EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

FACULTY OF
SCIENCE
Computer Graphics

Computer Graphics (Graphische Datenverarbeitung)

- Introduction -

WS 2022/23

Overview

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- Today
  - Administrative stuff
  - History of CG
  - Photo Realism

  - Math Primer

- Next
  - Geometric Primitives
  - Triangle Meshes
  - Ray-Triangle Intersections

CG lecture
Administrative Issues

General Information

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- 4 V + 2 Ü
- Lectures in English
- Time and Location
  - Tue, 8:15-10, F122
  - Thu, 14-15, F122
  - Lectures will be recorded

- ECTS:
  - 9 credit points

- Web-Page
  - www.graphics.uni-tuebingen.de
  - ILIAS
  - Schedule, Slides as PDF
  - Literature, Assignments, other Information

Team

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- Lecturer
  - Hendrik Lensch
    - Maria-von-Linden-Str. 6, 20-7/A24
    - E-mail: hendrik dot lensch at uni-tuebingen.de

- Assistants
  - Faezeh S Zakeri
    - Maria-von-Linden-Str. 6, 20-30/A24
    - E-mail: faezeh-sadat dot zakeri at uni-tuebingen.de at uni-tuebingen.de

  - Lukas Ruppert
    - Maria-von-Linden-Str. 6, 20-30/A24
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  - Raphael Braun
    - Maria-von-Linden-Str. 6, 20-30/A18
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Exercise Groups

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- Wed 10–12, F122

- **You need to register:**
  - ILIAS
  - apply for WSI account

Weekly Assignments

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- Weekly assignment sheets
  - Theoretical & programming assignments
    - You will build your own ray tracing system

Without the exercises you will have a hard time passing the exam

- **You need to reach at least 50% in the exercises to be admitted to the exam!**

- On good performance (> 75%) in the exercises you can earn a bonus of 0,3 for your final grade if you pass the written exam.

Weekly Assignments

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- Weekly assignment sheets
  - Hand in assignments by next Monday
    - PDFs and Code via ILIAS
  - Exercise meetings
    - You present correct solutions
    - Discuss problems with teaching assistant
  - Groups of max. 2 students allowed

Java to C++ Mini Course

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- As the exercises will be in C++
  - we do offer a tiny course on C++
  - explain the differences to Java

- You will learn
  - how to compile your own C++ program
  - how to chase segmentation faults

Wednesday, 19.10.!!

Grading

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- Final Exam
  - Written exam:
    Dates tba
  - Minimum: 50% to pass

- Exercises
  - **Permission to participate in final exam if > 50%**
  - Bonus of 0.3 if > 75%

Text Books

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- Suggested Readings:
  - Matt Pharr, Greg Humphreys, ***Physically Based Rendering : From Theory to Implementation***, Morgan Kaufmann Series, 2005
  - Peter Shirley, ***Fundamentals in CG***, 2. Ed, AK Peters, 2005
  - Alan Watt, ***3D Computer Graphics***, Addison-Wesley, 1999

  - Foley, Van Dam, et al., ***Computer Graphics: Principles and Practice***, Addison-Wesley, 2. Ed, 1996
  - Andrew Glassner, ***An Introduction to Ray-Tracing***, Academic Press, 1989
  - Andrew Glassner, ***Principles of Digital Image Synthesis***, 2 Bände, Morgan Kaufman, 1995

  - Andrew Woo, et al., ***OpenGL Programming Guide***, 3. Ed., Addison-Wesley, 1999
  - Thomas Akenine-Möller, Eric Haines, ***Real-Time Rendering***, 2nd Ed., AK Peters, 2002
  - Randima Fernando, Mark Kilgard, ***The Cg Tutorial***, Addison Wesley, *2003*
  - Randima Fernando, ***Cg Gems***, Addison Wesley, 2004

Course Syllabus (1)

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- Geometric Primitives
  - Triangles, Meshes
  - Ray/Triangle Intersections
- Transformations
  - Camera Transformations
- Ray Tracing
  - Basics intersections
  - Acceleration structure
- Light Transport
  - Shading / BRDFs
  - Rendering Equation
  - Path Tracing
- OpenGL

Course Syllabus (2)

- Textures
  - Bilinear Interpolation
  - MipMapping
  - Environment Mapping
- Aliasing
  - Fourier Analysis
  - Antialiasing / Super Sampling
  - Importance Sampling
- Volumes
  - Rendering
  - Visualization
- Image-Based Rendering
  - Light Fields

Course Syllabus (3)

