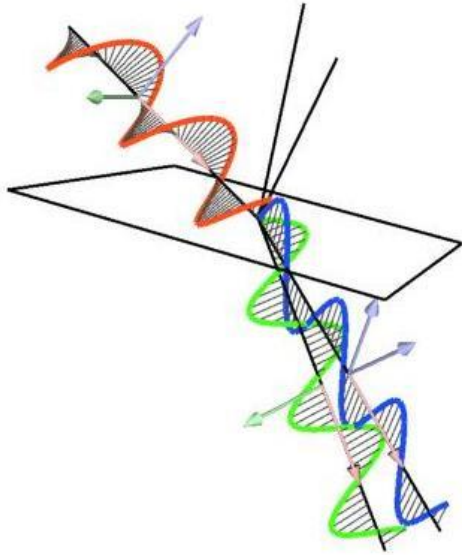
Spherical Piecewise Constant Basis Functions (SPCBFs)

- Proposal a new basis function SPCBFs for PRT, and a real-time rendering framework for dynamic scenes that supports all-frequency shadows, and arbitrary rigid transformation of objects.
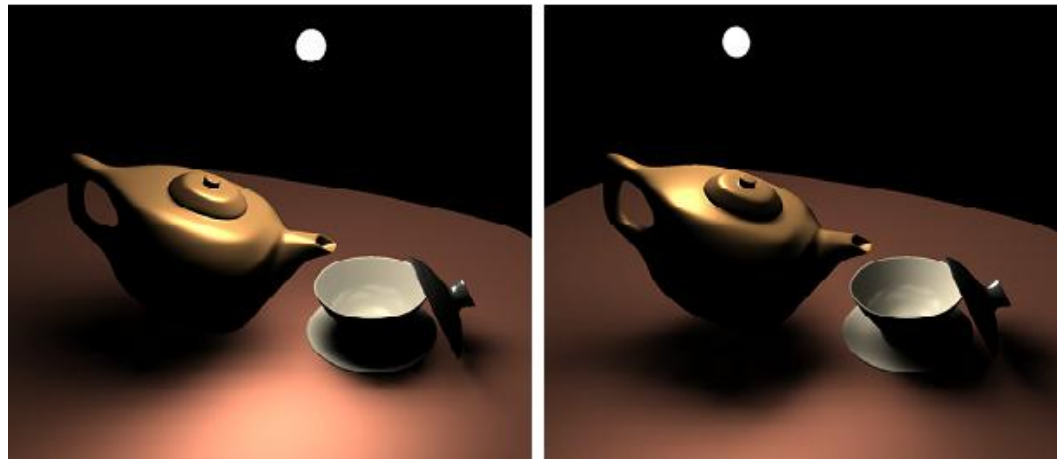
Result Videos of SPCBFs
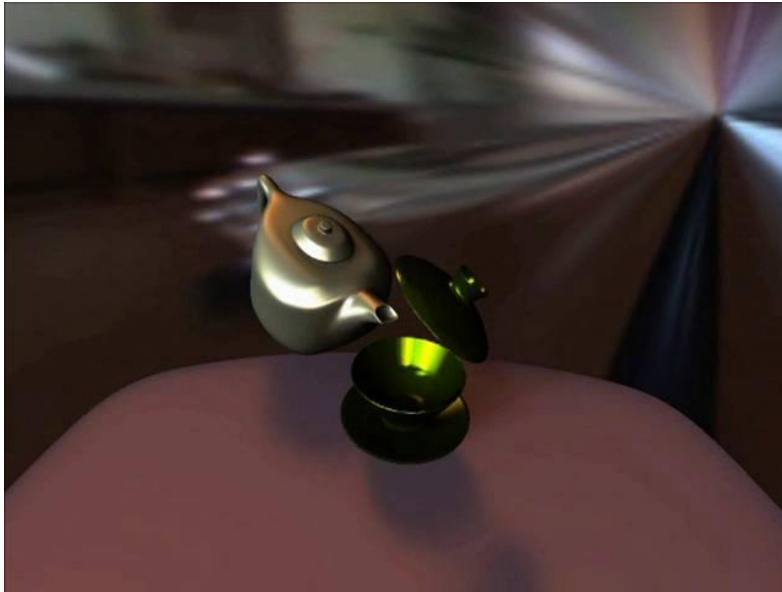
IEEE Transactions on Visualization and
Computer Graphics 2008

Real-time Translucent Material Editing

- Proposal a method for editing translucent materials in real-time. Useful for material design.

