CS580:
Graduate-Level Computer Graphics
- Focus on rendering/generation and
recent DL approaches

Sung-Eui Yoon
(윤성의)

Course URL:
http://sgvr.kaist.ac.kr/~sungeui/GCG

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About the Instructor

- **2019:** 차세대 과학자상 수상 **(IT** 부문**)**
- **Test-of-Time Award 2006 at 2015, High Performance Graphics**

- **Produced a few professors at GIST (**렌더링**), KOREATECH (**시뮬레이션, 충돌탐지**), SKKU (**이미지 검색**)**
- **Interns/post.doc/ collaborations at Disney, Adobe, AMD, Pixar**

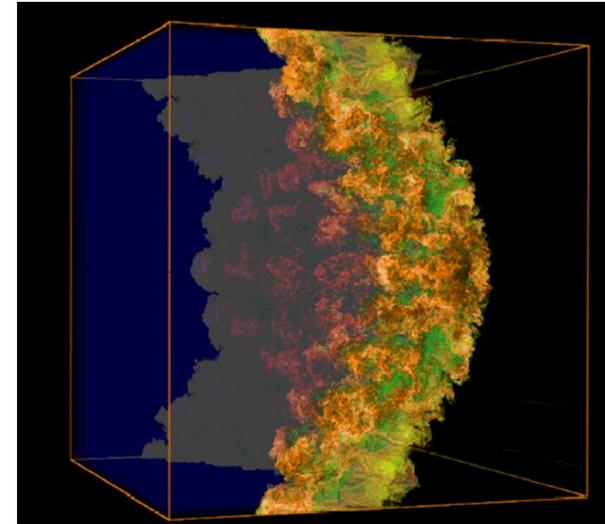# Past: Rendering Massive Geometric Data

Boeing 777, 470 M tri.

Large-scale virtual world, 83 M tri.

Scanned model, 372 M tri. (10 GB)

Over 3 Terabytes of geometric data

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Present: Intelligent Ray Tracing, Image Search, Motion Planning

- **Designing *scalable and intelligent graphics and geometric algorithms* to efficiently handle massive models on commodity hardware**
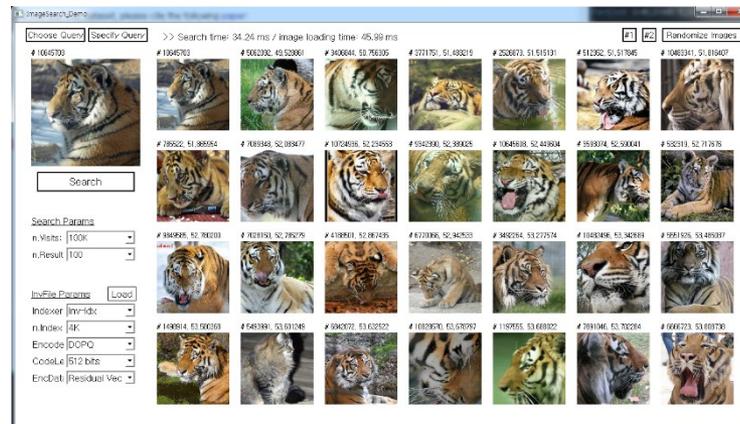

Photo-realistic rendering

Image search

Motion planning

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About the Instructor

- **Contact info**
  - **Email: KLMS or sungeui@kaist.edu**
  - **Office: 3432 at CS building (E3-1)**
  - **Homepage: http://sgvr.kaist.ac.kr/~sungeui**

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Class Information

- **Class time**
  - **10:30pm ~ 11:45pm on MW**
  - **Offline class in this semester**

- **Office hours**
  - **Right after class or KLMS board**

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TA Information

- **Jumin Lee (**이주민**)**
  - https://zoomin-lee.github.io/
  - **Office: 3440 at CS building (E3-1)**

- **Share questions on KLMS first, before sending emails to TAs**

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Overview

- **We will discuss various parts of computer graphics, especially on interactive rendering**

Modelling   **Simulation & Rendering**   **Image**

Computer vision inverts the process

Image processing deals with images

Robotics/AR combine real and virtual worlds

AI techniques are applicable across these area

Applications of Computer Graphics

- **Games**
- **Augmented or virtual reality (AR/VR)**
- **Movies and film special effects**
- **Product design and analysis**
- **Medical applications**
- **Scientific visualization**