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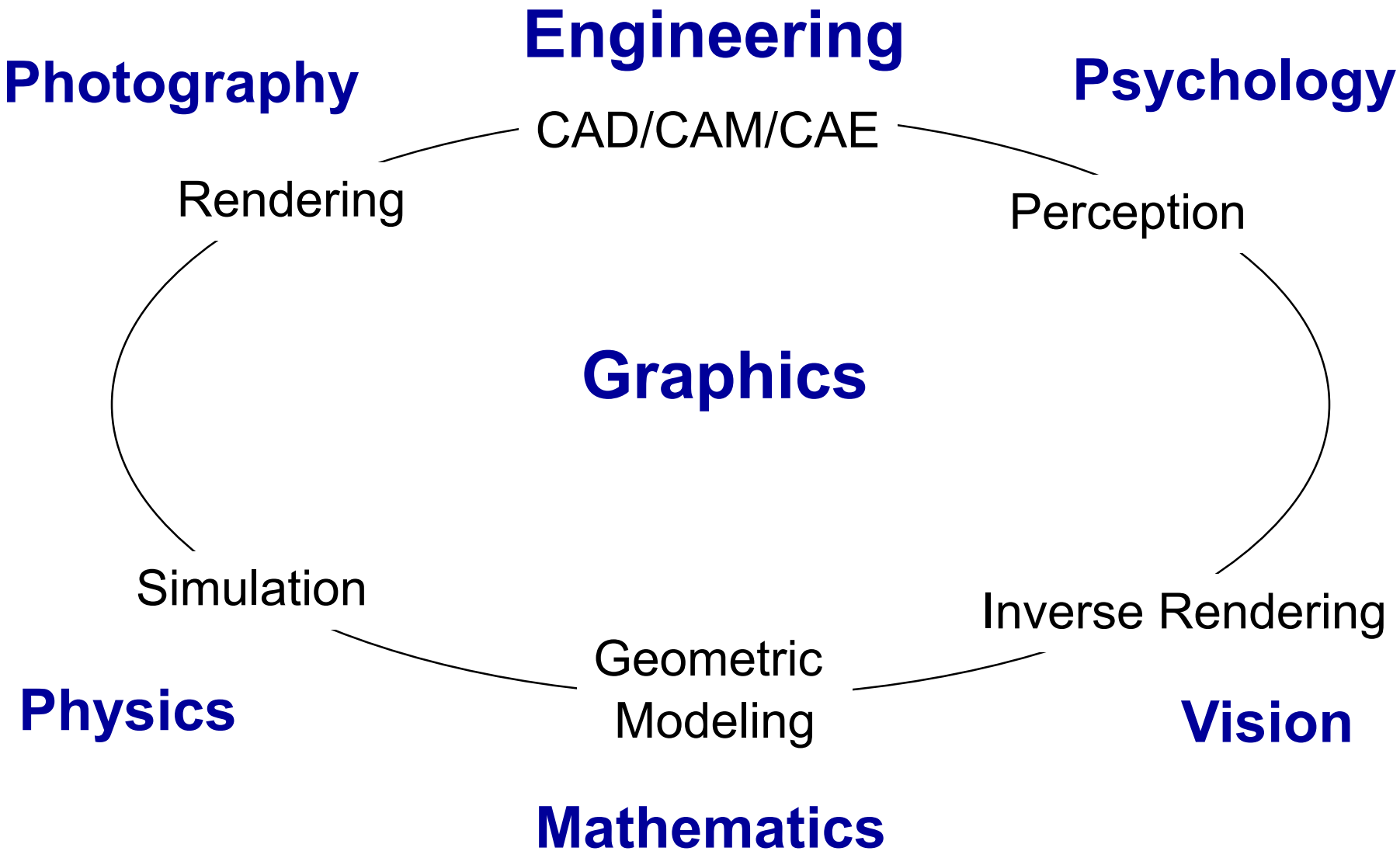
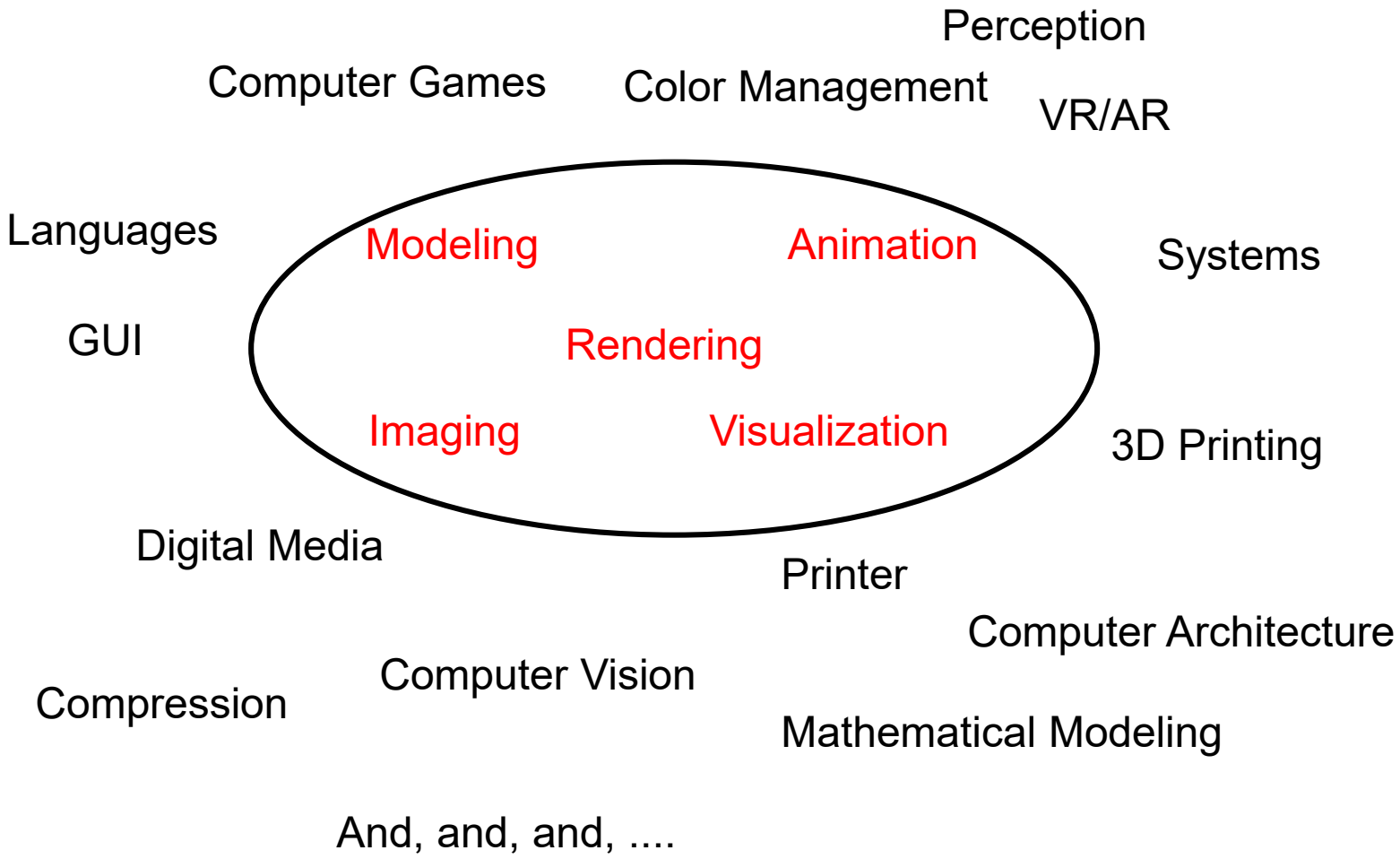
- Neural Rendering
  - Deep Signed Distance Functions
  - NeRF – Neural Reflectance Fields
- Modelling
  - Splines
  - Subdivision Surfaces
- Color
  - Color Spaces
  - HDR
  - Composition
- Realtime Rendering

