Real-Time High Quality Rendering

GAMES202, Lingqi Yan, UC Santa Barbara

Lecture 1: Introduction and Overview

Welcome!

Logo created by Junqiu Zhu

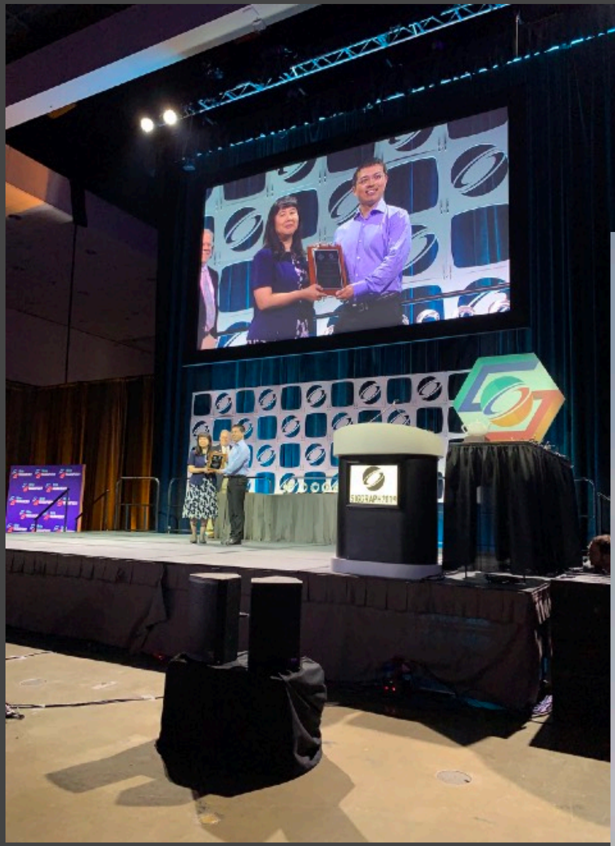
Welcome!

Cyberpunk 2077

Instructor

- Lingqi Yan
    - Assistant Professor @ UCSB
    - Web: www.cs.ucsb.edu/~lingqi/
Email: lingqi@cs.ucsb.edu
    - Research: Rendering in Computer Graphics
    - Hobbies:
research, video games, piano, NBA, traveling, etc.

Instructor's Achievements



2019: ACM SIGGRAPH Outstanding Doctoral Dissertation Award

2019: Oscar Nominee for Best Visual Effects

竞技之王 小队排名 第 1 小队总击杀 9

[redacted]
击杀
1
造成伤害
615
生存时间
16:23
急救次数
0
重生次数
0

ME
击杀
6
造成伤害
1118
生存时间
18:16
急救次数
0
重生次数
0

[redacted]
击杀
2
造成伤害
491
生存时间
18:16
急救次数
0
重生次数
0

2019: six APEX Champions in one evening

Course Staff

- Teaching Assistants
  - 万健洲（wanjianzhou@qq.com）
  - 周锦超（zhoujinchao@buaa.edu.cn）
  - 邓俊辰（junchendeng@gmail.com）
- More will be recruited from current students (based on need)

About this Course

What is GAMES202 about?

Real-Time High Quality Rendering

Intermediate level — connecting basic knowledge and research

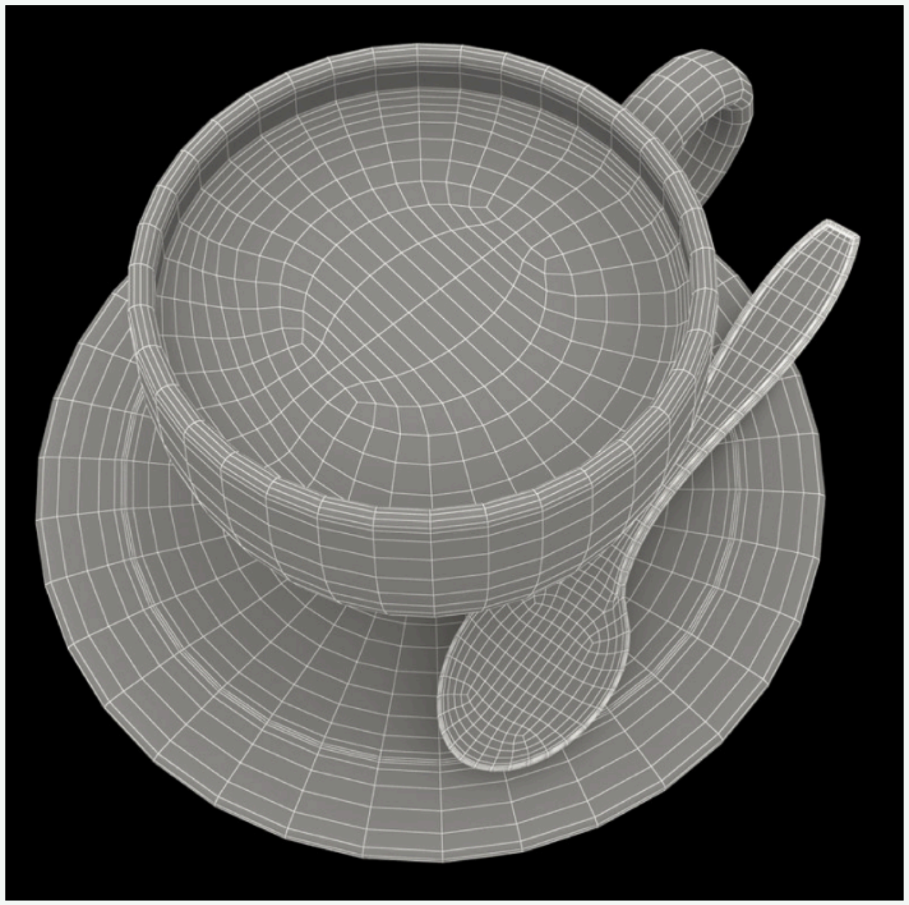
What is GAMES202 about?

- **Real-Time High Quality Rendering**
  - Speed: more than 30 FPS (frames per second),
    even more for Virtual / Augmented Reality (VR / AR): 90 FPS
  - Interactivity: Each frame generated on the fly

- **Real-Time High Quality Rendering**
  - Realism: advanced approaches to make rendering more realistic
  - Dependability: all-time correctness (exact or approximate),
    no tolerance to (uncontrollable) failures

What is GAMES202 about?

- Real-Time High Quality Rendering
  - What is Rendering?



3D scene (meshes, lights, etc.)

Calculating light -> eye

Image

What is GAMES202 about?

- Highest level: 4 different parts on real-time rendering

Shadows
(and env)

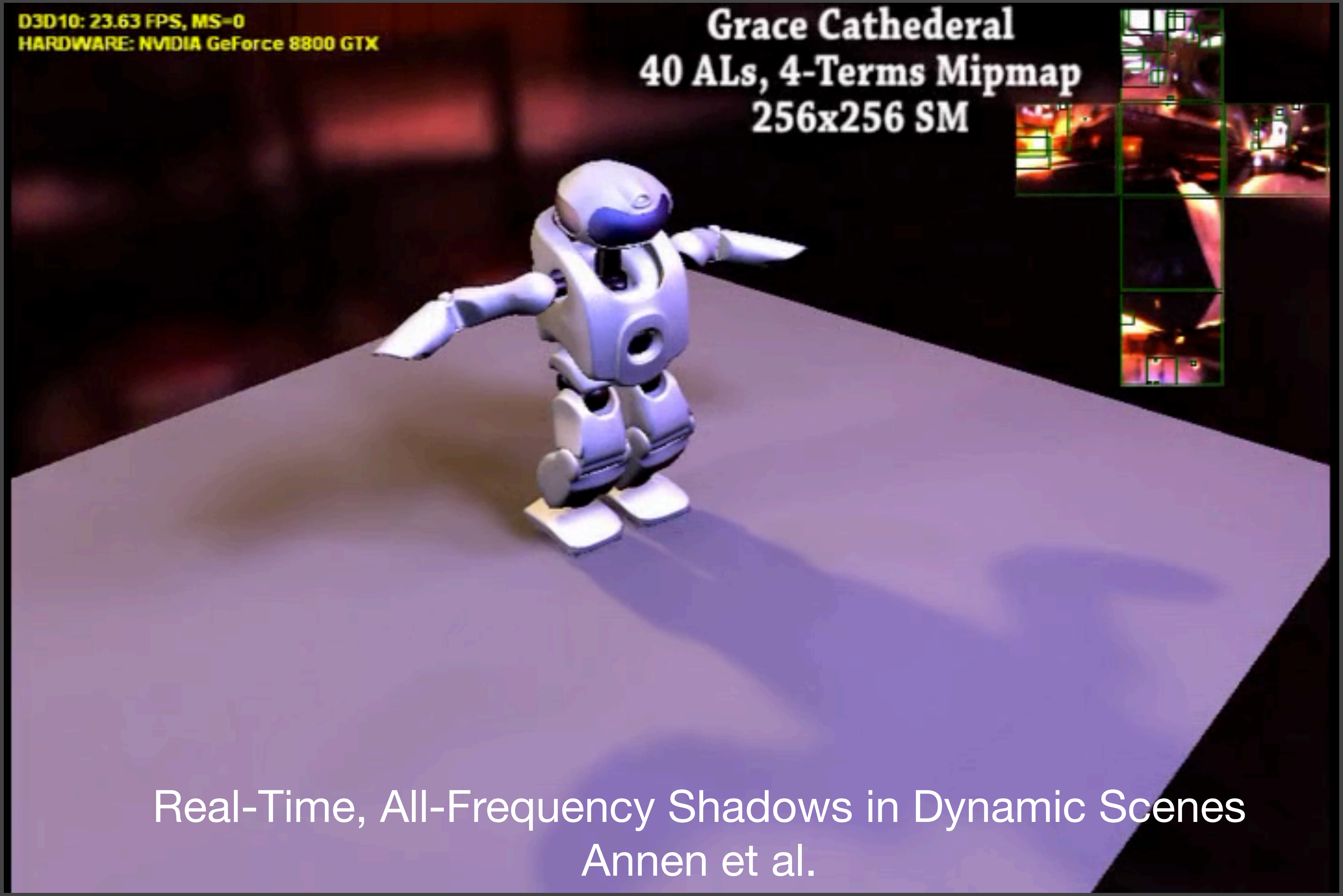
Global Illum.
(Scene/image space,
precomputed)