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Games

2D game

3D shooting game

Large-Scale Open World w/ High Quality Rendering

- ## Witcher 3
  - ### Used its own engine

High Quality Mobile Games

- **Big game industry at Korea**

- **Lineage 2 – Revolution**
  - **Based on Unreal engine**

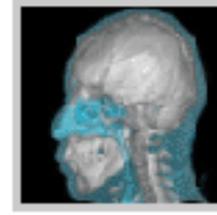# Movies and Film Special Effects
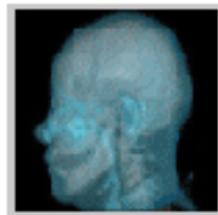

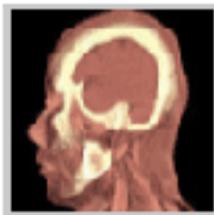
Toy story

Matrix

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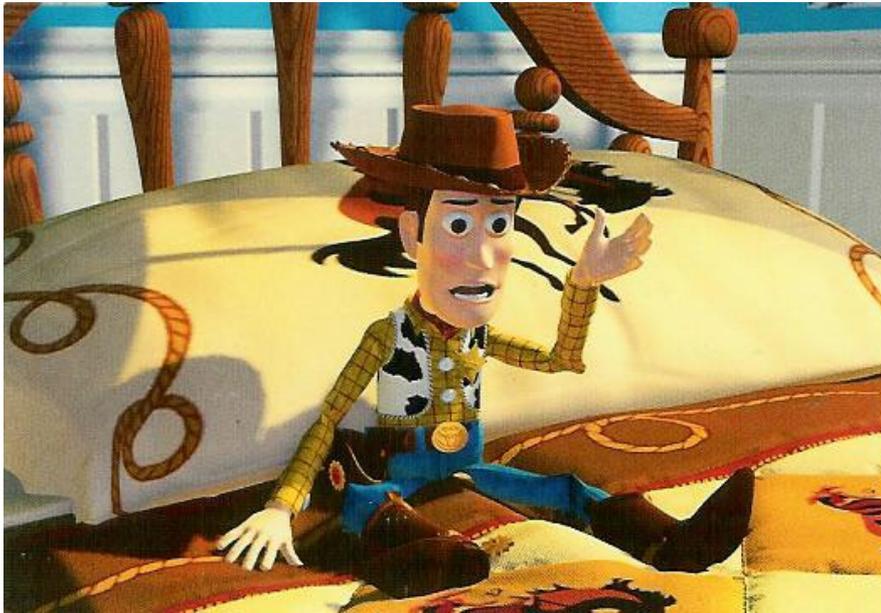
3D Movies

Avatar 1 and 2

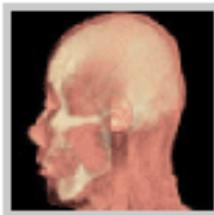# Product Design and Analysis

- **Computer-aided design (CAD)**

Medical Applications

- **Visualizing data of CT, MRI, etc**

Rapidia homepage

Medical Applications

- **Visualizing data of CT, MRI, etc**
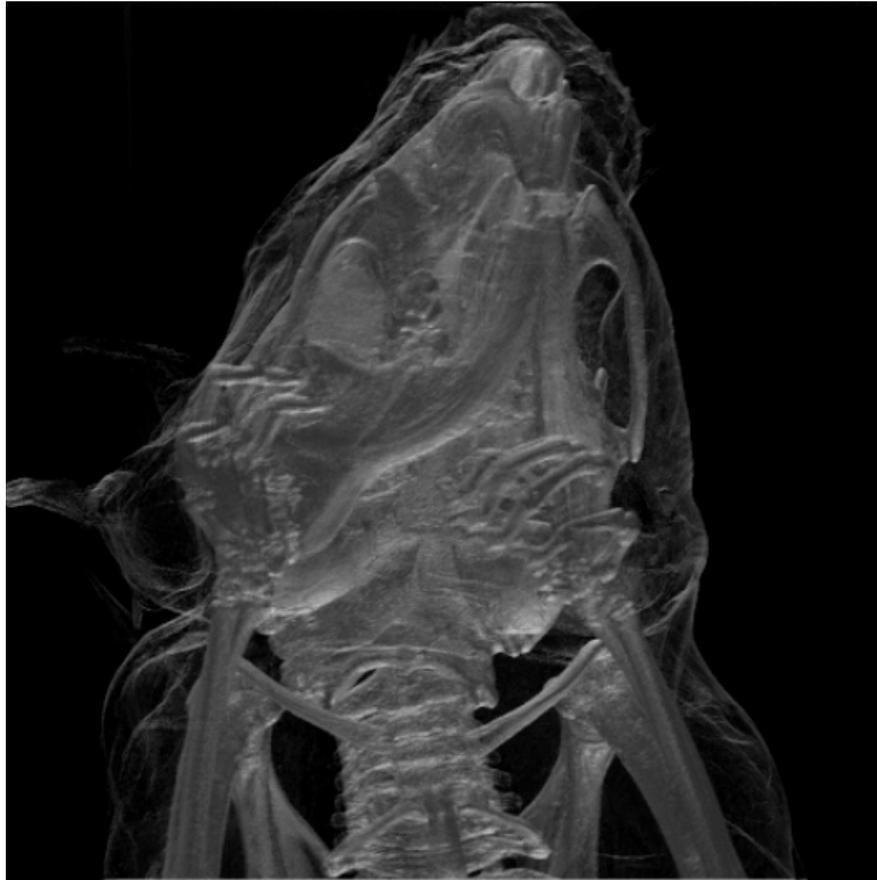
Wikipedia