What is Computer Graphics ?



What is Computer Graphics?



Historical Perspective

- A short history of graphics:
  - 1950: MIT Whirlwind (CRT)
  - 1955: Sage, Radar with CRT and light pen
  - 1958: Willy Higinbotham “Tennis for Two”
  - 1960: MIT „Spacewar“ on DEC PDP-1
  - 1963: Ivan Sutherland‘s „Sketchpad“ (CAD)
  - 1969: ACM Siggraph founded
  - 1968: Tektronix storage tube ($5-10.000)
  - 1968: Evans&Sutherland (flight simulators) founded
  - 1968: Douglas Engelbart: computer mouse
  - 1970: Xerox: GUI
  - 1971: Gouraud shading
  - 1974: Z-buffer
  - 1975: Phong shading model
  - 1976: First animations rendered
  - 1979: Eurographics founded
  - 1980: Whitted: Ray tracing

Historical Perspective

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- A short history of graphics (Cont.):
  - 1981: Apollo Workstation, IBM PC
  - 1982: Silicon Graphics (SGI) founded
  - 1984: X Window System
  - 1984: First Silicon Graphics Workstations (IRIS GL)
  - Until mid/end of 1990s: Dominance of SGI in the high end
    - HW: RealityEngine, InfiniteReality, RealityMonster, ...
    - SW: OpenGL, OpenInventor, Performer, Digital Media Libs, ...
  - End of 1990s:
    Low- to mid range taken over by „PCs“ (Nvidia, ATI, ...)
    - HW: Fast development cycles, Graphics-on-a-chip, ...
    - SW: Direct 3D & OpenGL, computer games
  - 1995: First feature film “Toy Story”
  - 1996: Image-based Rendering
  - 2001: Featuring (realistic) virtual humans “Final Fantasy”
  - 2006: GeForce-8-Series: Fully programmable GPU
  - 2009: Reinvention of Stereo: “Avatar”
  - 2016: Vulkan