Physically-
based
Shading

Real-time
ray tracing

Course Topics

- Shadow and Environment Mapping



Real-Time, All-Frequency Shadows in Dynamic Scenes
Annen et al.

Course Topics

- Interactive Global Illumination Techniques

~2 seconds / frame

Micro-Rendering for Scalable, Parallel Final Gathering
Ritschel et al.

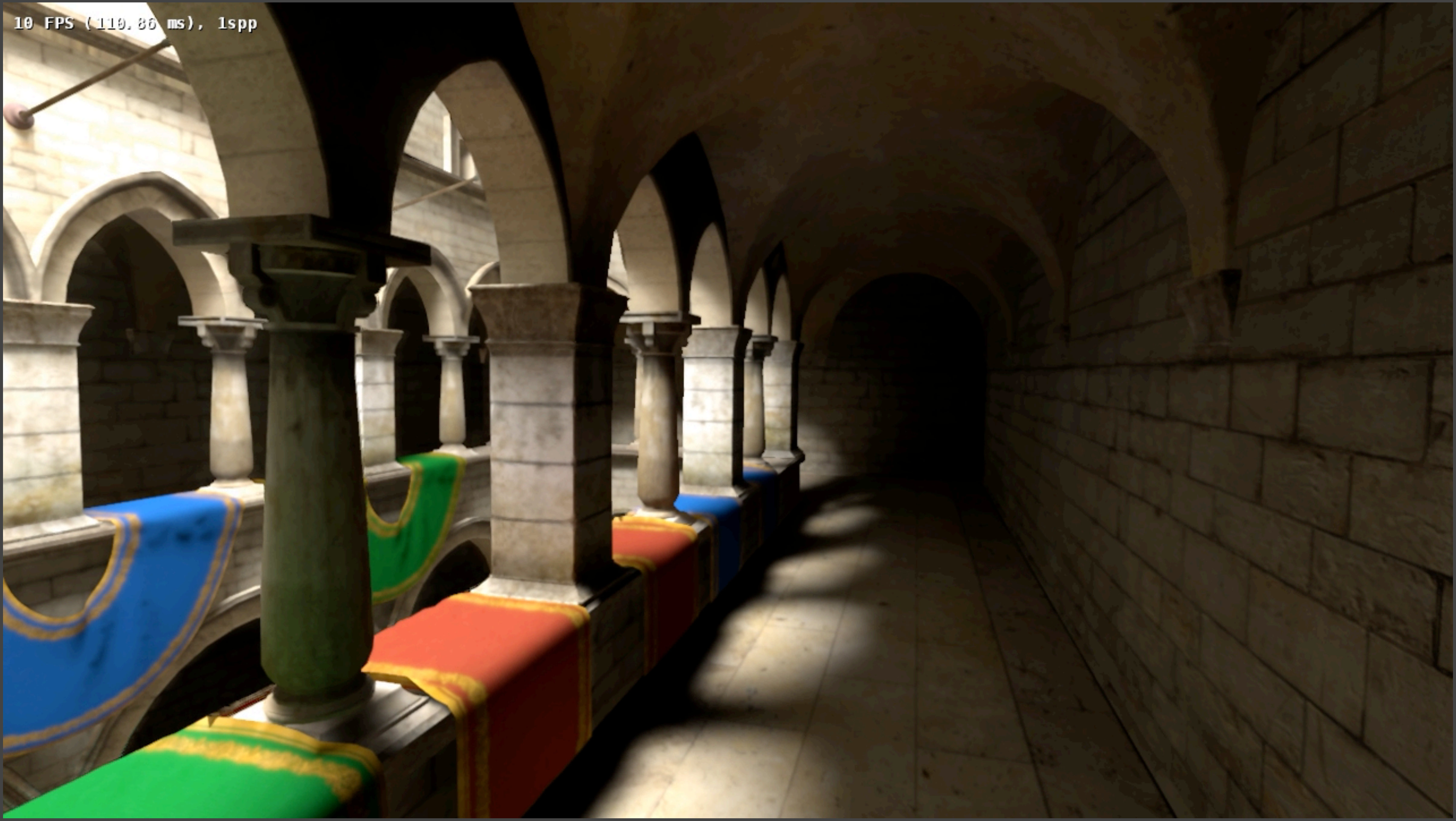
Course Topics

- Precomputed Radiance Transfer

Global Illumination with Radiance Regression Functions
Ren et al.

Course Topics

- Real-Time Ray Tracing



Course Topics

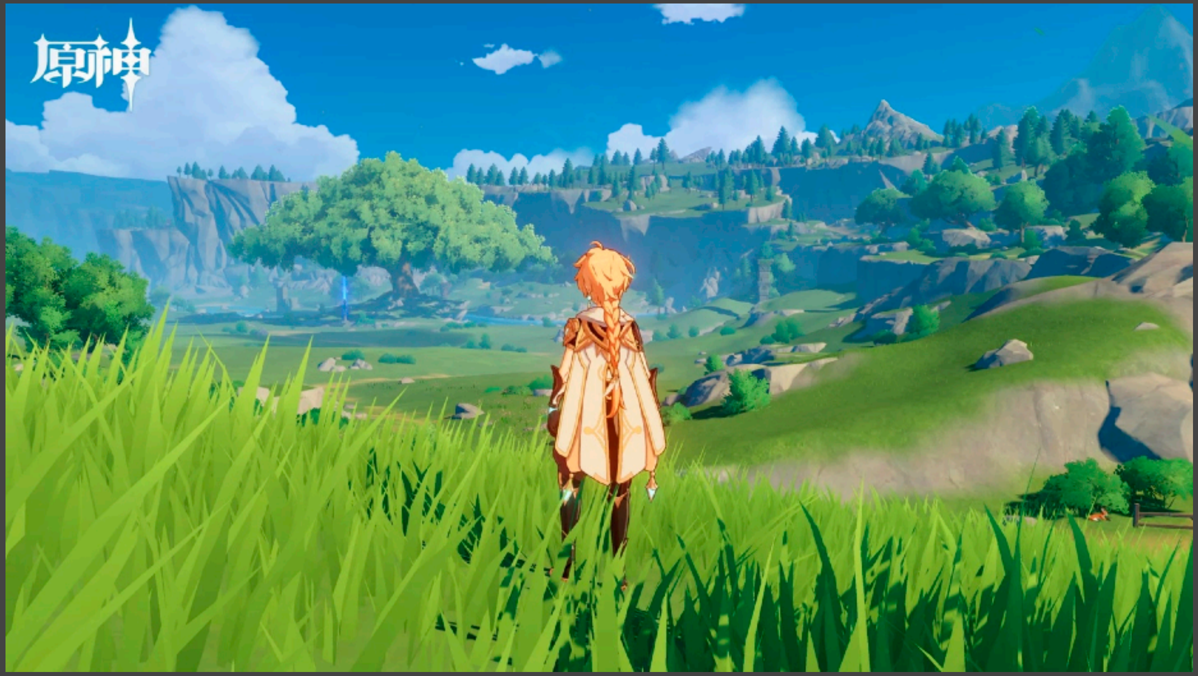
- Participating Media Rendering, Image Space Effects, etc.