Mouse skull (CT)

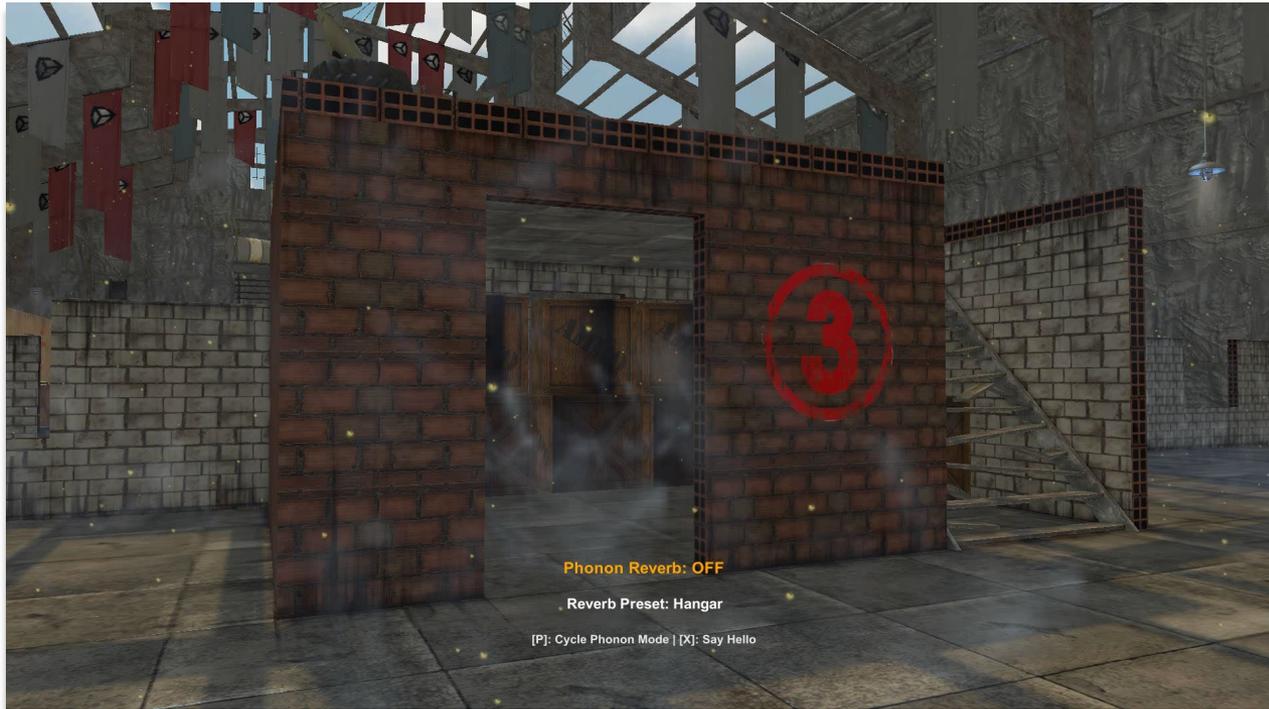# Head-Mounted Display (HMD) for VR

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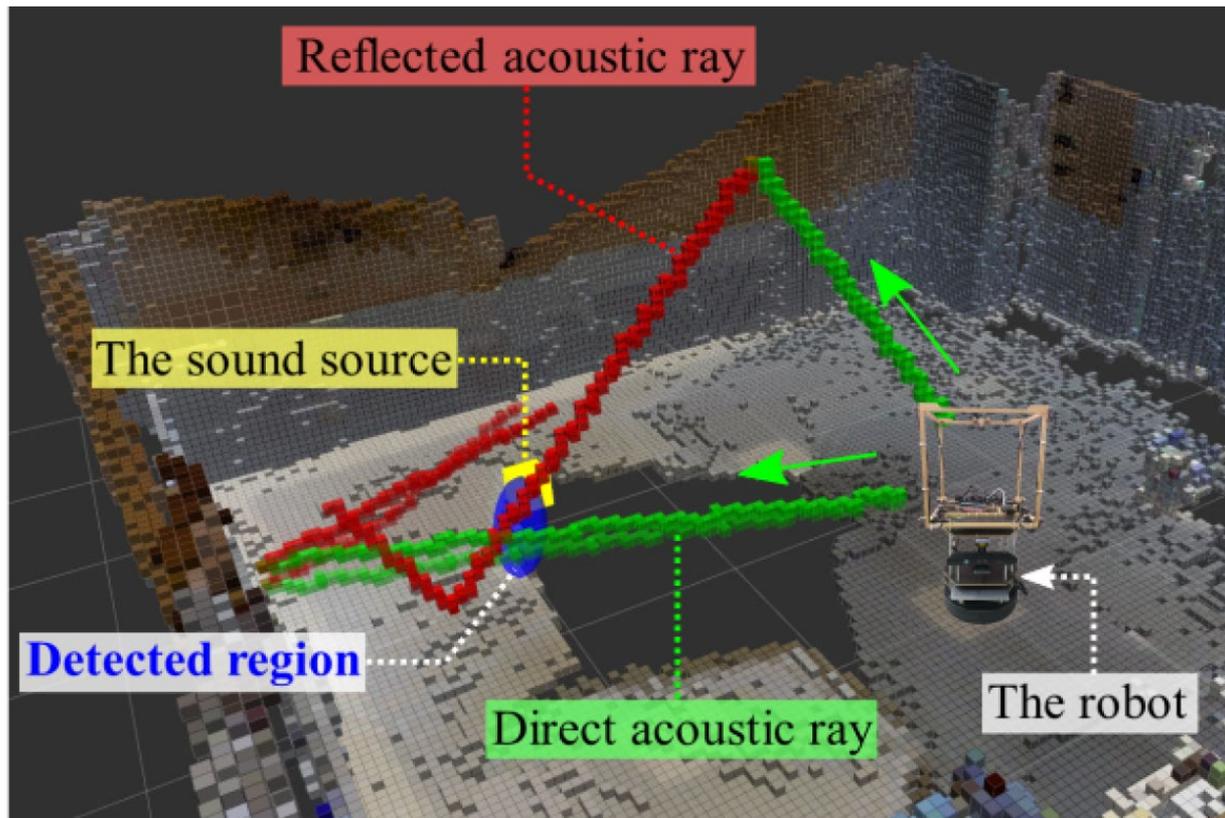# Spatial Computing supported by Apple

Ack: Techopedia