Historical Perspective

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- A short history of graphics (Cont.):
  - Today computer graphics is ubiquitous
    - Movies, games, ads, medicine, CAD, visual analytics, ….
    - On any device: cell phone, camera, TV, cars ….
    - Realtime ray tracing
    - Programmable graphics hardware, GLSL, Cuda
  - Computer graphics technology has been driven by games
    - This trend has reach other areas in computer science.
    - Massively parallel computing for image processing, simulation, or machine learning

Photo Realism

CG will change the way you look at and perceive the world around you

Photorealistic Rendering

- long standing goal
  in computer graphics
- ingredients:
  - camera model
  - scene model
  - illumination model
  - rendering algorithm

Image Intensity - Dynamic Range

- loss of contrast in dark / bright areas

Same Scene – Different View

left

right

Perspective

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- How can the same room look so different?

Perspective

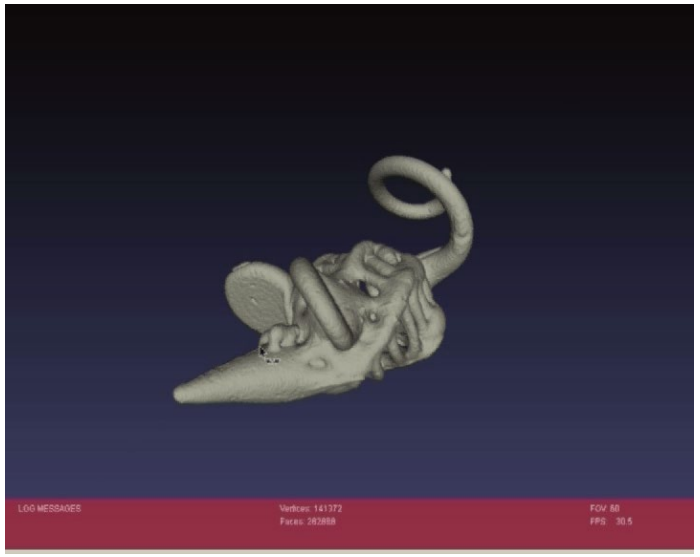
- How can the same room look so different?