Results of Real-time Editing
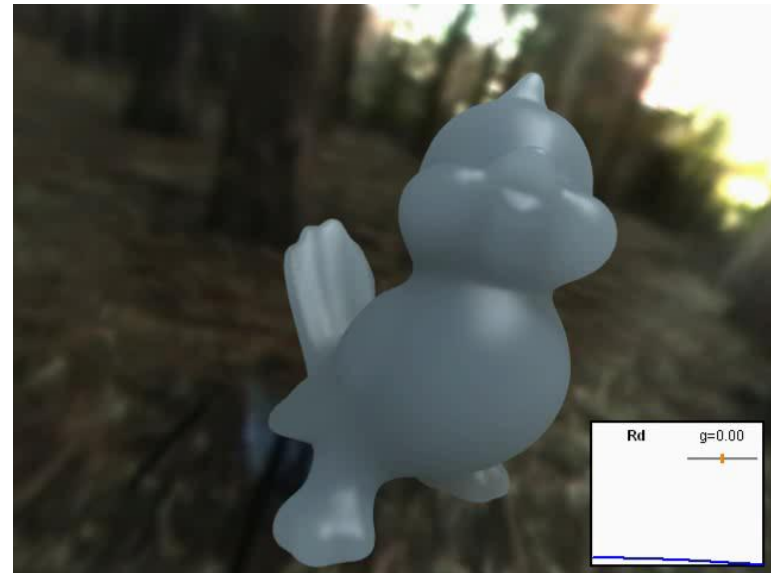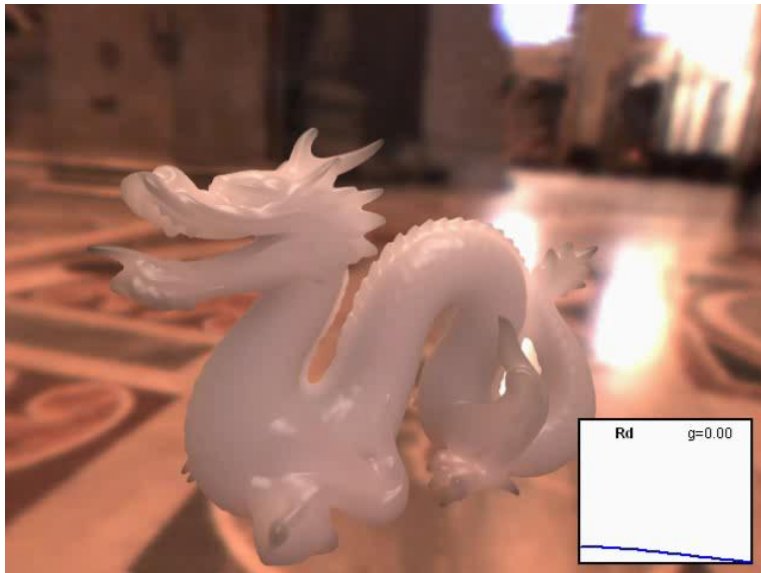
Eurographics 2007
Computer Graphics Forum

- Point based rendering of large scenes

(a)
Points

(b)
Polygons – same number of primitives as (a)
Same rendering time as (a)

(c)
Polygons – same number of vertices as (a)
Twice the rendering time of (a)

Figure 5: Comparison of renderings using point and polygon primitives.

Computer Animation

- – 2D
  - Shape Blending (from a polygon to another)
  - Image Morphing
- – 3D
  - Key frame based animation
  - Deformation based animation
  - Kinetic based animation/ human animation
  - Video based animation

Feature based Image morphing

- **Morphing is a special effect that changes one image into another through a seamless transition**

Deformation of 3D models
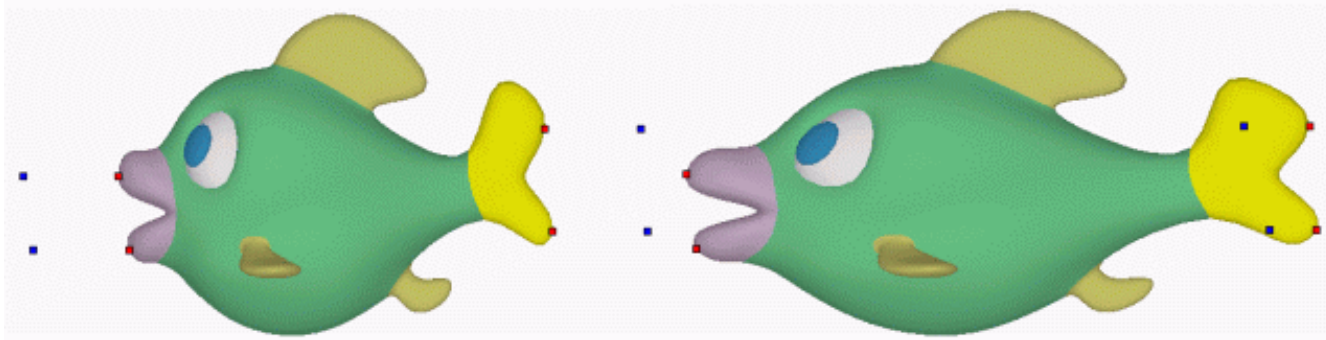
3D FFD(Free-Form Deformation)