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Sound Rendering

Sound Localization

- **React to sound in AR applications**
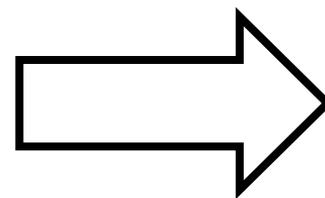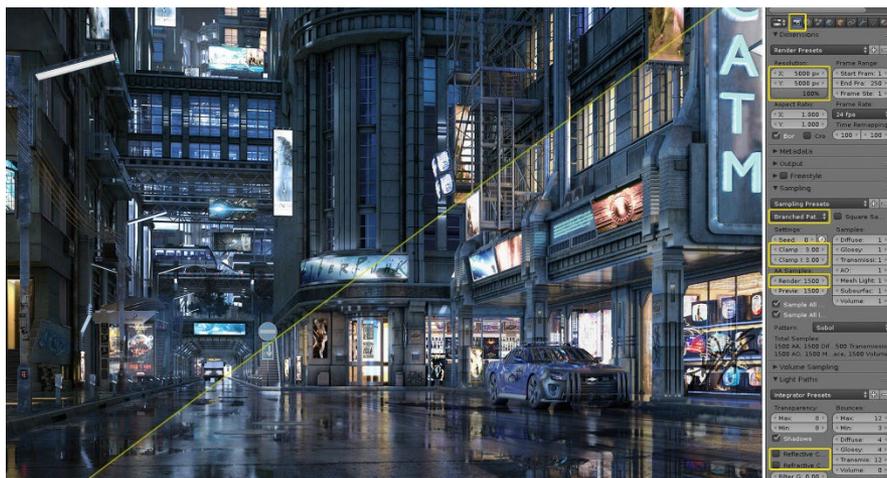 - **Tightly couple real and simulated environments**