Single scattering

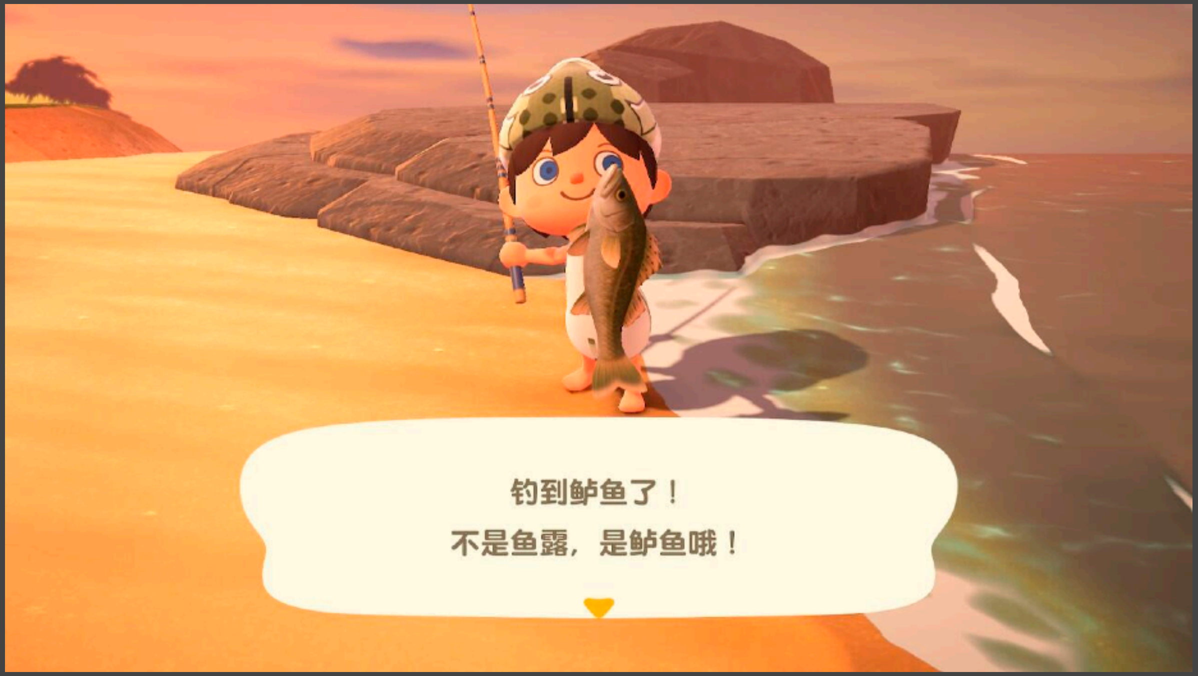
Image space reflection

Course Topics

- Non-Photorealistic Rendering
  - But will not be in depth / per game



Genshin Impact



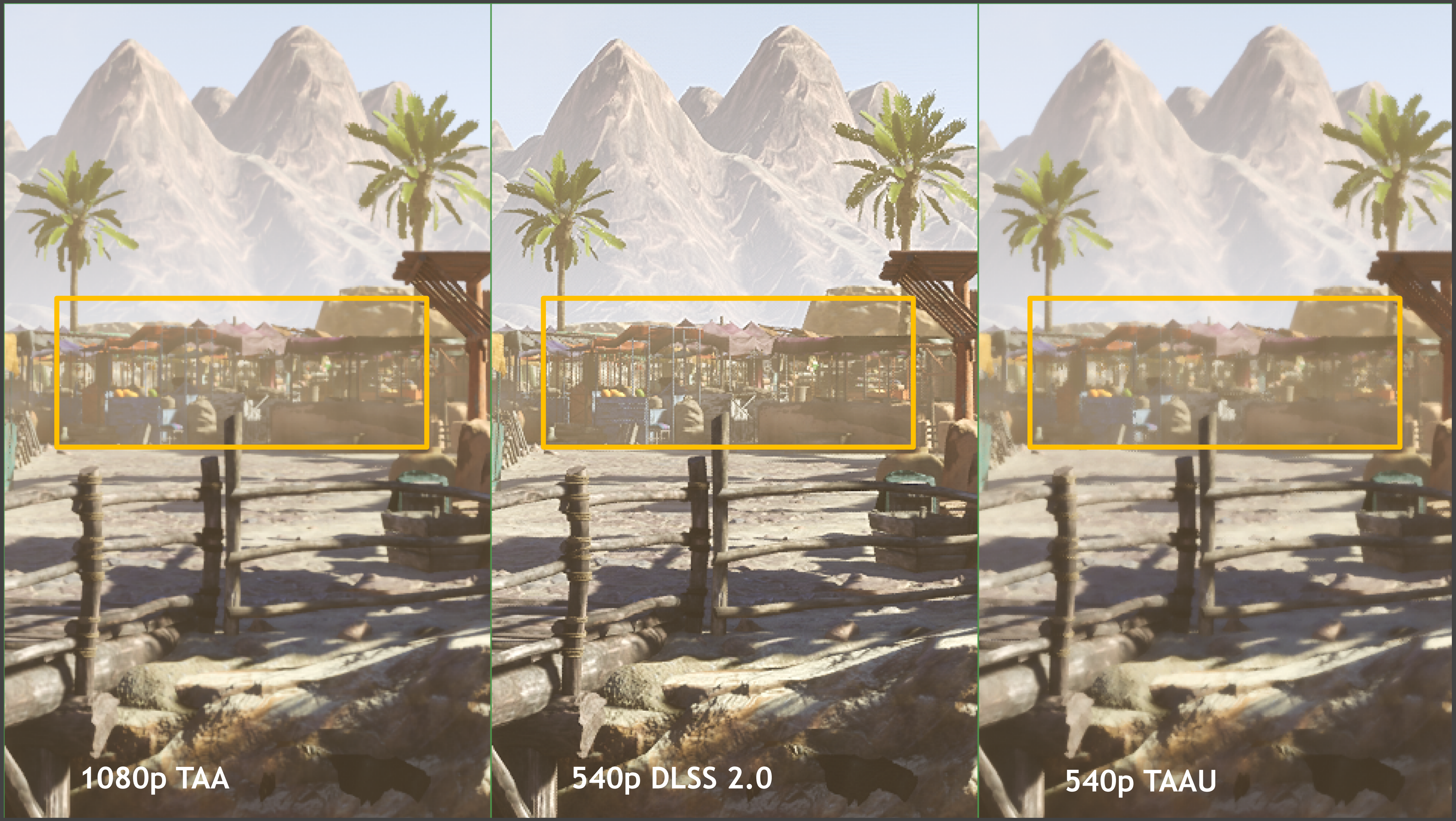
钓到鲈鱼了！

不是鱼露，是鲈鱼哦！

Animal Crossing: New Horizons

Course Topics

- Antialiasing and supersampling



Course Topics

- Chatting about techs!