Shape Deformation using a Skeleton to Drive Simplex Transformations

- Morphing by Strain Field Interpolation

MOrphing Based on
Strain Field Interpolation

gymnastic patterns

CASA 2004

- Artificial fish

- **Video-based Animation**
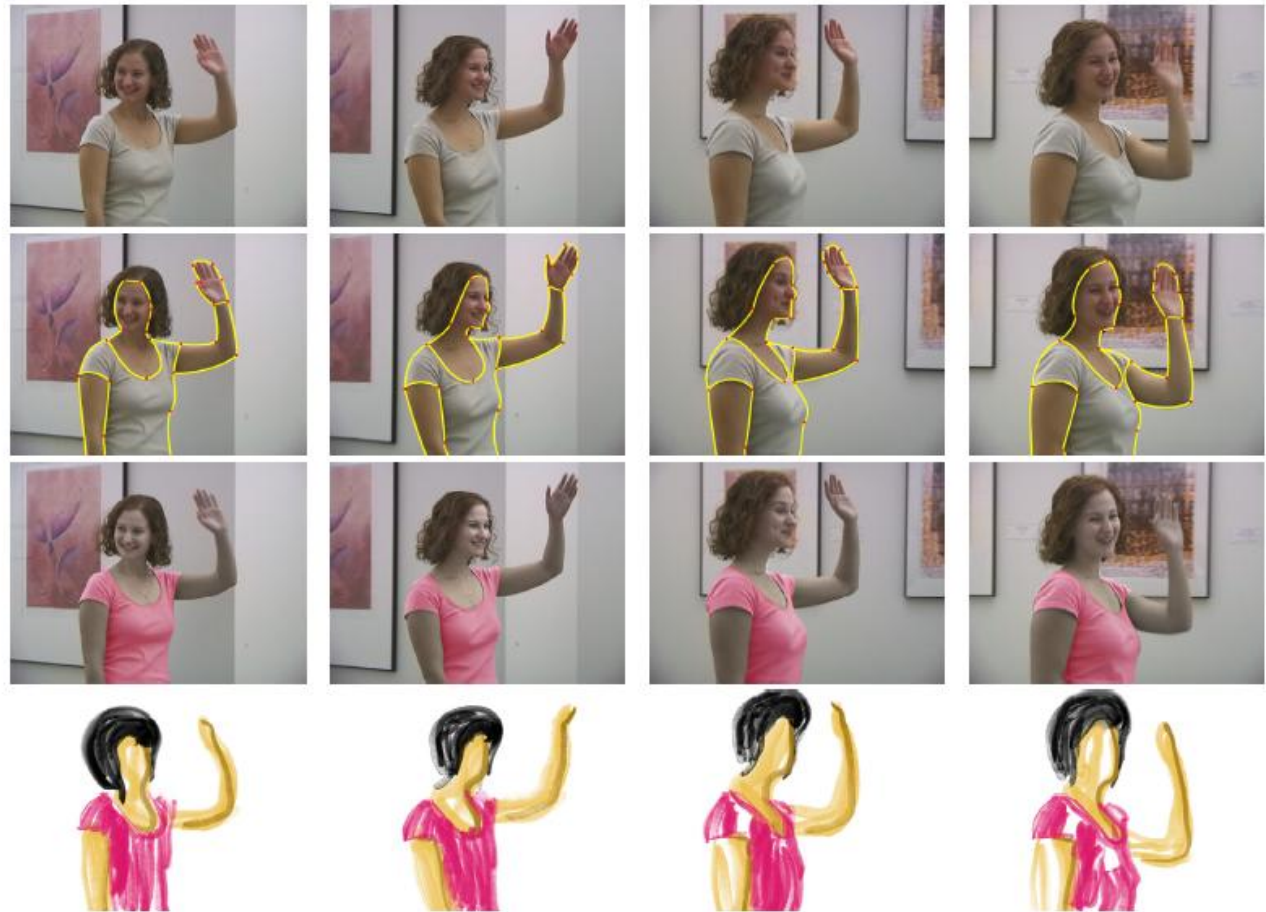
Geometry Processing

- **Mesh parameterization and its application**
  - Geometry image and Seam Computation
  - Geometry texture transfer and synthesis

- **Registration**

- **Feature sensitive geometry processing**
  - Feature classfication and editing
  - Mesh Segmentation

Geometry processing

- **Acquisition and modeling**
  - **Registration**
  - **Topology repair and editing**
  - **parametrization**
- **Feature sensitive geometry processing**
  - **Feature extraction and editing**
  - **segmentation**

3D Data Acquisition and Modeling

- Acquisition and modeling pipeline

Bunny Entity

Scan →

Point Patches

↓ **Registration**

Mesh Generation

Remeshing

Mesh Repair

Topology Editing

...
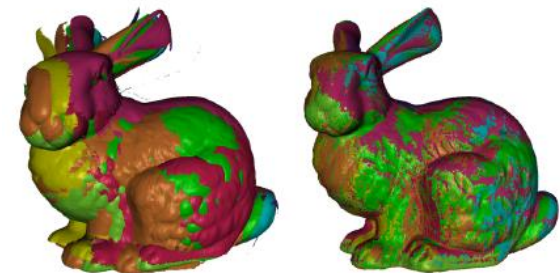
Point Representation

←

Bunny Mesh Model

3D Data Acquisition and Modeling

- Registration of 3D data sets (1)
  - We treat local registration as an optimization problem and study the convergence from the geometry viewpoint.
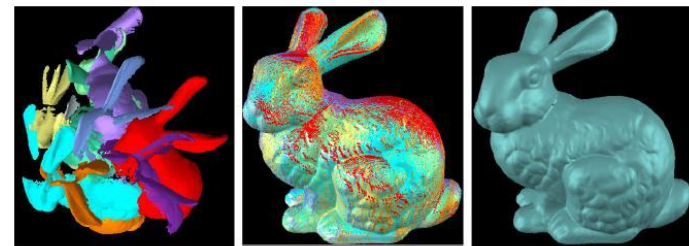
(a)
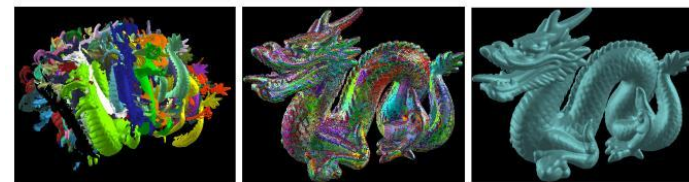
(b)

International Journal of Computer Vision 2006 (Impact factor 6.085)

3D Data Acquisition and Modeling

- Registration of 3D data sets (2)
  - Use robust integral invariants as feature descriptors to compute global registration of fractured objects.