Realistic Data Generation for Deep Learning

- **Apply CG techniques for generating realistic data for deep learning, which require lots of data**

GPU

Realistic modeling, rendering & simulation

Training data for learning

About the Course

- **We will focus on the following things:**
  - **Study basic concepts of physically-based rendering**
  - **Study recent techniques, and discuss their pros and cons**

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Photo-Realistic Rendering

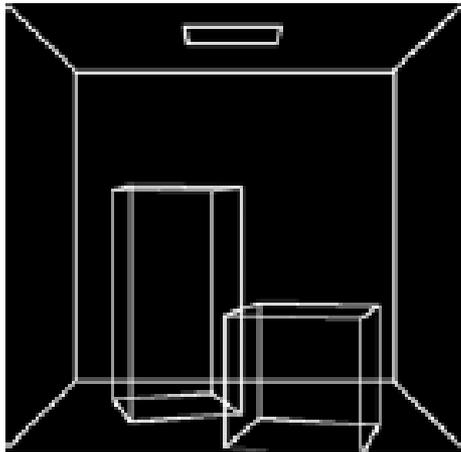- **Achieved by simulating light and material interactions**

from Prof. Bala's slide

- **Rendering equation**
  - **Mathematical formulation of light and material interactions**

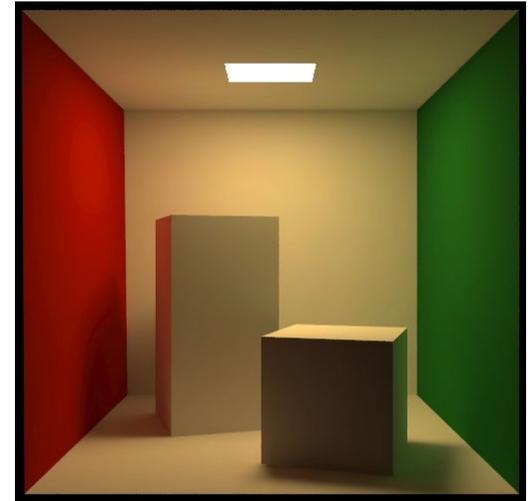# Global Illumination (GI)

- **GI algorithms solve the rendering equation**
  - **Generate 2D image from 3D scene**