Unreal Engine 5 Demo

Course Topics

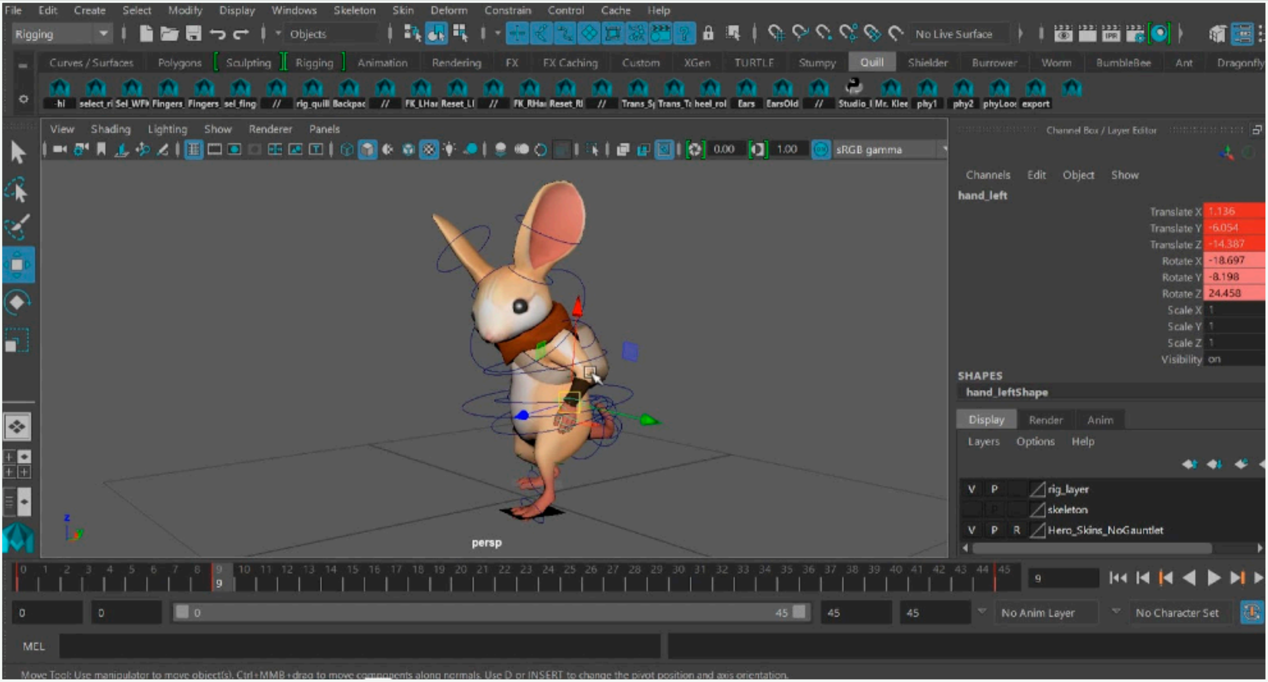
- Chatting about games!

~~Golf II~~
The Last of Us Part II
(2020 Game of the Year)

Monster Hunter Rise
(2021)

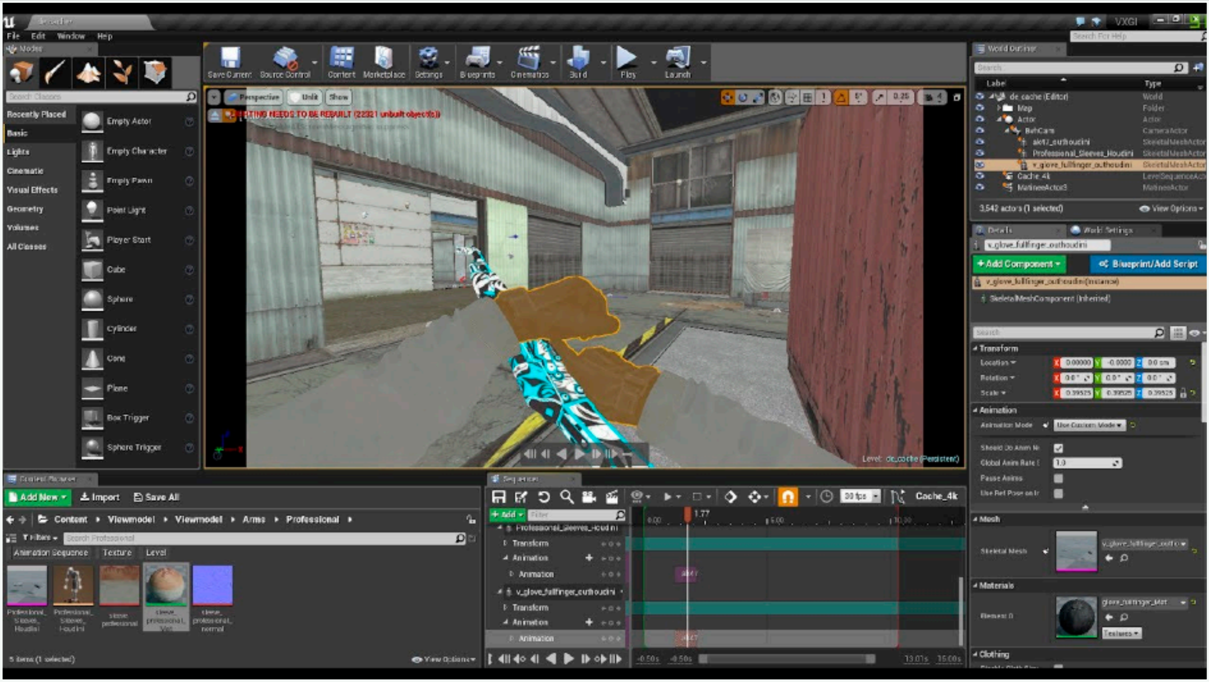
What is GAMES202 NOT about?

- 3D modeling or game development using Unreal Engine (where can I learn them?)


File Edit Create Select Modify Display Windows Skeleton Skin Deform Constrain Control Cache Help
Rigging
Curves / Surfaces Polygons Sculpting Rigging Animation Rendering FX FX Caching Custom XGen TURTLE Stumpy Quill Shielder Burrower Worm BumbleBee Ant Dragonfly
View Shading Lighting Show Renderer Panels
sRGB gamma
Channel Box / Layer Editor
Channels Edit Object Show
hand_left
Translate X 1.136
Translate Y -6.054
Translate Z -14.387
Rotate X -18.697
Rotate Y -8.198
Rotate Z 24.458
Scale X 1
Scale Y 1
Scale Z 1
Visibility on
SHAPES
hand_leftShape
Display Render Anim
Layers Options Help
rig_layer
skeleton
Hero_Skins_NoGauntlet
persp
No Anim Layer
No Character Set
MEL

Modeling character animation in Maya

[http://tutorials.cgrecord.net/2017/08/17-minute-animation-process-in-autodesk.html]

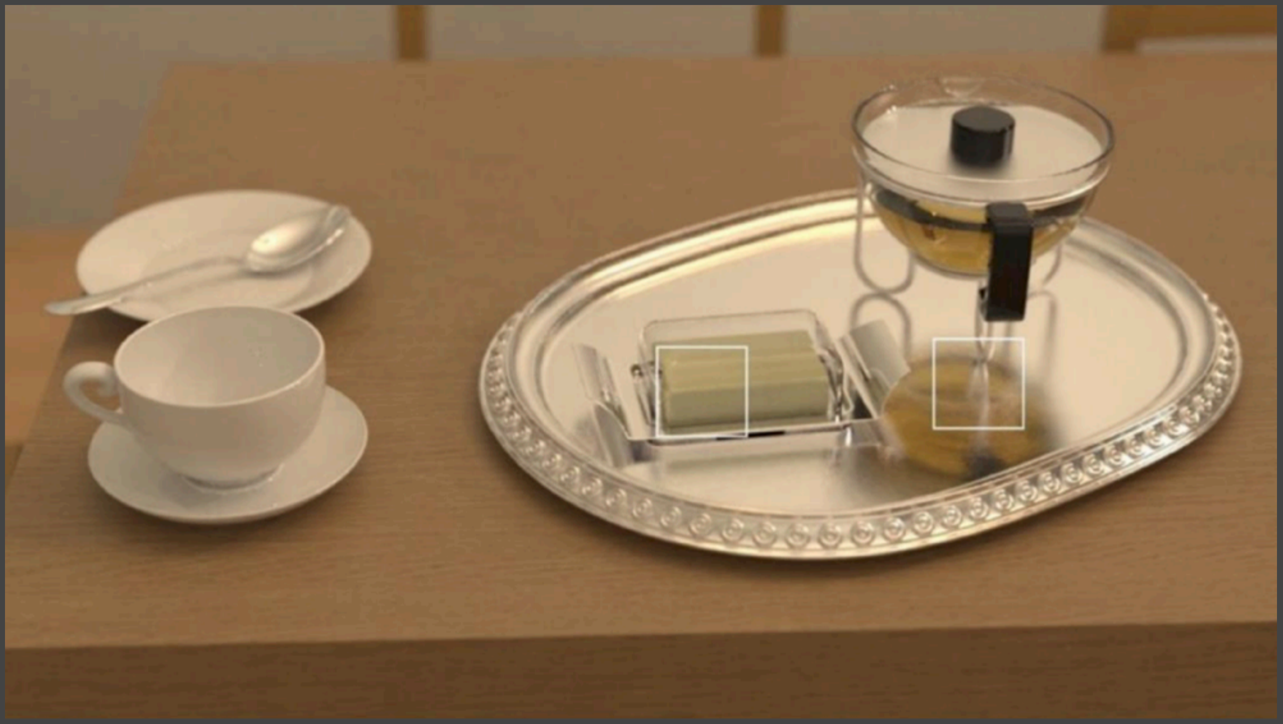


CSGO PoV Cam set up in Unreal Engine

[https://www.youtube.com/watch?v=3TQ18SmQSw0]

What is GAMES202 NOT about?