ACM SIGGRAPH 2006
(Impact factor 4.081)

3D Data Acquisition and Modeling

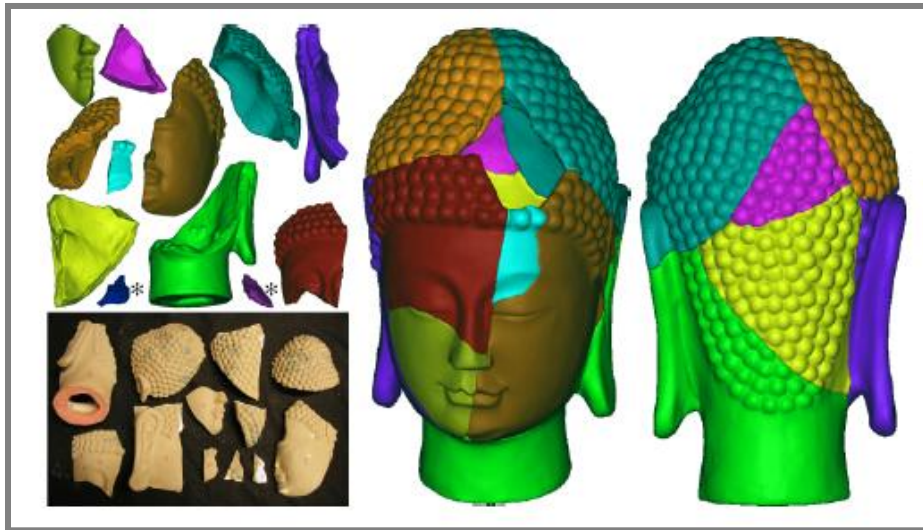- Topology repair and editing of 3D models (1)
  - Meshes from scanned point reconstruction may have geometric and topological errors.
  - We presented a robust and efficient algorithm to repair topological error based on volumetric data.
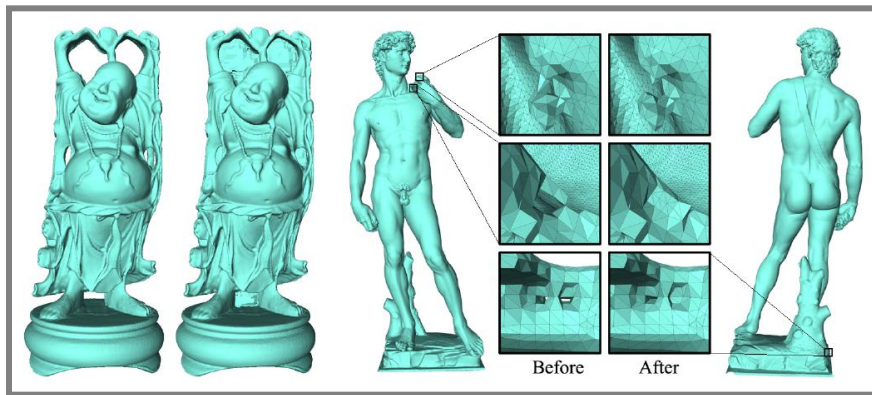
IEEE Transactions on Visualization and Computer Graphics 2007 (Impact factor 1.794)

1087716 and 8254150 Polygons

3D Data Acquisition and Modeling

- Topology repair and editing of 3D models (2)
  - **We also developed a method to edit the topology of the object which meets the user's prospect.**
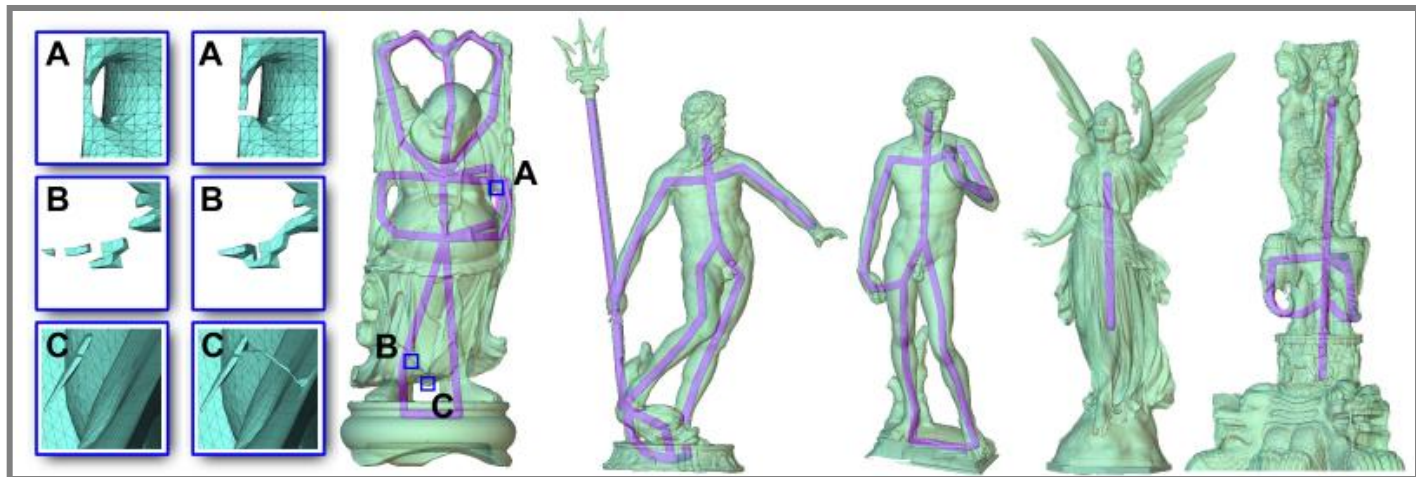
ACM SIGGRAPH 2007

