Computer Graphics

Introduction

Prof. SHENG Bin, CS, SJTU

Outline

▸ Course information

▸ What is computer graphics?

▸ Computer graphics applications and related research areas

Course information

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Course information

▸**Course webpage:** http://www.cs.sjtu.edu.cn/~shengbin/course/cg/home.html

▸ Pre-requisites

▸ A basic familiarity with analytic geometry, calculus, linear algebra

▸ A programming ability on C/C++ programming

Textbook & references

- Textbook
  - D. Hearn, M.P. Baker, and W. R. Carithers.
    Computer Graphics with OpenGL, 4th edition, Pearson Education, 2011.
  - Complementary materials (Papers, books, etc.)
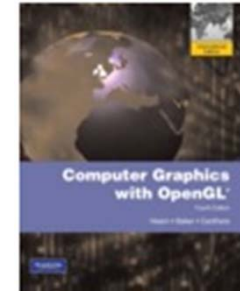
- References
  - *OpenGL Programming Guide: The Official Guide to Learning OpenGL Version 3.0 and 3.1, 7th Edition, 2009. [OpenGL 4.3, 8th Edition, 2013]* *http://www.glprogramming.com/red/*
  - *OpenGL Reference Manual: The Official Reference Manual to OpenGL Version 1.4, 4th Edition, 2004.* *http://www.glprogramming.com/blue/*
  - *OpenGL Shading Language, 3rd edition. Addison Wesley, 2010. (OpenGL3.1, GLSL1.4)*
  - *Graphics Shaders: Theory and Practice, by Mike Bailey etc. A K Peters, 2nd, Oct. 2011.*
  - *OpenGL SuperBible, 4th edition. Addison Wesley, 2007. (OpenGL2.1) [6th edition, 2013. (OpenGL4.3)]*
  - *Ray Tracing from the Ground Up, by Kevin suffern. A K Perter, 2007.*
  - *Game Physics, by David H. Eberly, 2nd edition. Morgan Kaufmann, 2010.*

Textbook & references

▶ *Edition of OpenGL Programming Guide*

  ▶ The latest

   ▶ *8th Edition, 2013 -> OpenGL Version 4.3*

  ▶ The previous

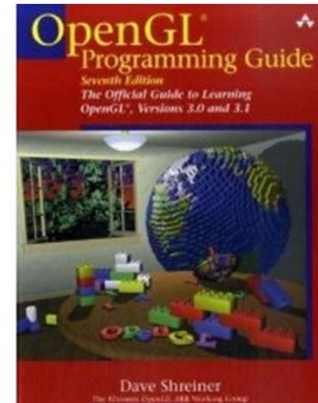   ▶ *7th Edition, 2009 -> OpenGL Version 3.0 and 3.1*

   ▶ *6th Edition -> OpenGL Version 2.1*

   ▶ *5th Edition -> OpenGL Version 1.5 and 2.0*

   ▶ *4th Edition -> OpenGL Version 1.3 and 1.4*

   ▶ *3rd Edition -> OpenGL Version 1.2*

   ▶ *1st, 2nd Edition -> OpenGL Version 1.1*

The latest version currently: OpenGL4.4, released on July 22, 2013.

http://www.opengl.org/documentation/current_version/

Grading policy

▶Course Projects: 70%

  Mid-term evaluation: 20%

  Final Exam: 50%

▶Assignments: 30

  ▶ No late assignment and programming practice is accepted usually

Main topics

- Graphics hardware & software

- Graphics theories & algorithms

  - Graphics primitives, modeling and viewing transformation, clipping, lighting and illumination / shading

- Graphics programming in OpenGL/GLUT

- Interactive input methods & CG User Interface

- Advanced topics* (chosen from the following topics)

  - Physically based simulation

  - Advanced techniques directed to real-time rendering

  - Computer Graphics in Virtual Reality and Augmented Reality

  - Paper discussion

- It is not a course about graphic design, using graphics tools like PhotoShop or Maya

How to learn

▶ Reading the books and complementary material is necessary

▶ Reading more references and papers is encouraged

▶ Learning by doing

▶ Practice!!

  ▶ "Try it and see!"

  ▶ Writing programs to test various concepts and techniques

Computer Graphics
Introduction

What is Computer Graphics?