- Expensive (but more accurate) light transport techniques in movies / animations (where can I learn this?)

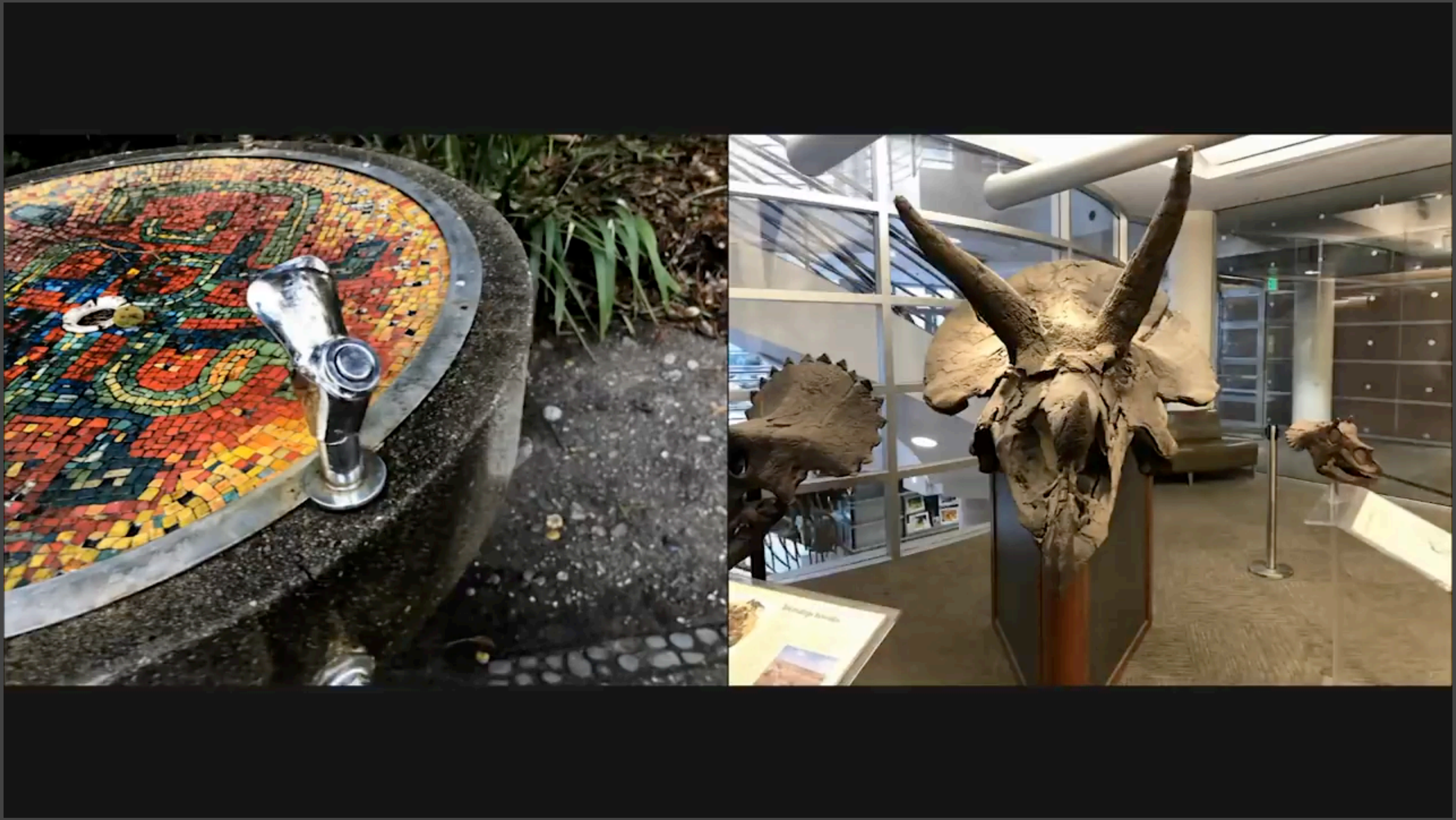


Manifold Metropolis Light Transport
Jakob et al.

Gradient Domain Path Tracing
Kettunen et al.

What is GAMES202 NOT about?

- Neural Rendering



NeRF: Representing Scenes as Neural Radiance Fields for View Synthesis
[Mildenhall et al.]

What is GAMES202 NOT about?

- Using OpenGL
- Scene / shader optimization
- Reverse engineering of shaders
- High performance computing
  e.g. CUDA programming

Questions?

How to study GAMES202?

- Understand the difference between science and technology
  - Science != technology
  - Science == knowledge
  - Technology == engineering skills that turn science into product
- Real-time rendering =
  fast & approximate offline rendering + systematic engineering
- Fact: in real-time rendering technologies,
  the industry is way ahead of the academia
- Practice makes perfect

How to study GAMES202?

- If you are watching live streams of this course
  - Be active asking questions!
- If you are watching recordings
  - 1.25x - 1.5x playback speed is recommended!

Why study GAMES202?

Computer Graphics

is

AWESOME!

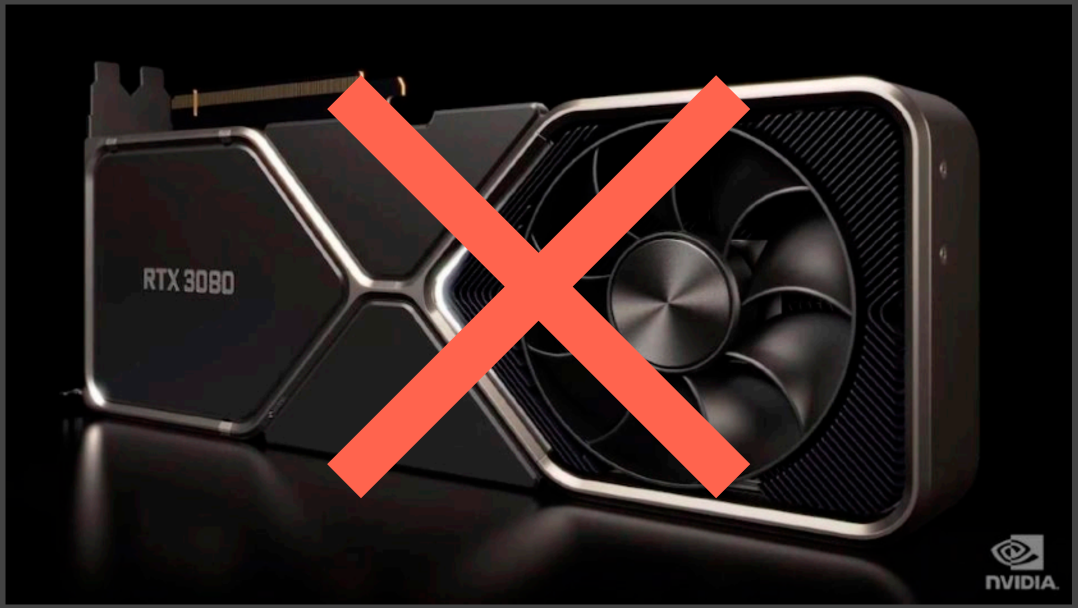
Course Logistics

Prerequisites

- Strong interest in Rendering, Graphics
- Computer Graphics experience
  - GAMES101 or equivalent
  - Basic calculus
- What else to be prepared?
  - Basic OpenGL Shader Language (GLSL)!
  - The next lecture will briefly review it
  - Assignment 0 (optional, will be released with the next lecture) will help you warm up quickly