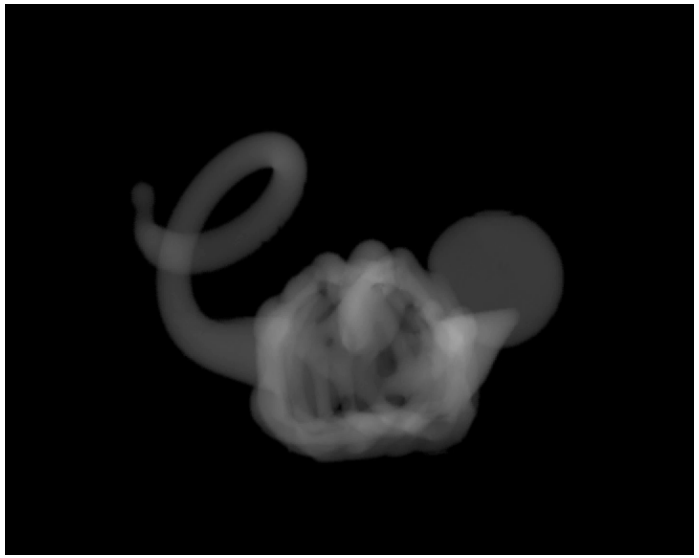
Lens Properties

- focus, depth of field, aberrations

Scene Description

Visualization of Complex Geometry

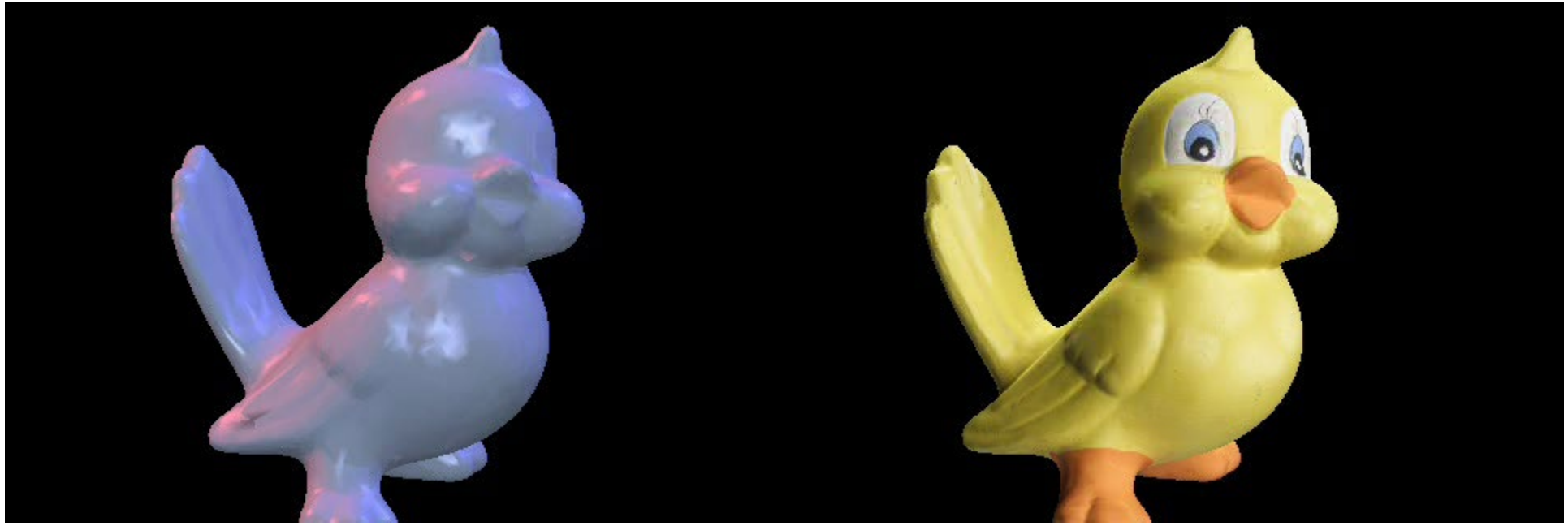




[Hullin, Fuchs, Ihrke, Seidel, Lensch – SIGGRAPH 2008]

Realistic 3D Model

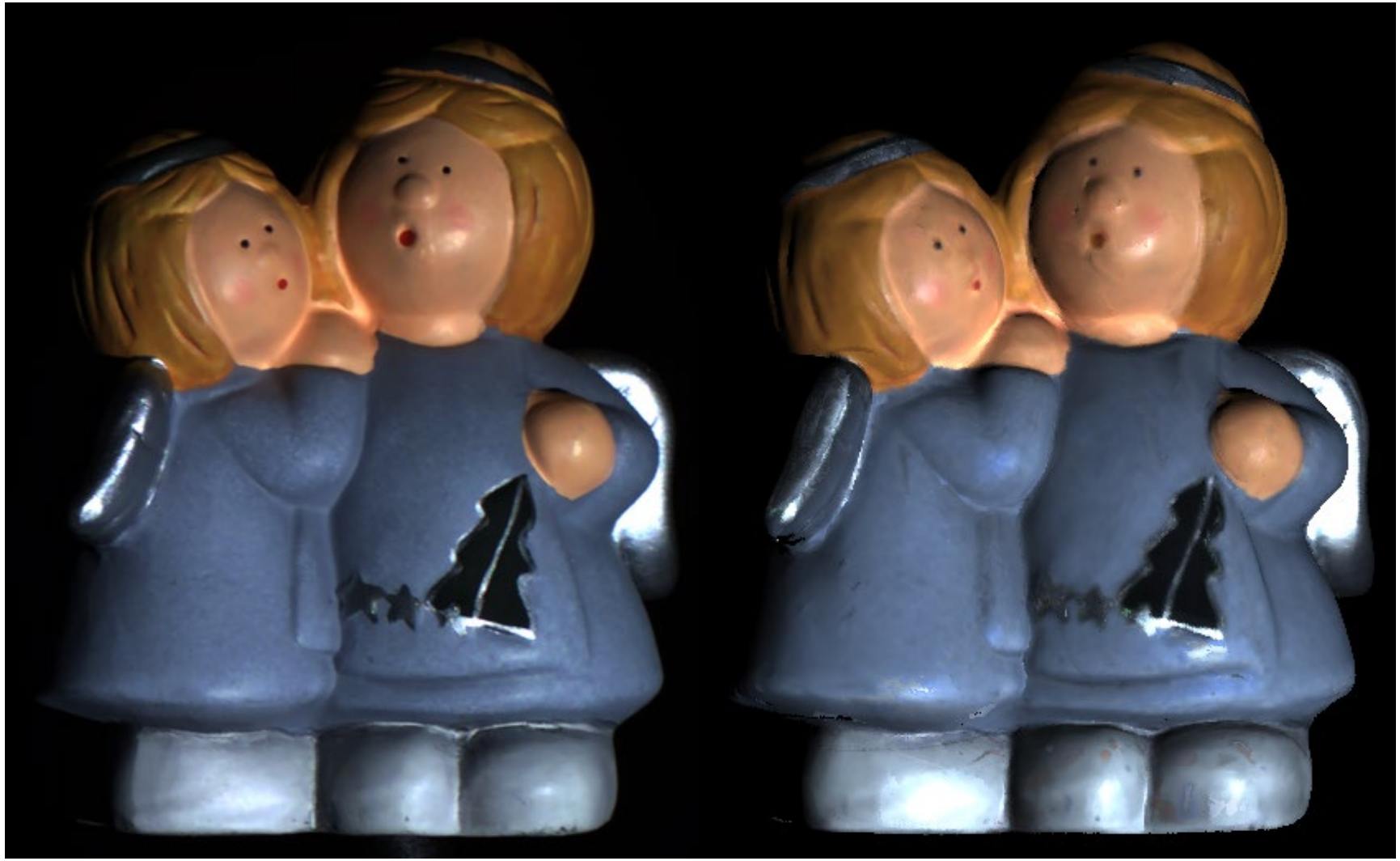
- model consists of
  - 3D geometry
  - color
  - texture