- Computer Graphics
    - Coined in 1960 by William Fetter, a graphic designer for Boeing.
    - Business of generating images: **C**omputer-**G**enerated **I**mages
   - Images are made up of pixels.
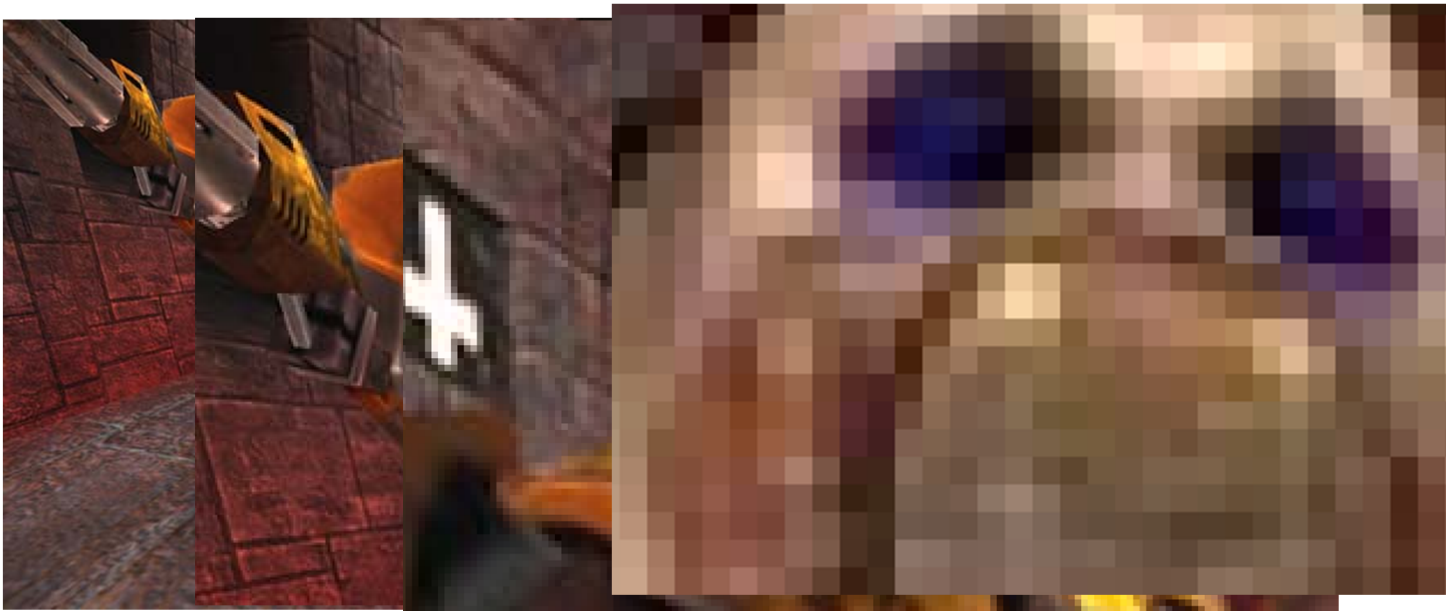
What is Computer Graphics?

Computers depict the world by putting pixels on 2D screen

▸ How to make it look like the 3D thing on 2D screen?
- Shape
- Surface information
- Lighting
- Perspective

What is Computer Graphics?

▸ How to make it look like the real 3D thing on 2D screen?

　▸ **Shapes**: straight lines, triangle, squares, circles, …

　▸ Small shapes to be put together into a structure, called wireframe
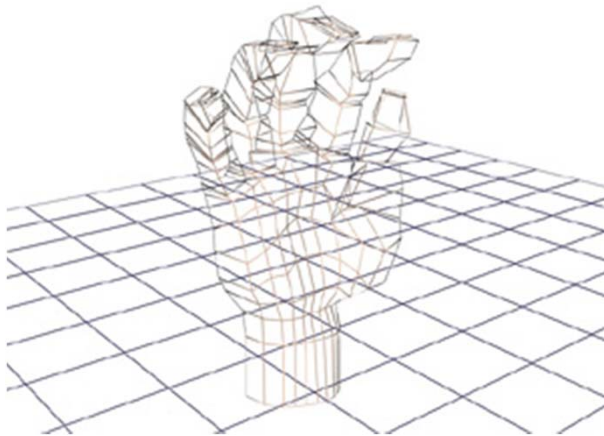
The wireframe of a hand made from relatively few polygons -- 862 total.
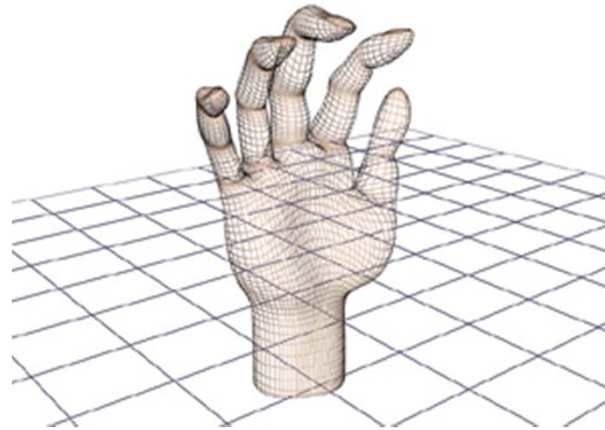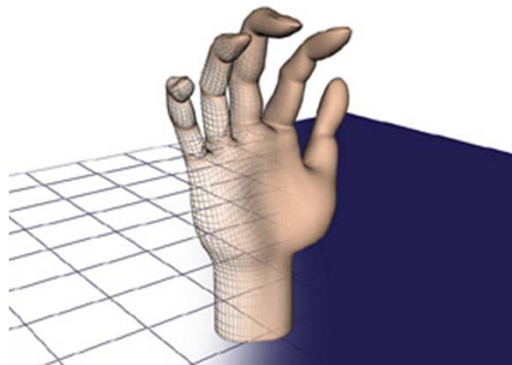
More natural and rounded, but many more polygons -- 3,444.