1087716, 8254150, 28055742, 10000000 Polygons

3D Data Acquisition and Modeling

- Geometry Image and
  Skeleton-Based Seam Computation
  - From 3D model to image, using coordinates
    instead of (r,g,b) value

Original (500K faces: genus 1)
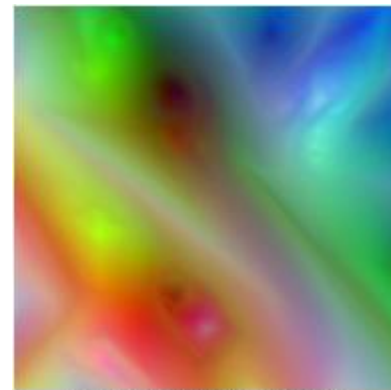
Geometry image (257x257)

- The key of geometry image is to compute the **Seam: Skeleton-Based method** by Zhu Xuping

3D Data Acquisition and Modeling

- **Optimal Surface Parameterization Using Inverse Curvature Map (Ricci Flow)**
  - The major goals during mesh parameterization are to minimize both the angle distortion and the area distortion.

Feature Sensitive Geometry Processing

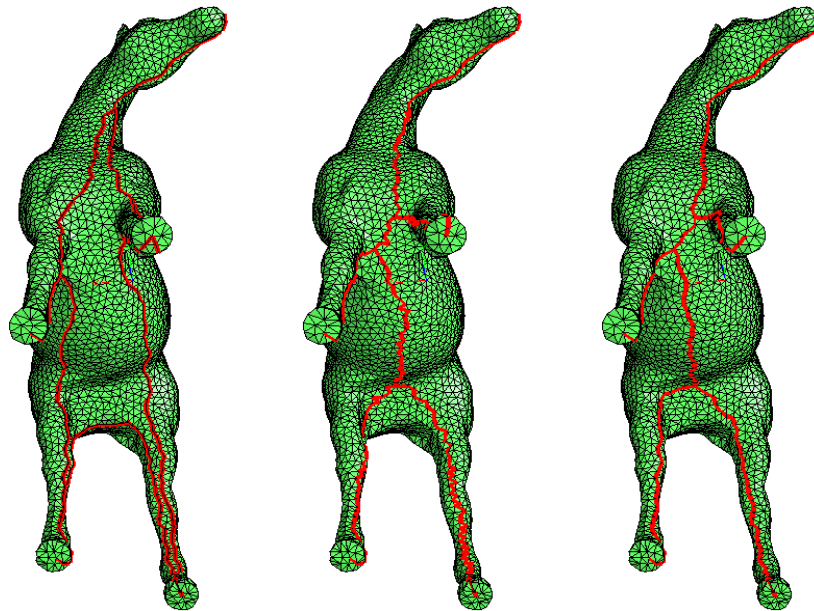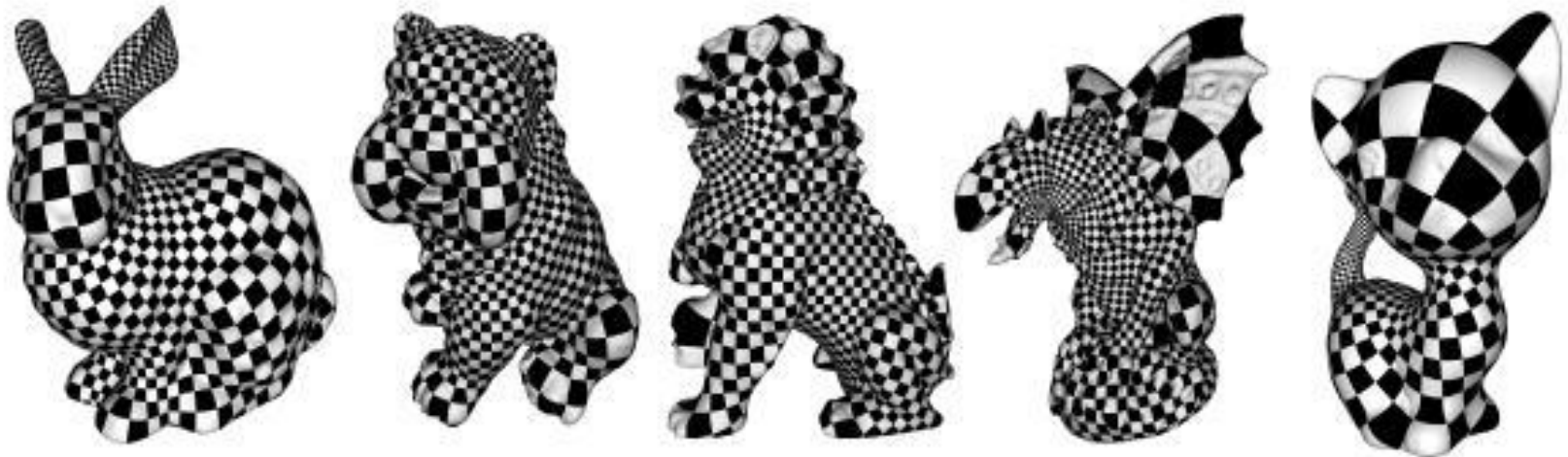- Based on *feature sensitive metric*. It's a framework for handling features on surfaces

- Fs metric definition:
  - based on idea of image manifold
  - Unit normal vectors $\mathbf{n}(\mathbf{x})$ $\mathbf{x} \in \Phi$
  - $\mathbf{x} \in \mathbb{R}^3$ mapped to $\mathbf{x}_f = (\mathbf{x}, w\mathbf{n}) \in \mathbb{R}^6$
  - w: non-negative weight
  - Φ_f : 2-manifold embedded in $\mathbb{R}^6$
  - Fs distance between two points is defined as Euclidean $\mathbb{R}^6$ geodesic distance