General Information

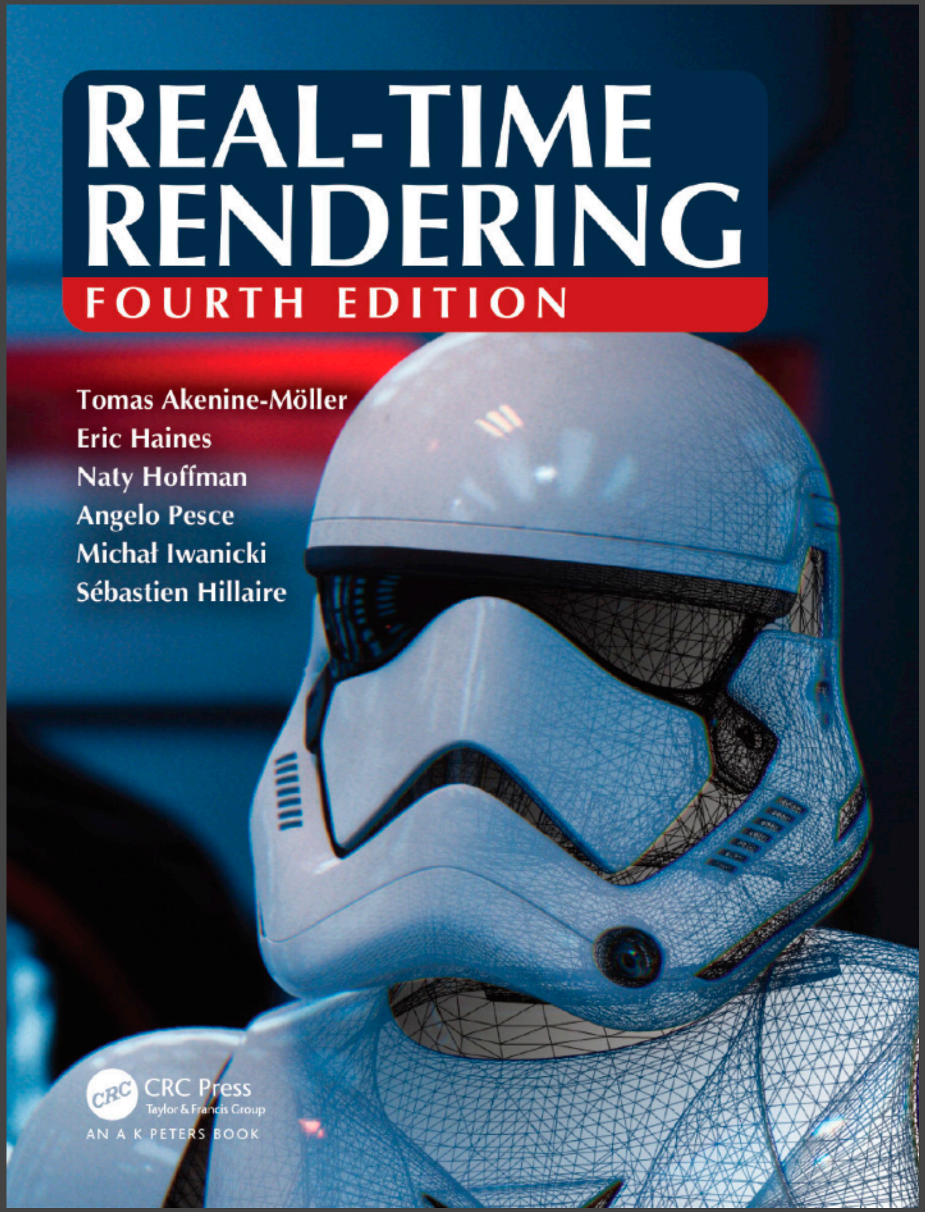
- Modern Course
  - Comprehensive but
    no need to have extreme hardware!
  - Pace / contents subject to change



- Course Website
  - http://www.cs.ucsb.edu/~lingqi/teaching/games202.html
  - Has all the needed information
  - Syllabus, slides, reading materials, etc.

References

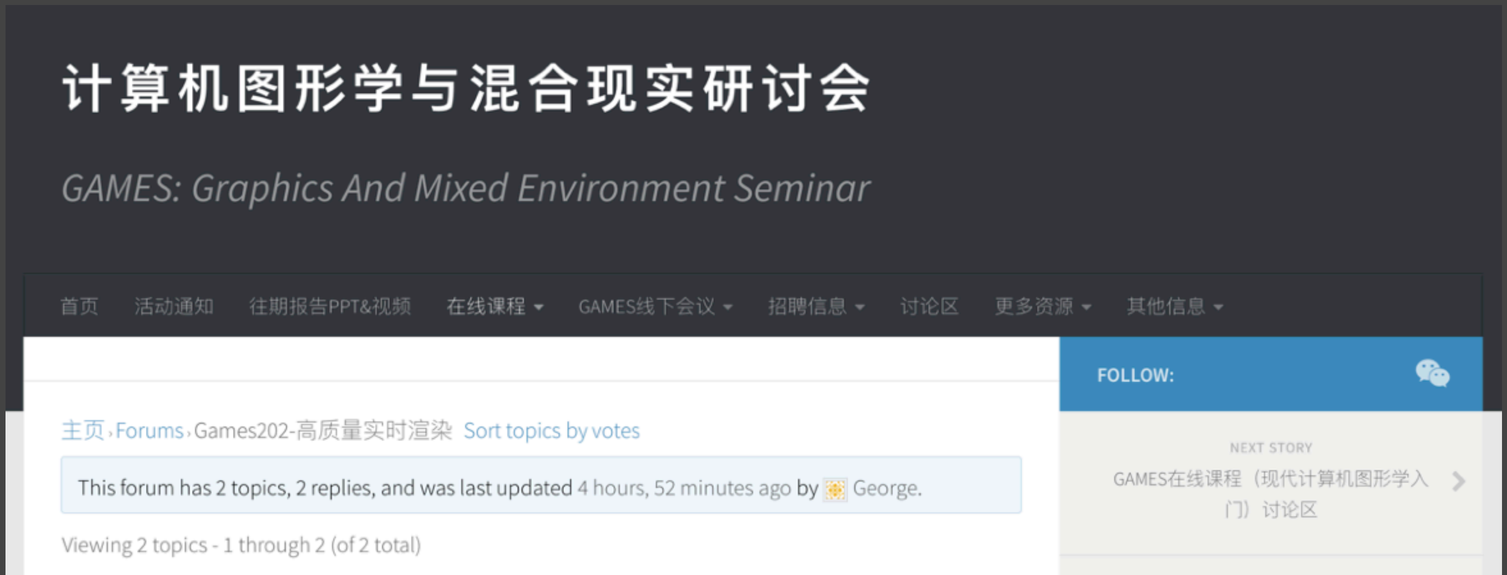
- No Required Textbooks
  - Reading materials (if any) will available online before lectures
  - Mainly SIGGRAPH courses + engine design docs
  - Lecture slides will be available after class
- Possible reference
  - Akenine-Moller et al., “Real-time Rendering", 4th edition.
  - Still not quite related (unlike the tiger book to GAMES101)



Q & A

- Sign up on our BBS for discussion (http://games-cn.org/forums/forum/games202/)

- And QQ group!