What is Computer Graphics?

- How to make it look like the real 3D thing on 2D screen? (cont.)

  - **Surface information**

    - Color: what color is it? Is it the same color all over?

    - Texture(纹理/质地): Does it appear to be smooth, or any irregularity on the surface?

    - Reflectance(反射): How much light does it reflect? Sharp or fuzzy?

Adding a surface to the wireframe begins to change the image from something obviously unreal to a picture we might recognize as a hand.
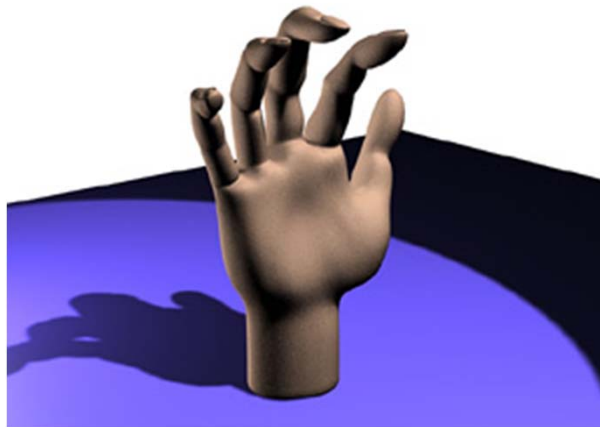
What is Computer Graphics?

- How to make it look like the real 3D thing on 2D screen? (cont.)

  - **Lighting:** play a key role in two effects

    - Shading: when a light shining on an object is stronger on one side than on the other. Illusion of depth, height and width.

    - Shadows: illusion of weight of 3D objects

Lighting in an image not only adds depth to the object through shading, it "anchors" objects to the ground with shadows.

What is Computer Graphics?

▸ <u>How to make it look like the real 3D thing on 2D screen?</u>
<u>(cont.)</u>

    ▸ **Perspective (透視):** the objects in a scene look like they eventually converge at a single point in the distance.

What is Computer Graphics?

- ▸ Computer Graphics
  - ▸ Generate 2D images of a 3D world scene represented in a computer.

- ● Main tasks
  - ● *Modeling*: (shape) creating and representing the geometry of objects in the 3D world
  - ● *Rendering*: (light, perspective) generating 2D images of the objects
  - ● *Animation*: (movement) describing how objects change in time

Computer Graphics Applications
and
Related Research Areas

Early applications of computer graphics

▶ Data Visualization

 ▶ Graphs and charts

  ▶ line/surface graphs,
    bar/pie charts, …

  ▶ For summarize financial,
   statistical, economic…data
    for reports.

(From: http://www.dotnetgoodies.com/ and http://shipanalysis.com)

Early applications of computer graphics

- **Computer Aided Design (CAD)**

  - CAD/CADD (Computer Aided Drafting & Design)

  - CAM (Computer Aided Manufacturing)

  - Semiconductor (IC, LSI, VLSI) Product Design

- **Used in the design of buildings, automobiles, aircraft, watercraft, spacecraft, computers, … etc.**

  - Better way to transfer of design ideas

    Ohio State Univ. - Section 10: CAD/CAM/CADD/CAE
    http://design.osu.edu/carlson/history/lesson10.html
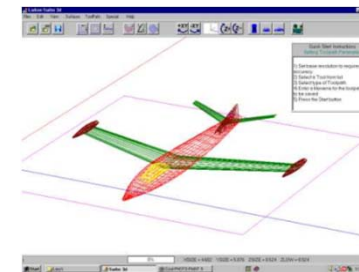
Early applications of computer graphics

- Computer Aided Design (CAD)

  Case: Boeing 777, based CAD system: CATIA (Computer-Aided Three-dimensional Interactive Application)

 **"100% digitally designed using 3D solids technology"**

  - Boeing reaped huge benefits from design automation
    - Elimination of > 3000 assembly interfaces, without any physical prototyping
    - 90% reduction in engineering change requests (6000 to 600)
    - 90% reduction in material rework
    - ……