Color

- reproduce the same appearance or at least the best possible approximation on arbitrary output devices

CG or Photography?



Material Properties

Relighting in Virtual Environments

[Fuchs, Blanz, Lensch, Seidel – ACM TOG 2007 & EG 2007]

Direct Reflections

diffuse

glossy

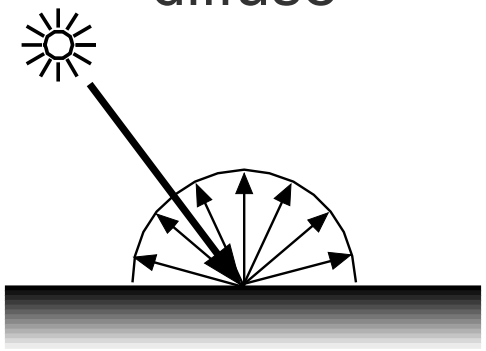
mirror

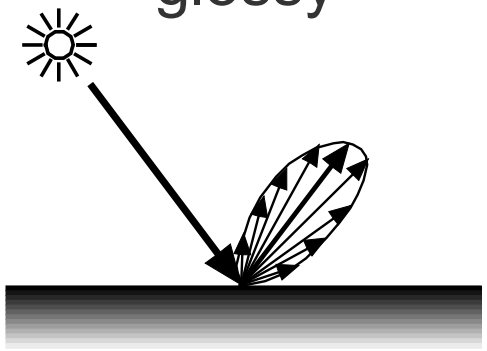
Direct Reflections

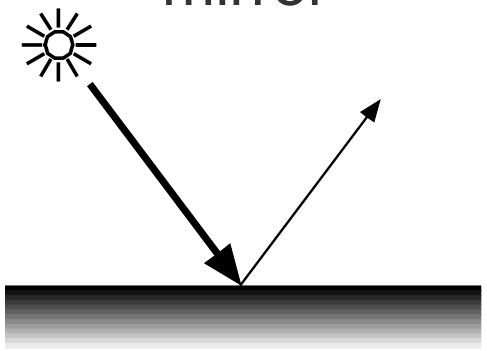
diffuse

glossy

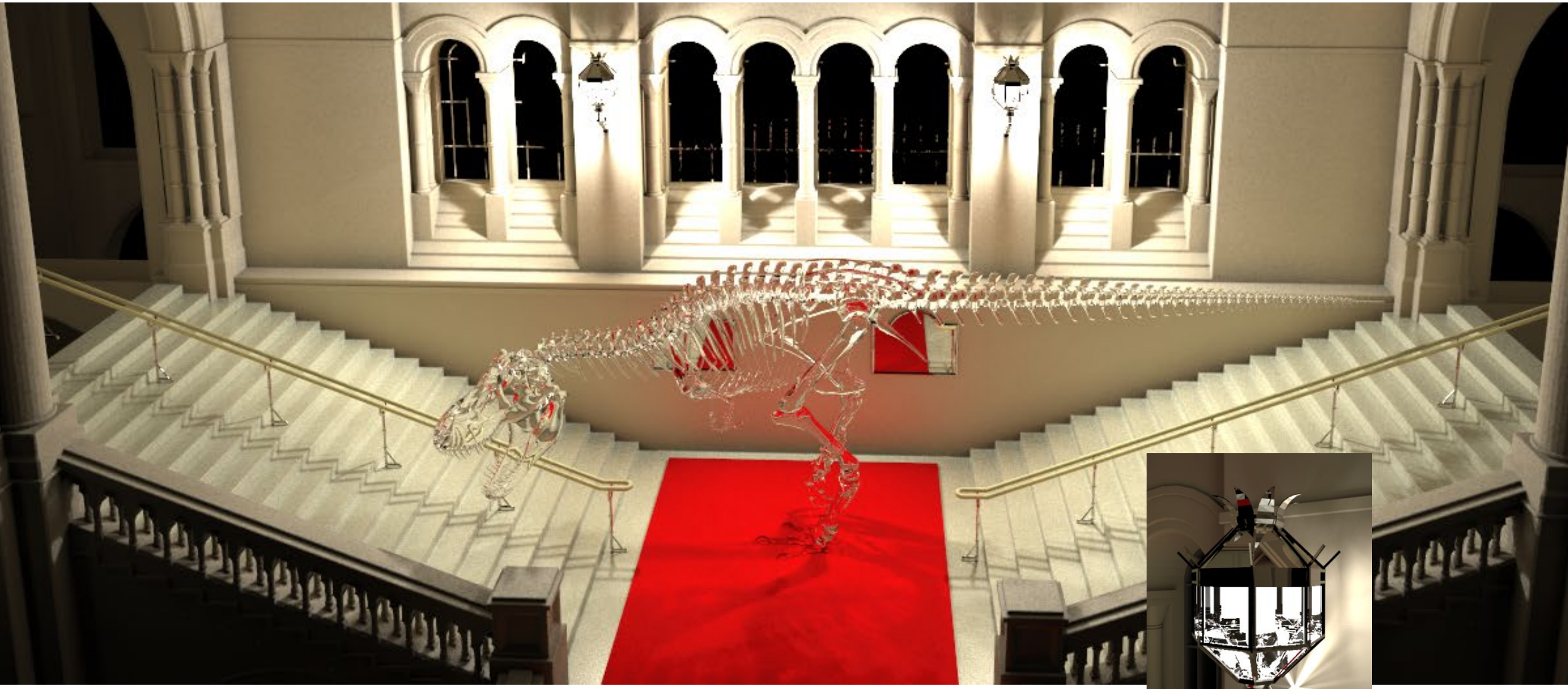
mirror





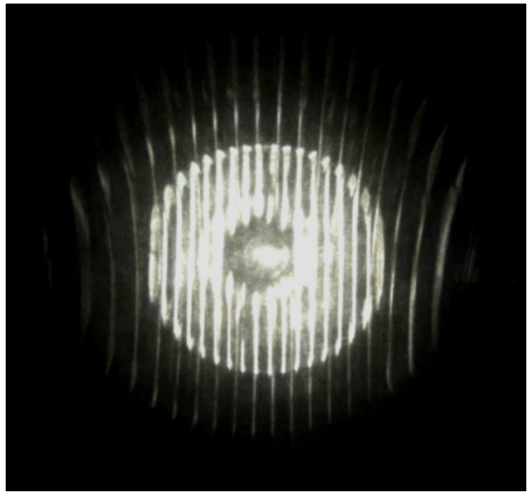


High-Quality Rendering



Illumination

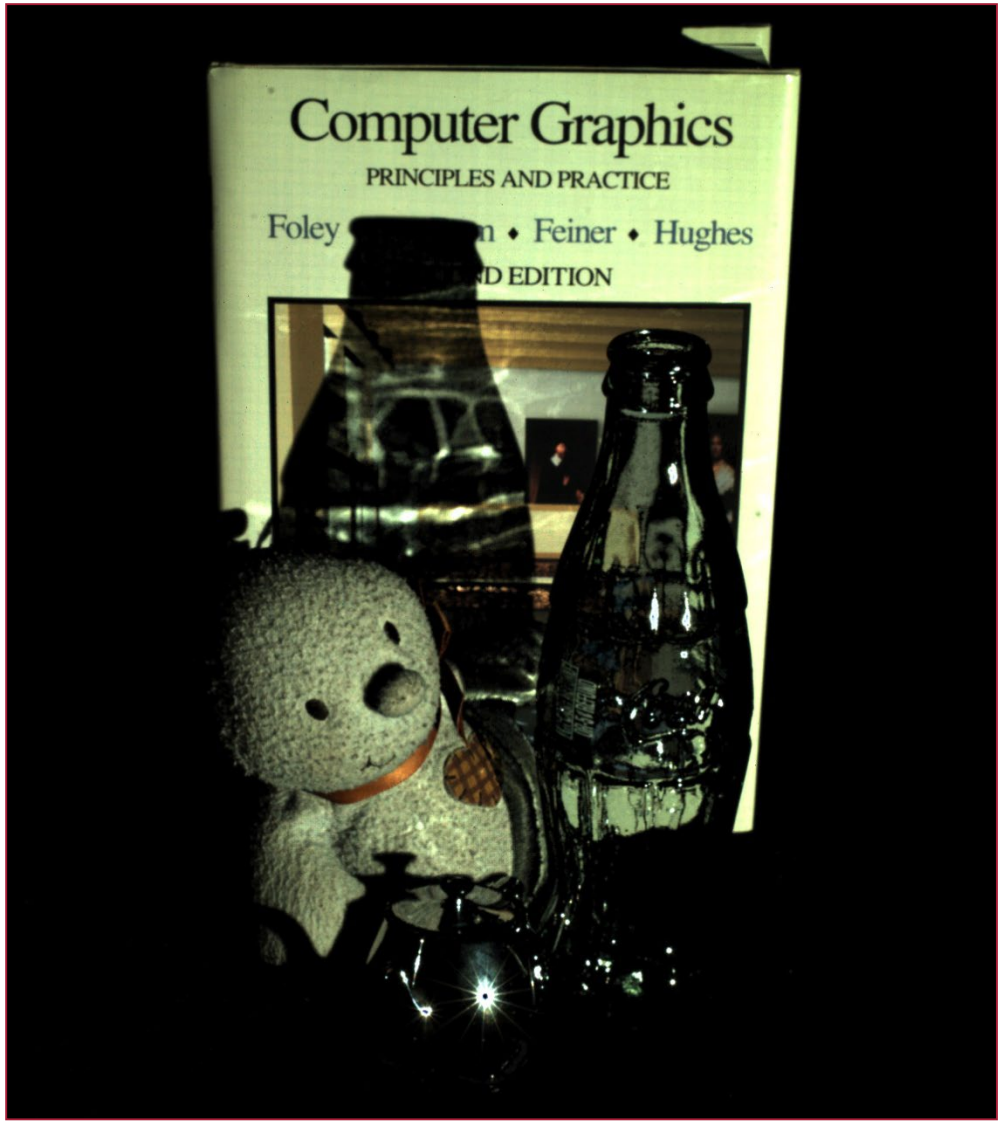
Directionally-varying Light Sources



Global Illumination Effects

- light scatters multiple times

- shadows
- refractions
- interreflections