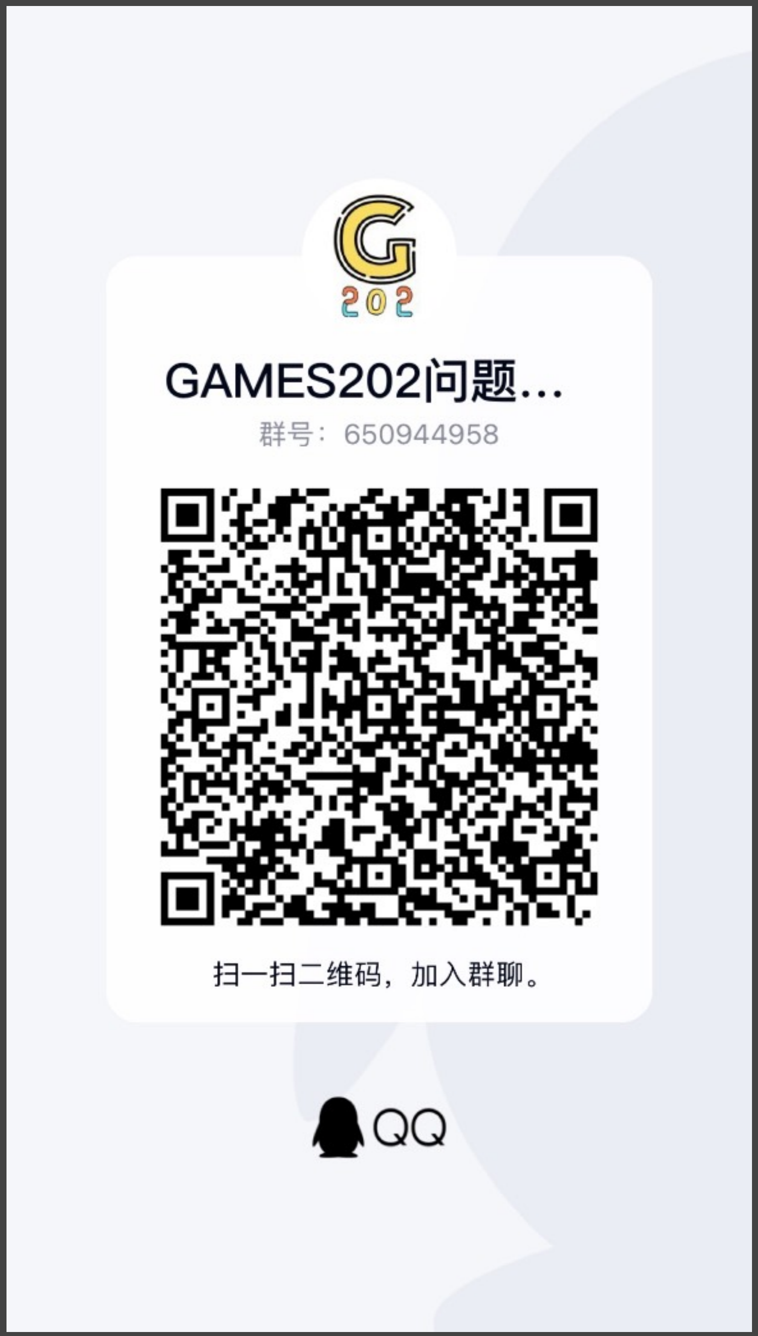
计算机图形学与混合现实研讨会

GAMES: Graphics And Mixed Environment Seminar

主页 › Forums › Games202-高质量实时渲染 Sort topics by votes

This forum has 2 topics, 2 replies, and was last updated 4 hours, 52 minutes ago by George.

Viewing 2 topics - 1 through 2 (of 2 total)



GAMES202问题…

群号：650944958

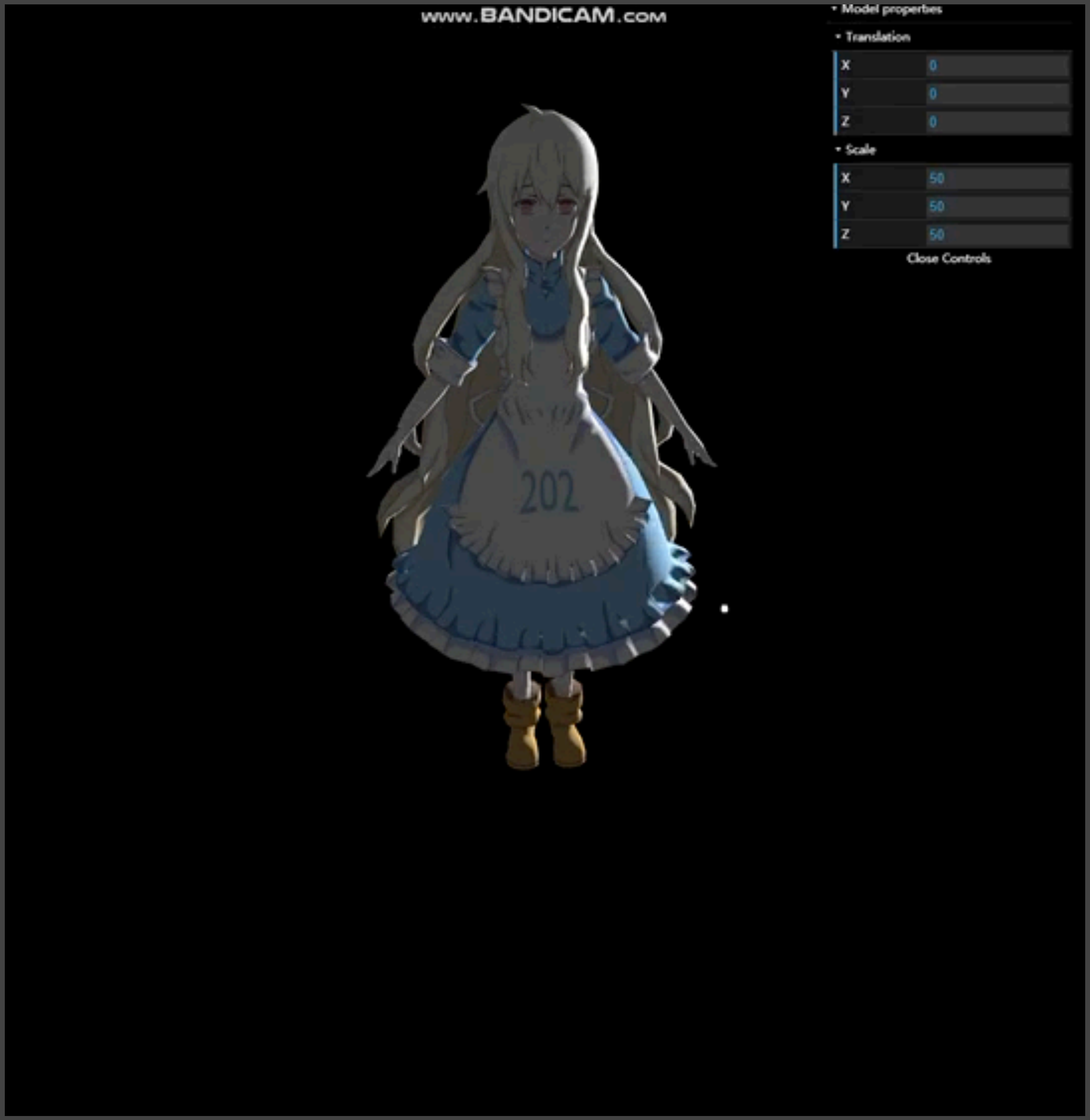
扫一扫二维码，加入群聊。

Assignments

- Assignments
  - 5 programming assignments (excluding assignment 0)
  - About 1.5 week for each assignment
  - Language: OpenGL Shader Language (GLSL)
  - Code skeleton will be provided (Javascript + WebGL)
- Submission
  - Submit your project by 11:59PM AoE (Anywhere on Earth) on/before the due dates
  - Feedback will be provided in a week

Assignments

- A quick look at our assignment skeleton



Model properties

Translation

X 0

Y 0

Z 0

Scale

X 50

Y 50

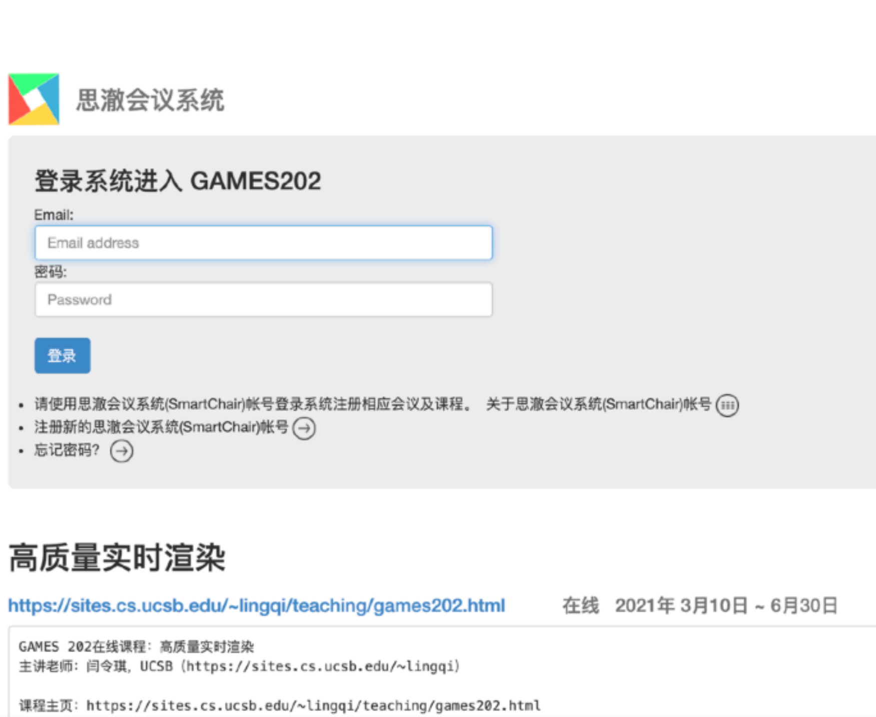
Z 50

Assignments

- Assignment Submission Website (http://smartchair.org/GAMES202)

- No Exams

- Course Project / Final Project
  - Starting midway of this course
  - References will be provided, but you decide the topic
  - Best work will be posted online for showing off



登录系统进入 GAMES202

- 请使用思澈会议系统(SmartChair)帐号登录系统注册相应会议及课程。 关于思澈会议系统(SmartChair)帐号
- 注册新的思澈会议系统(SmartChair)帐号
- 忘记密码?