Computer graphics applications

▶ VR (Virtual Reality) Environments

▶ VR: User interacts and views with a 3D world using "more natural" means

Ohio State Univ. - Section 17: Virtual Reality
http://design.osu.edu/carlson/history/lesson17.html
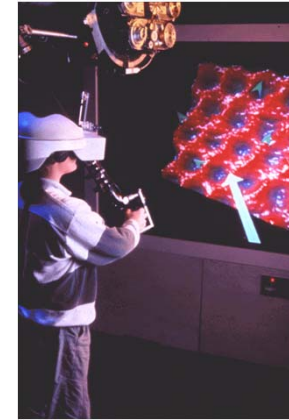
Multi-projector VR system used for training at the Nellis Air Force Base in Nevada. (From:
http://www.gizmodo.com.au/2007/10/military_vr_simulator_is_close/)
Video:
MilitaryVR-5Channels
MilitaryVR-4Projector

Computer graphics applications

- **Education and Training**
  - Graphics are used to generate models of physics, financial, political, social, economic, and other as educational aids.
  - Computer Aided Instruction (CAI)
  - Examples: flight simulators, ships simulators, heavy-equipment operators.
  - flight-simulator
  - simulator-intro
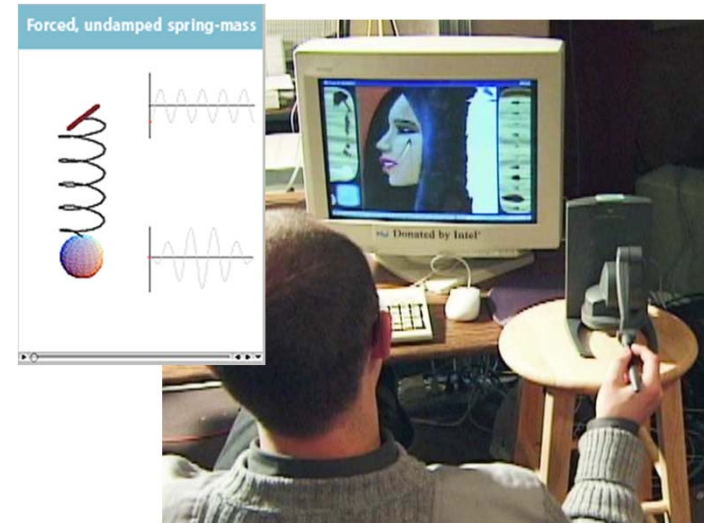
Computer graphics applications

▸ **Augmented Reality**

  ▸ Combine the virtual and the real world together.

▸ **Three features**

  ▸ Combines real and virtual

  ▸ Interactive in real time
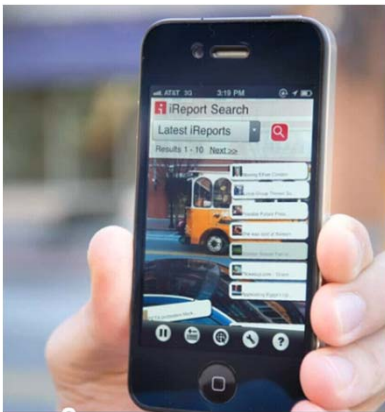
  ▸ Registered in 3D

Fig. 1. A typical "backpack" setup (left) for Mobile AR versus a lightweight handheld

Head-Mounted Display   Smart Phone

*(From: Towards Massively Multi-User Augmented Reality on Handheld Devices)*

*Argon: the Augmented Reality Web Browser,
by Georgia Tech.*

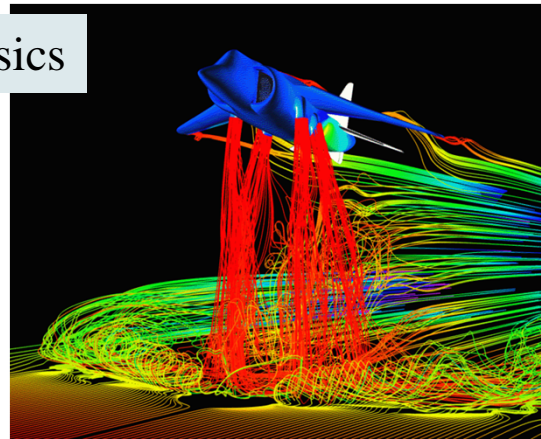# Computer graphics applications

▶ Data Visualizations

  ▶ Scientific Visualization: to graphically represent scientific, engineering, or medical data, and to analysis the data

    ▶ Visualizing millions to billions of data points

    ▶ Exploring results from numerical analysis
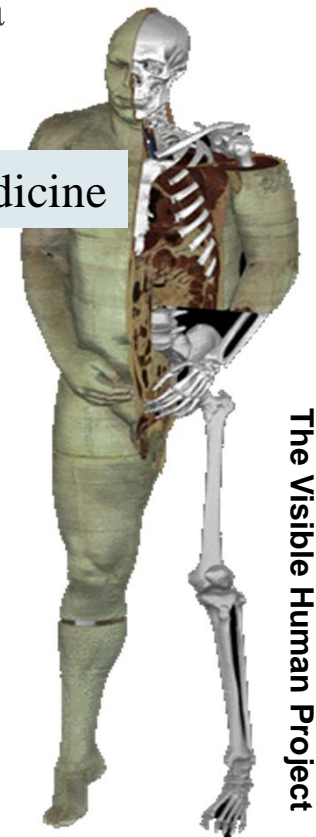
    ▶ Getting the meaning from complex data sets