Feature Sensitive Geometry Processing

- ## Robust Feature Classification and Editing
  - **A unified framework for feature sensitive geometry processing. Significant features on surfaces are automatically extracted, classified and used for editing.**
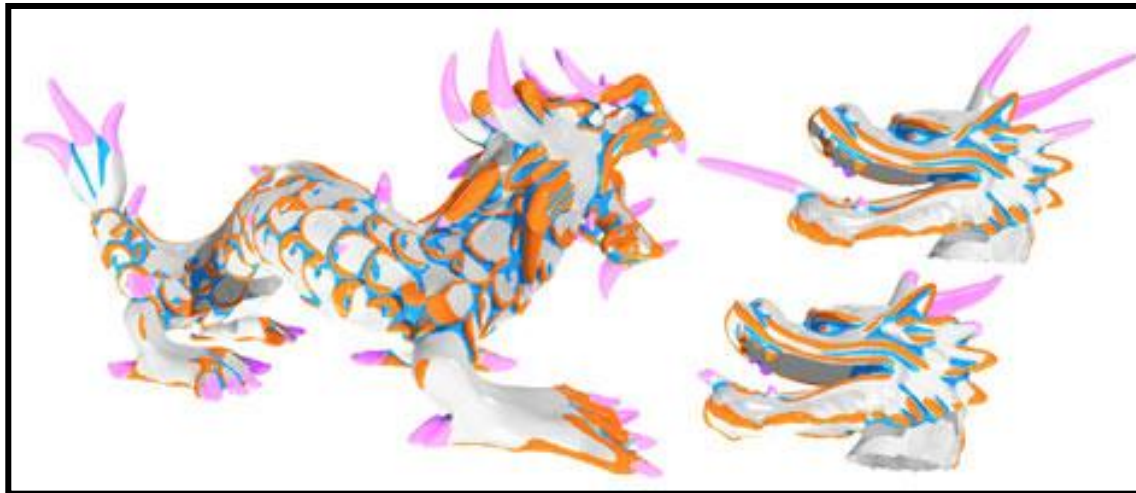
Feature
Extraction,
Classification
and Editing

IEEE Transactions on Visualization and
Computer Graphics 2007

Feature Sensitive Geometry Processing

- ## Feature Sensitive Mesh Segmentation
  - Using integral and statistical invariants and feature sensitive hierarchical remeshing.
  - Fast Mesh Segmentation using Random Walks (400~1200 times fast)
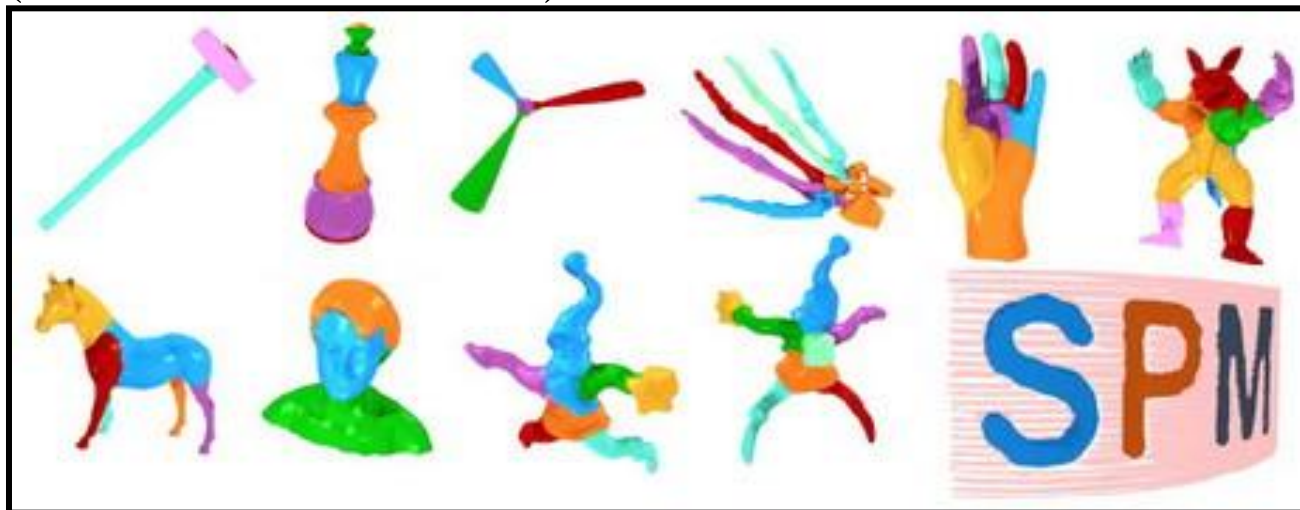
ACM Solid and Physical Modeling 2006, 2008

Video-based Rendering

- **Video-Based Waterfall Animation in Chinese Painting Style**

Demo

- **Vectorizing Cartoon Animations**
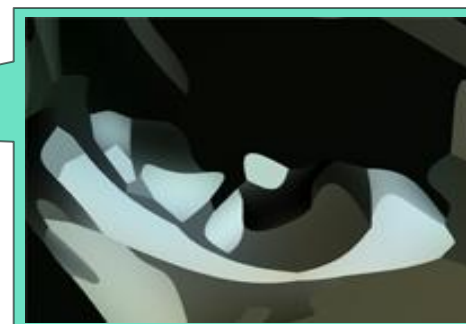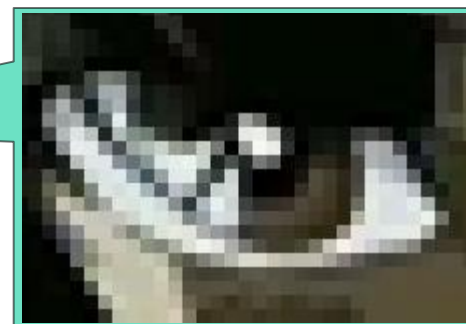
Demo