from Prof. Bala's slide
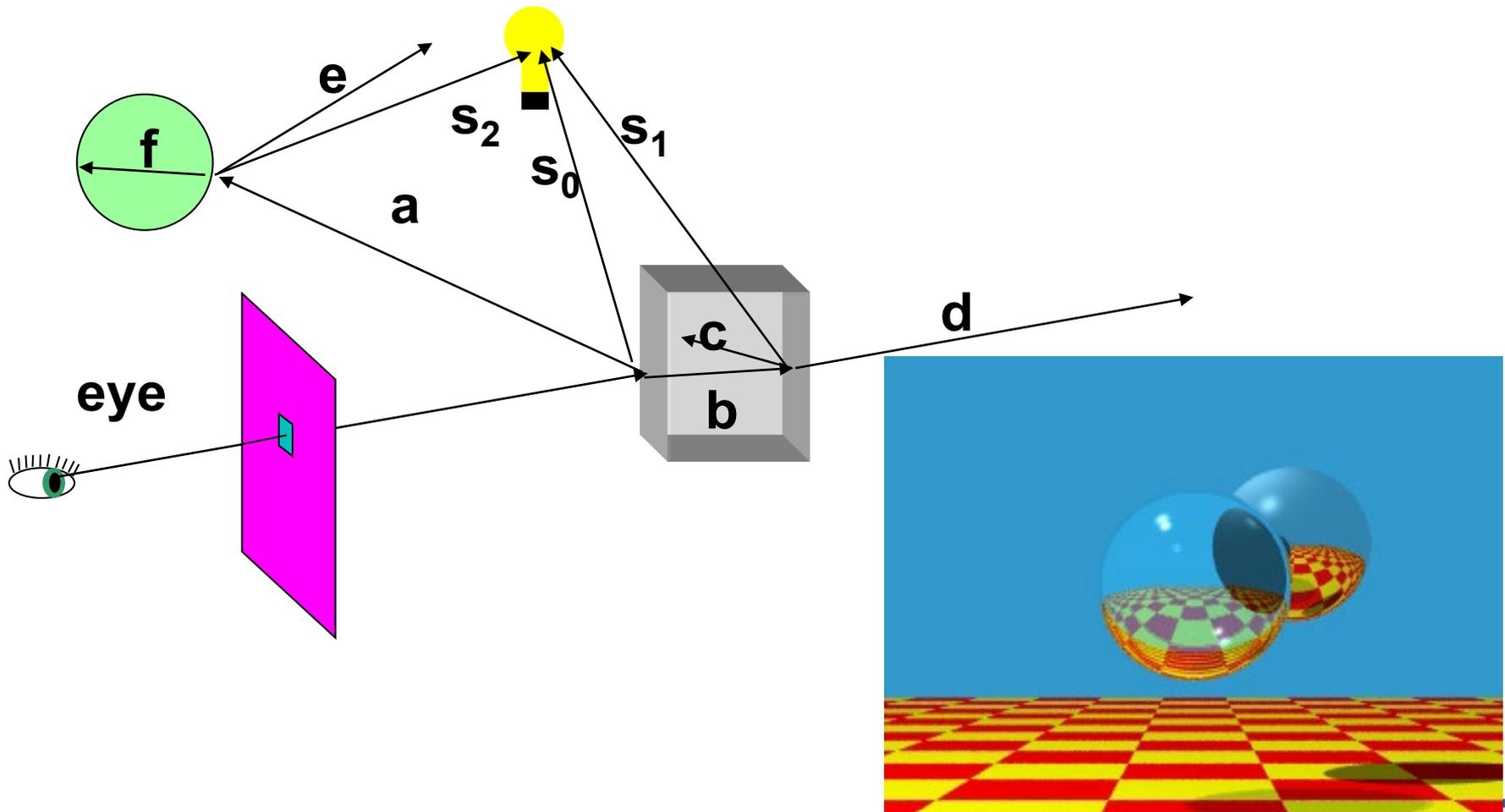
GI Algorithm

+

Emission (light sources)
Geometry (objects)
BRDF (materials)

Classic Methods of GI

- **Ray tracing**
    - **Introdued by Whitted in 1980**
- **Radiosity**
    - **Introduced in 1984**
- **Monte Carlo rendering**

Classic Ray Tracing

- **Assume perfect specular or diffuse material**

Classic Radiosity

- **Assume diffuse inter-reflections**

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Advanced Global Illumination

- **Extend to handle more realistic materials than just perfect specular/diffuse**
  - **Classic ray tracing and classic radiosity are basic building blocks**
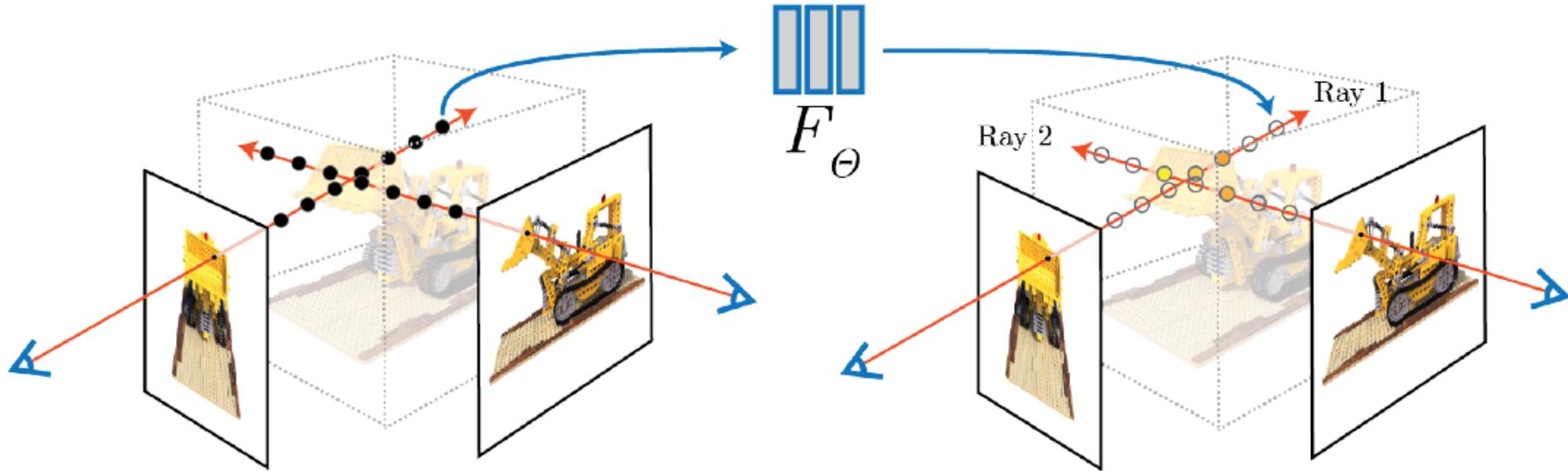