- caustics
- …



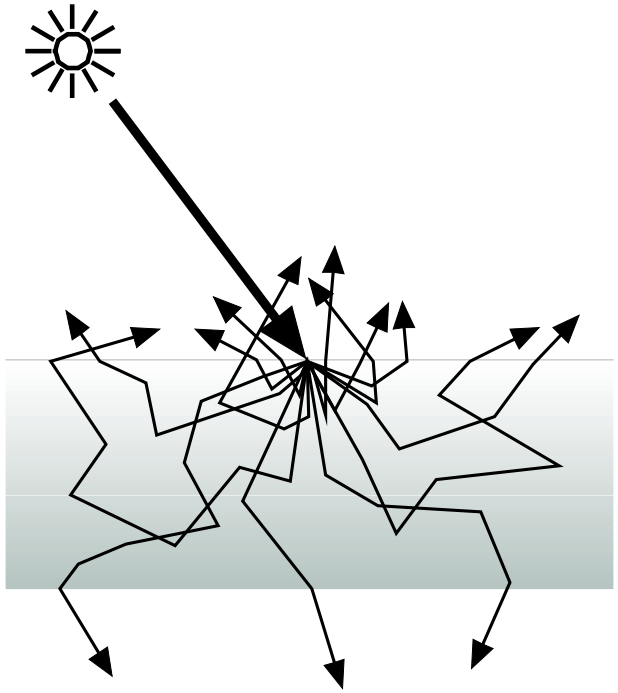
Light Transport

Caustics

- light patterns formed by focused refractions/reflections

Subsurface Scattering

translucent



Translucent Objects

- light transport through the object
- scattering dampens high frequencies

Complex Scattering in Fibers

- the overall appearance is due to scattering within and between fibers

Participating Media

- fog, smoke, liquids …
- scattering inside volume
- reduces contrast in background areas
- background blurred

Wrap-Up

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- Computer Graphics
  - Rendering
  - Modeling
  - Visualization
  - Animation
  - Imaging
- Young, dynamic area
  - Progress driven by research & technology
- Big industry!
- Interdisciplinary field
  - Relations to mathematics, physics, engineering, psychology, art, entertainment, …

Wrap-Up

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- Lots of different visual effects

- Homework:
  - Start looking around for interesting visual phenomena!

Math Primer

Overview

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- Today
  - About the computer graphics group in Tübingen
  - Administrative stuff
  - History of CG
  - Photo Realism
  - Math Primer
- Next
  - Ray Tracing
- This week (Wednesday): C++ – Mini Course

We offer

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- Topics for
  - Bachelor theses
  - Master theses
  - Individual lab courses (Praktika)

- Jobs (for performing students):
  - Teaching assistant
  - Research assistant