- Some Results

Top row: original cartoon video
Bottom row: Vectorized cartoon video

- Some Results

Top row: original cartoon video
Bottom row: Vectorized cartoon video

- **Shrinkability Maps for Content-Aware Video Resizing**

demo

- **Shrinkability Maps for Content-Aware Video Resizing**

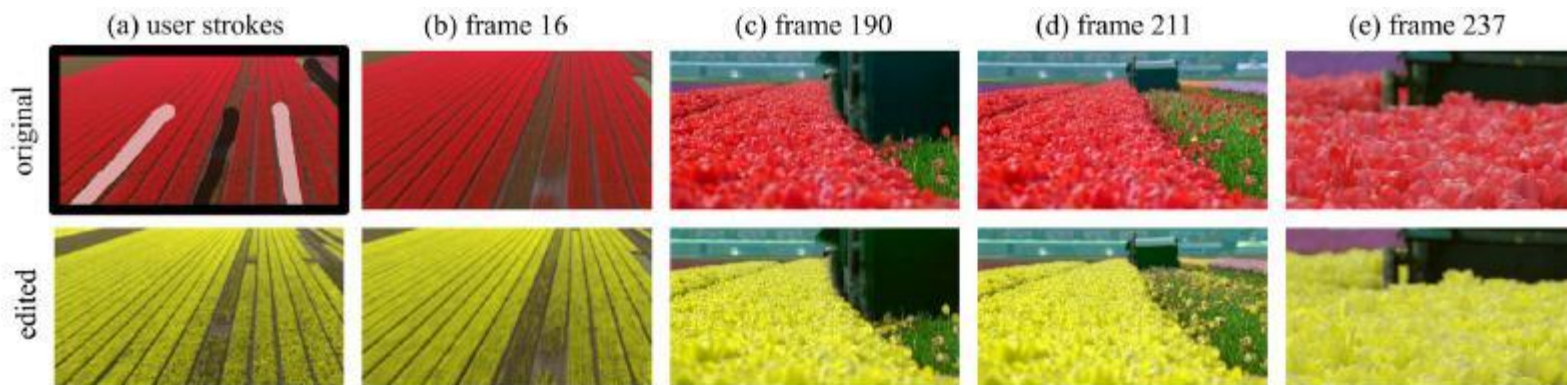**demo**

- **Efficient Edit Propagation on Images and Videos**
  - we present an efficient method for editing images and videos by propagating from sparse and imprecise user inputs.

| (a) user strokes | (b) frame 16 | (c) frame 190 | (d) frame 211 | (e) frame 237 |

ACM SIGGRAPH ASIA 2009

- **Sketch2photo: Internet Image Montage**
  - We present a system that composes a realistic picture from a user provided sketch with text labels. The composed picture is generated by seamlessly stitching several photographs automatically searched from internet according to the sketch and its text labels.
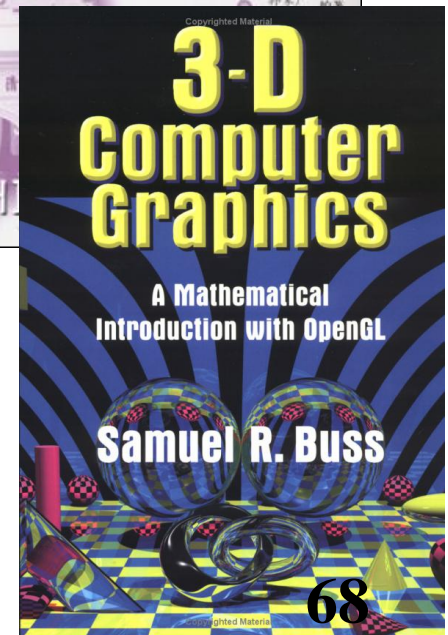
- Sketch2Photo法国获奖