Medicine

Biology
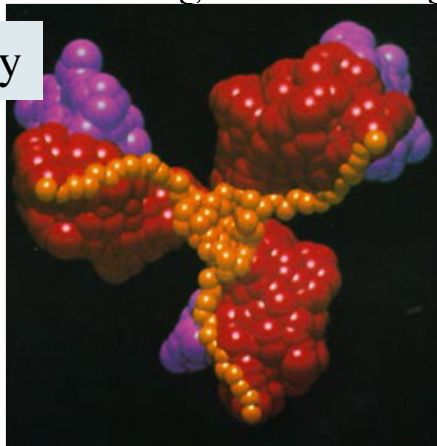
Physics

Frame from Nelson Max DNA visualization

Airflow around a Harrier Jet
(NASA Ames)

The Visible Human Project

Computer graphics applications

▶ Computer Art

▶ Electronic Cartoon, Watercolor/Oil Painting, Fine Arts

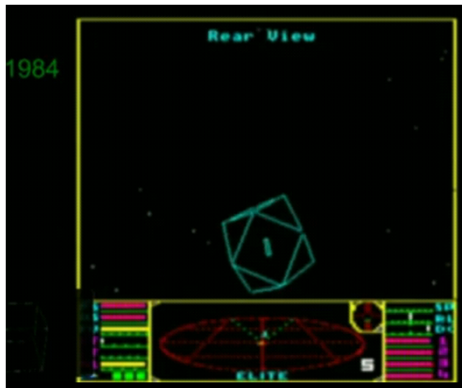Lillian Schwartz: After Picasso

CGI Characters by *Ryan Kittleson*

watercolor illustrations
(graphics.uni-konstanz.de)

Computer graphics applications

Evolution of 3D graphics in video games (1984-2008)

History of CGI in movie (1973-2007)

Computer graphics applications

Pixar: Monster's Inc.

▶ Entertainment

▶ Music Video (MTV), Television Show, Movie and Game

1999: The Matrix

2003: The Lord of the Rings - Gollum

1995: Toy Story, 1st full CG feature film


Final Fantasy *(Square, USA)*

2009

Computer graphics applications

Animators can use CG techniques to animate almost anything now in a movie!

- 2009: Avatar

  - How can all of these implemented into a rich 3D, CG scene?

  - Motion-capture
    - The actor/actress is dressed in a special suit;
    - A set of video cameras records from different places;
    - Motion data is input into the computer as the movements for the virtual character
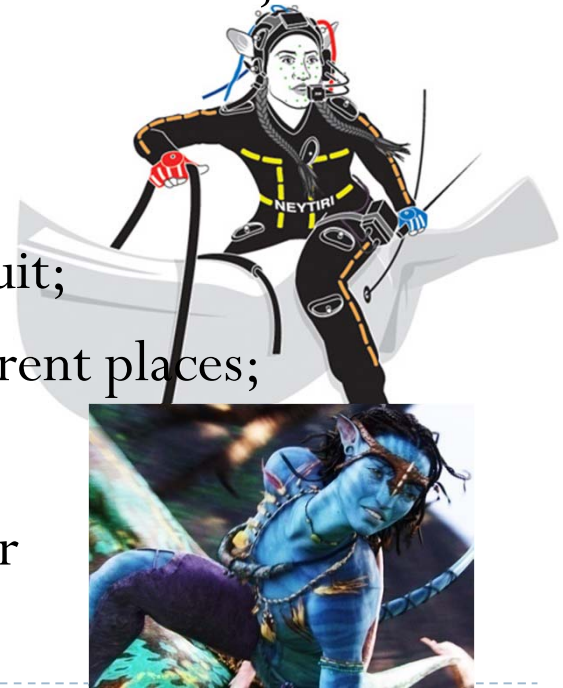
Research Highlights in Computer Graphics

‣ A annual conference on computer graphics convened by ACM SIGGRAPH organization from 1974.

http://s2013.siggraph.org/

   ‣ Technical papers session: the novel and high-quality research

   ‣ Computer Animation Festival: recently created CG films are played

   ‣ Courses, talks, panels and posters

   ‣ Sessions for arts: art gallery, art papers and studio

   ‣ Exhibition: companies in the engineering, graphics, motion picture…

‣ SIGGRAPH AISA, Euro Graphics, Pacific Graphics, SCA (Symposium on Computer Animation) …