from photon map paper

from Pixar movie

Sound and AR/VR Applications

- **How can we interactively generate sounds?**

- **How can we effectively locate sound sources?**

- **How can we integrate them with AR/VR applications?**

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NeRF: Representing Scenes as Neural Radiance Fields for View Synthesis

Physics-based Inverse Rendering

- **Differential rendering is desirable for deep learning**

Scene parameters

θ

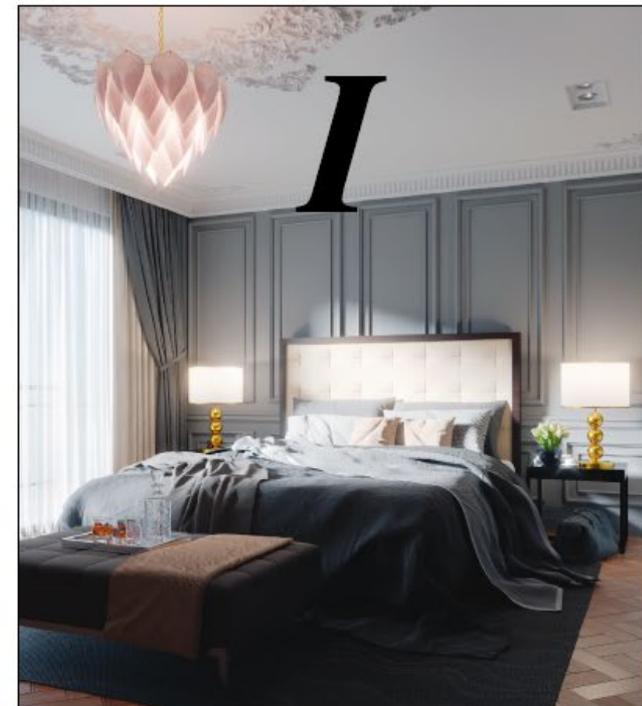Geometry, materials, lighting, ...

Inverse rendering

$$\theta = \mathscr{R}^{-1}(\boldsymbol{I})?$$

- Inverting **physics-based** forward rendering
- Crucial to many applications

Rendered image

$\boldsymbol{I}$

Scene: "bed classic" from Jiraniano

Some of Topic Lists

- **Ray tracing**
- **Path tracing**
- **BRDF**
- **Rendering equations**
- **Monte Carlo method**
- **Textures**
- **Lighting and shading**
- **Radiosity**
- **Instant radiosity**

- **GPU acceleration**
- **Sampling and reconstruction**
- **Sound rendering and localization**
- **Rendering for AR/VR**
- **Deep learning techniques**

Prerequisites

- **More or less CS380 (under. CG)**
- **Basic programming skill**
  - **Basic understanding on data structures (e.g., stack) and linear algebra (e.g., matrix multiplication)**
- **Basic deep learning knowledge & programming**

- **If you are not sure, please consult the instructor at the end of the course discuss it at KLMS w/ TAs**