Sketch2Photo被评选为2009年

全球互联网数字媒体领域十大创新技术之一

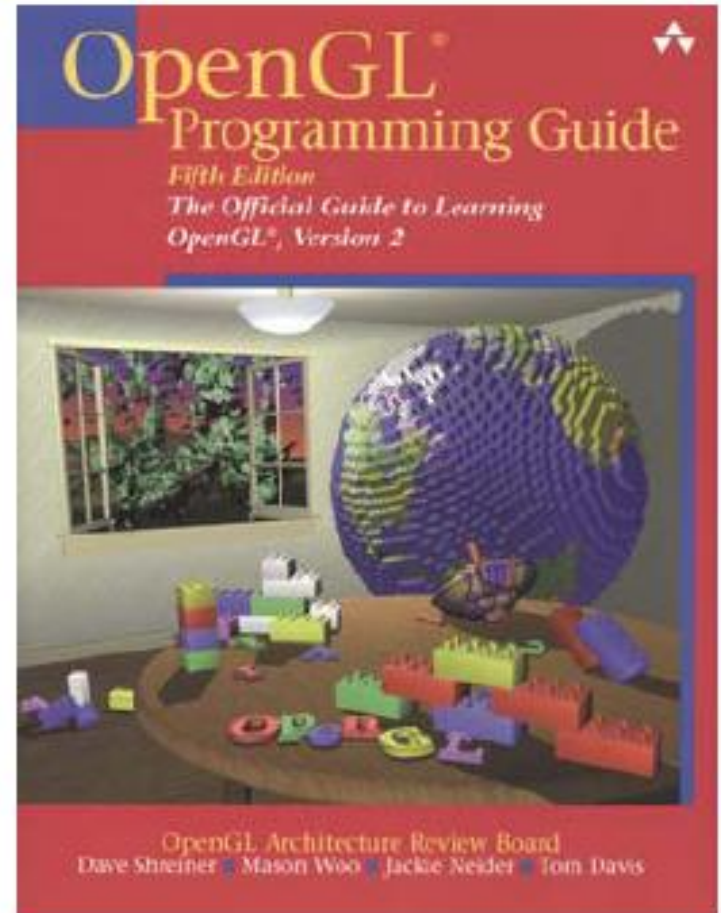# Requirements of the course

- Textbooks
  - 计算机图形学基础

  - **3D Computer Graphics:
    A Mathematical Introduction
    with OpenGL**

  - **Computer Graphics using OpenGL 3rd
    Hill FS, Kelley SM, 胡事民等译。**

  - **Other books can also be used as reference**

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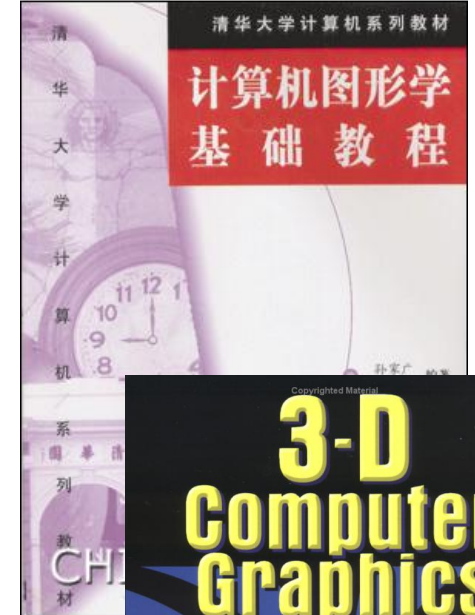
- OpenGL Redbook
  - **Optional but strongly recommend**
  - **OpenGL is a must in computer graphics, you will find this book very useful.**

Grading Policy

- Assignments (100%)
  - A reading assignment   (20%)
  - Homework assignment (20%)
  - Two programming assignments (30%+30%)
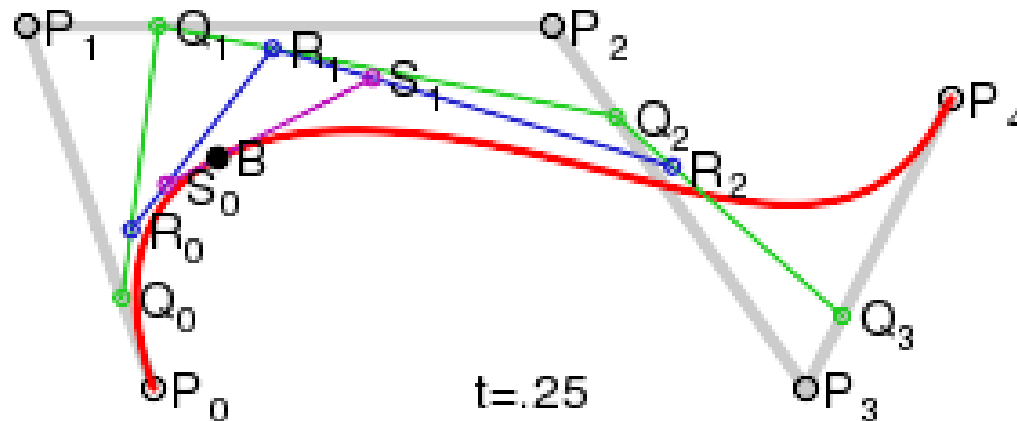
- No Final Exam

Assignments

- Reading (20%)
    - Read Chapter 2 of textbook, and write a report with **5000 chinese characters.**
    - You may choose one topic for your report, such as
        - line rasterization,
        - polygon scan conversion
        - Clipping
        - anti-aliasing
        - hidden surface removal

- Homework assignment (20%)
  - On Bezier and B-spline curves

Assignments

- Projects (60%)
  - **Project 1 (Simple Ray Tracing) (30%)**
    - **Contain primitives of cube, polyhedron, sphere**
    - **Effects : phong model, texture, mirror, transparent, shadow**
    - **Optional: other BRDF models, acceleration techniques, high dimensional texture, soft shadows …**
    - **OpenGL is not allowed to use**

Assignments

- Projects (60%)
  - **Project 2 (Mesh Simplification) (30%)**
    - **Implement edge-collapse simplification algorithm**

    - **Use OpenGL for mesh display**

    - **We will provide a C++ 3D mesh loader library**

Thanks!

- **I. E. Sutherland**
  - 传奇经历：**I. E. Sutherland，38年生，美国人，CMU学士、Catech硕士、MIT博士，59年博士毕业，参军，26岁担任国防部高级研究计划署（DARPA）信息处理技术局局长(仅中尉衔)，该局曾组织Internet前身ARPANet等重大项目。**
  - **1964年起，先后在哈佛、Utah、Catech工作。并创办Evan& Sutherland公司。**
  - 制作一部电影，博士论文答辩时，边放映，边见解，大获成功。 **(PPT ?)**