‣ CG-related Journals

   ‣ ACM TOG, IEEE TVCG, IEEE CG&A, CGF, TVC, CAVW, …
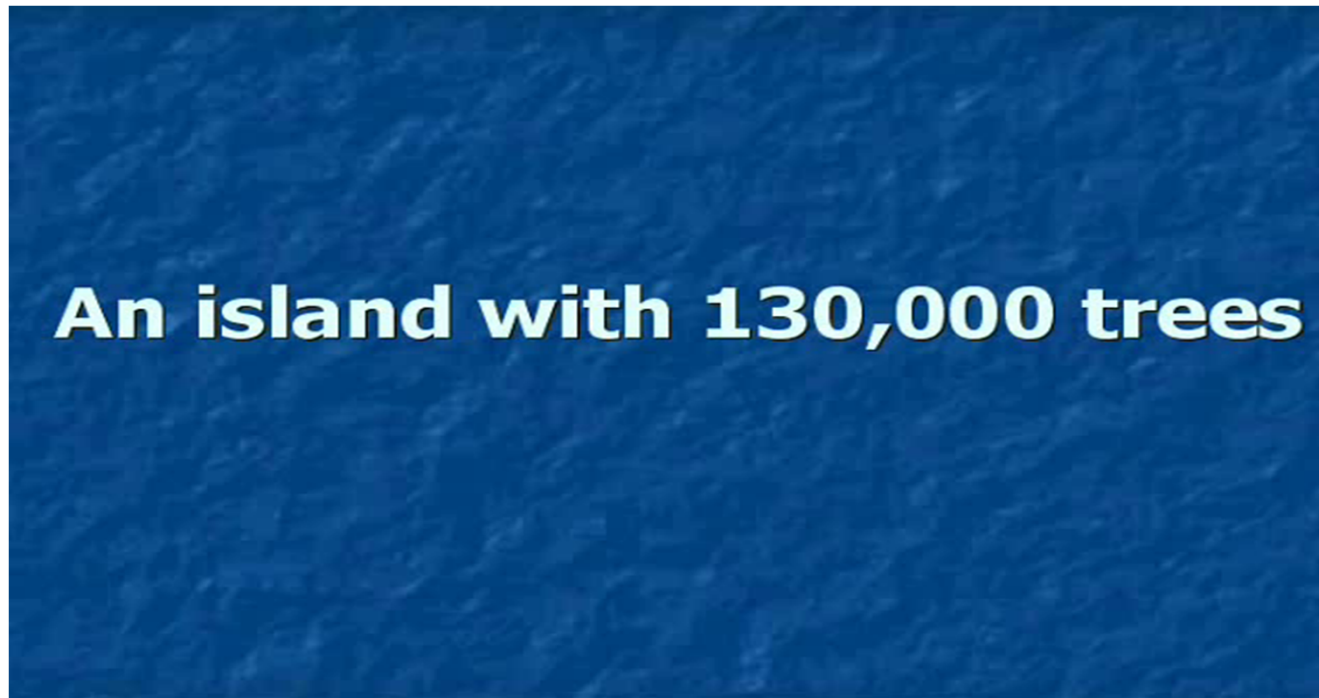
Research Highlights in Computer Graphics

▶ Topics (cont.)