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Resource

- **Rendering**
    - **1st edition, July 2018, 148 pages**
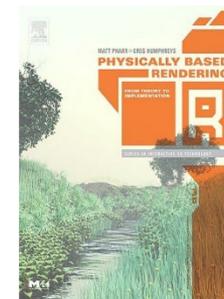   - **Sung-eui Yoon, Copyright 2018**
    - **https://sgvr.kaist.ac.kr/~sungeui/render/**
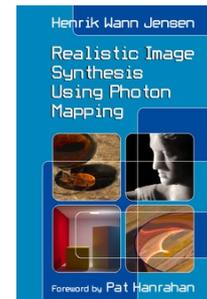
- **Reference**
    - **Physically based rendering, Matt Pharr et al.**
    - **Advanced Global Illumination, Philip Dutre et al. 2nd edition**
    - **Realistic Ray Tracing, 2nd edition, Peter Shirley et al.**
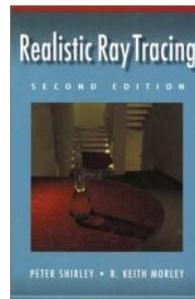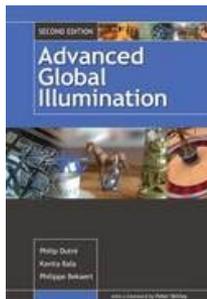
Other Reference

- **Technical papers**
  - **Graphics-related conference (SIGGRAPH, etc)**
  - **http://kesen.huang.googlepages.com/**
- **SIGGRAPH (Asia), ISMAR, CVPR/ICCV, ICRA/IROS papers and tutorials**
- **Course homepages**
- **Google or Google scholar**
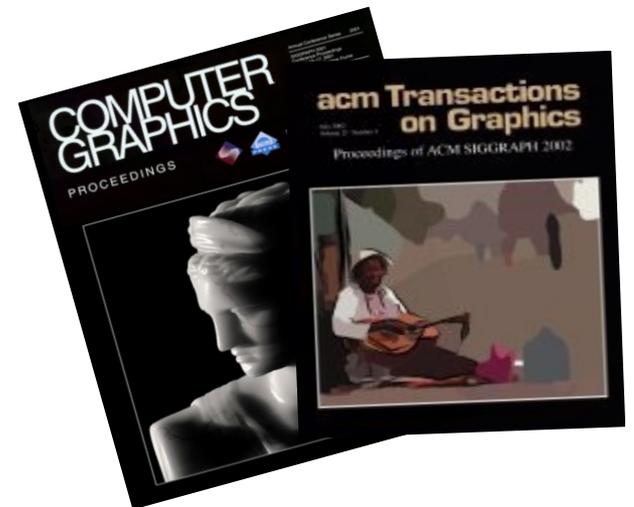
Course Overview

- **1/2 of lectures and 1/2 of student presentations**
  - **Mid-term & final-term exams with a few quiz**
  - **A few programming assignments**
  - **A few paper presentations**
  - **Team project (Major activity)**

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Important: What you will do

- **Paper presentation and final team project**
  - **Make a team of two or three members**
  - **Choose a topic for the team, and each team member presents papers related to it**
  - **All the team members implement techniques of a paper and improve them**
    - **Role of each team member should be clear**
  - **Present what the team did for the team project**

Course Awards

- **Best speaker and best project**
  - **Lunch or dinner for awardees with me and TAs**

- **A high grade will be given to members of the best project**

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Grading

- **Quiz, assignments, and exams: 30%**
- **Class presentations: 30%**
- **Final project: 40%**

- **Late policy**
    - **No score for late submissions**
    - **Submit your work before the deadline!**
- **Instructor/TA and students will evaluate presentations and projects**
    - **Instructor/TA: 50% weights**
    - **Students: 50% weights**

Class Attendance Rule

- **Late two times → count as one absence**
- **Every two absences →lower your grade (e.g., A- → B+)**

- **To check attendance, I'll call your names or take pictures**

- **If you are in situations where you should be late, notify earlier**

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Official Language in Class

- **English**
  - **I'll give lectures in English**
  - **I may explain again in Korean if materials are unclear to you**
  - **You are also recommended to use English, but not required**

Schedule

- **Please refer the course homepage:**
  - **http://sgvr.kaist.ac.kr/~sungeui/GCG/**

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Homework

- **Watch 2 SIGGRAPH or CVPR (or any top-tier conf) Videos**
  - **EGSR, HPG and I3D are also possible**
  - **ISMAR, ICRA, ECCV/ICCV are also possible**
  - **Write their summary and submit it online before Mon. class**
- **Example of summary**
  - **Just one paragraph for each summary**

  Title: XXX XXXX XXXX, Year: 2022
  Abstract: this video is about accelerating the performance of ray tracing. To achieve its goal, they design a new technique for reordering rays, since by doing so, they can improve the ray coherence and thus improve the overall performance.

Next Time

- **Ray tracing and radiosity**

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