▶ Rendering

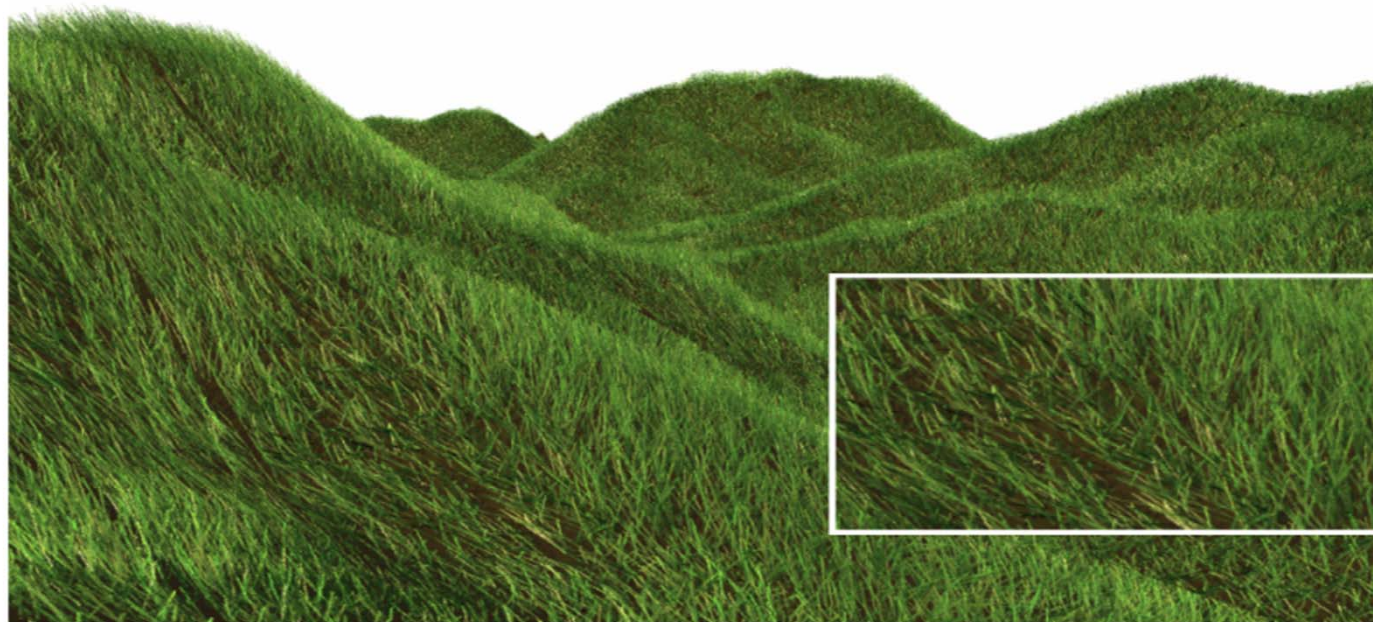▶ Computer animation

Research Highlights in Computer Graphics

- Topics (cont.)
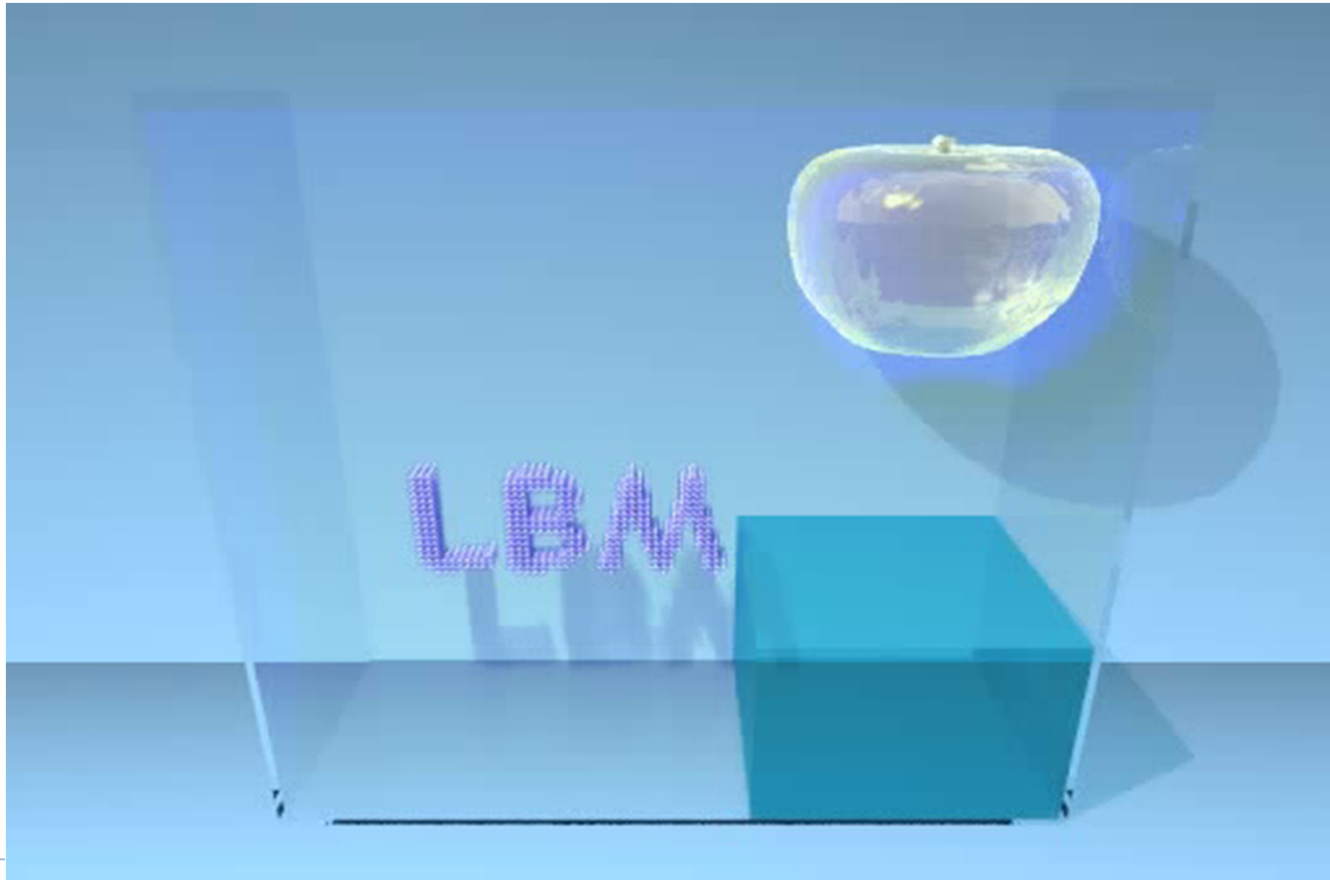 - Modeling and Rendering of large scale natural models

An island with 130,000 trees

Research Highlights in Computer Graphics

▶ Topics (cont.)

▸Time varying simulation of natural grassland

Research Highlights in Computer Graphics

- Topics (cont.) : Physically Based Modeling and Rendering (1)

Research Highlights in Computer Graphics

- Topics (cont.)
  - Physically Based Modeling and Rendering (2)

Research Highlights in Computer Graphics

- Topics (cont.):Physically Based Modeling and Rendering (3)

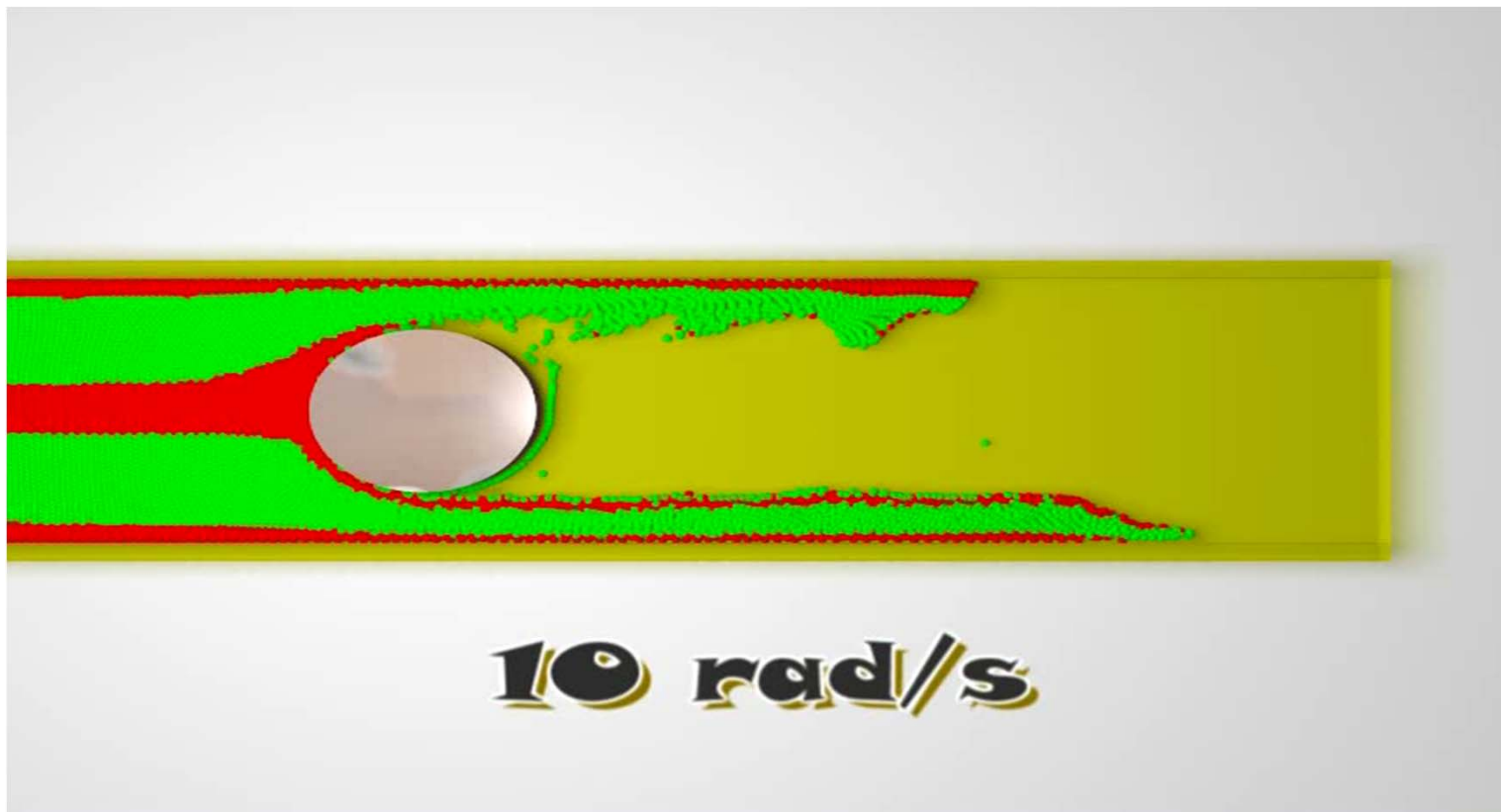 Videos_Wu\monroe1.mpg   (PG2005)

Research Highlights in Computer Graphics

▶ Topics (cont.): Physically Based Modeling and Rendering (3)

Research Highlights in Computer Graphics

- Topics (cont.): Physically Based Modeling and Rendering (3)

Research Highlights in Computer Graphics

▶ Topics (cont.): Filming   Effects

Research Highlights in Computer Graphics

▸ Topics (cont.): Video Layers Resconstruction (segmentation)

Research Highlights in Computer Graphics

▸ Topics (cont.): Augmented Reality

End