高质量实时渲染

https://sites.cs.ucsb.edu/~lingqi/teaching/games202.html 在线 2021年 3月10日 ~ 6月30日

GAMES 202在线课程：高质量实时渲染
主讲老师：闫令琪，UCSB（https://sites.cs.ucsb.edu/~lingqi）

课程主页：https://sites.cs.ucsb.edu/~lingqi/teaching/games202.html

No Need to Use An IDE!

- IDE: Integrated Development Environment
- An IDE Helps you parse a entire project
  - And gives hints on syntax / usages of member functions, etc.
- Since you'll be focusing on writing shaders most of the times in this course
  - No need to use an IDE this time
  - A text editor is perfectly fine
    - Sublime Text, Vi / Vim, Emacs, etc.
  - Online text editors are also great

Academic integrity

- Work alone for regular assignments
  - no copy-pasting from any other sources
- Do not publish your code (on Github, etc.) for assignments using our skeleton code
- Do not post your solution online
  - Discussion / explanation is welcomed

Questions?

Today’s Lecture

Outline

- Motivation
- Evolution of real-time rendering
- Technological and algorithmic milestones
  - Programmable graphics hardware
  - Precomputation-based methods
  - Interactive Ray Tracing

Motivation

- Today, Computer Graphics is able to generate photorealistic images
  - Complex geometry, lighting, materials, shadows
  - Computer-generated movies/special effects (difficult or impossible to tell real from rendered…)

[Artist: Teruyuki and Yuka]

Copyright (c)Hyun Kyung Up.All Rights Reserved.

[Artist: Hyun Kyung]

Motivation

- But accurate algorithms (esp. ray tracing) are very slow
  - So they are called offline rendering methods
  - Remember how long it takes to render 1 frame in Zootopia?

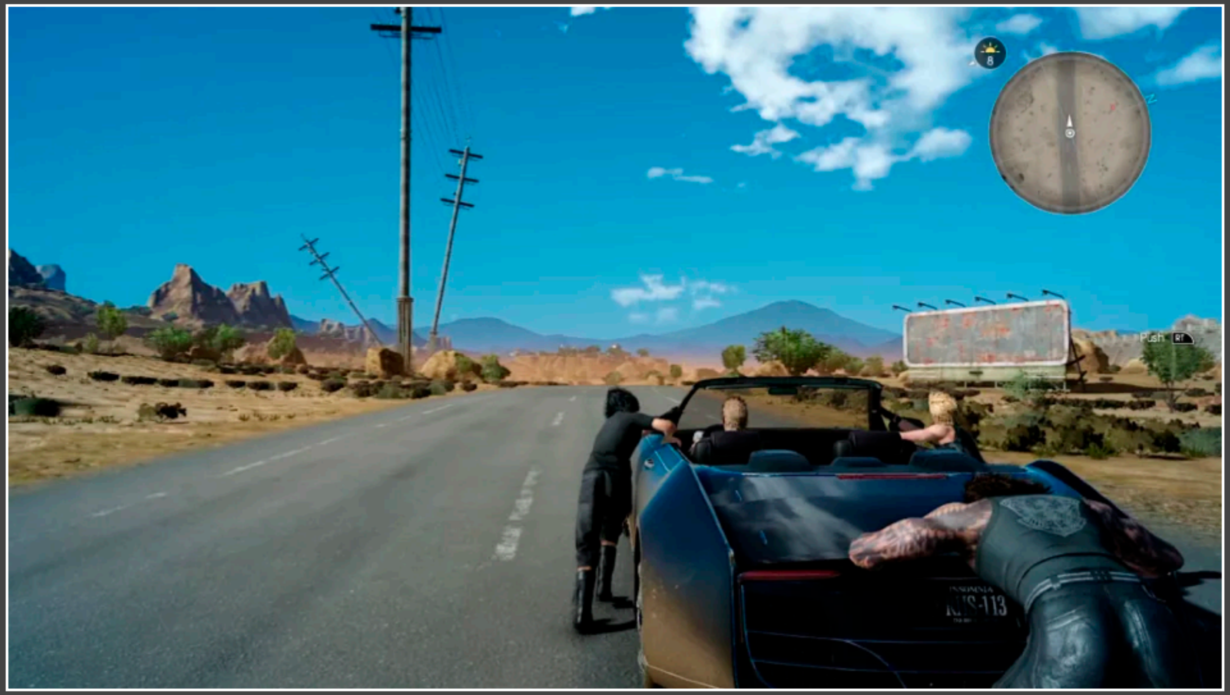
Zootopia, Disney Animation

Motivation

- With proper approximations, we can generate plausible results but runs much faster

© 2009, Narita/Schneider | Modeling by Masa Narita, www.masacgi.com | Shading, Lighting, Rendering, Compositing by Linus Schneider, www.pixelprinz.ch

Toyota 2000GT, from TurboSquid
(offline rendering)



Final Fantasy XV
(real-time rendering)

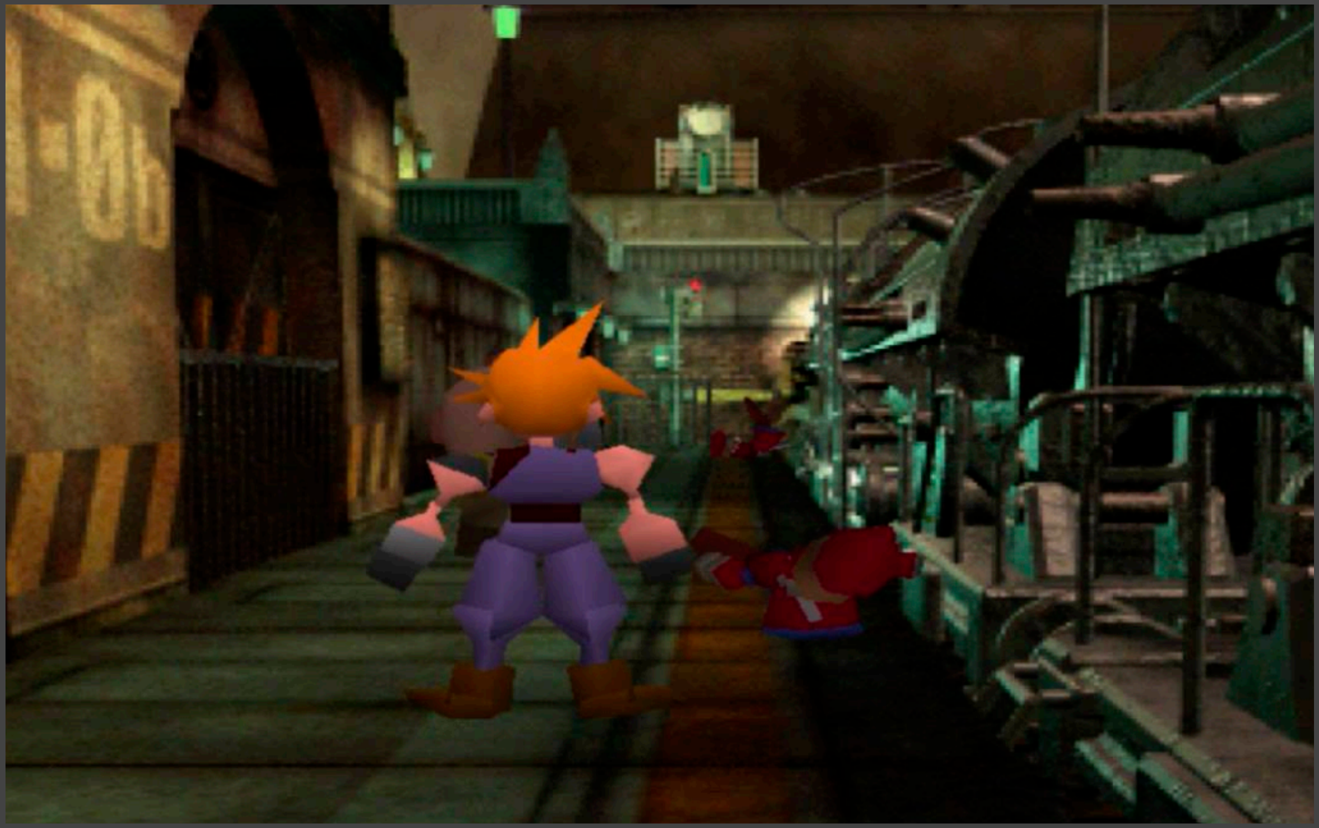
Evolution of Real-Time Rendering

- Interactive 3D graphics pipeline as in OpenGL
  - Earliest SGI machines (Clark 82) to today
  - Most of focus on more geometry, texture mapping
  - Some tweaks for realism (shadow mapping, accum. buffer)

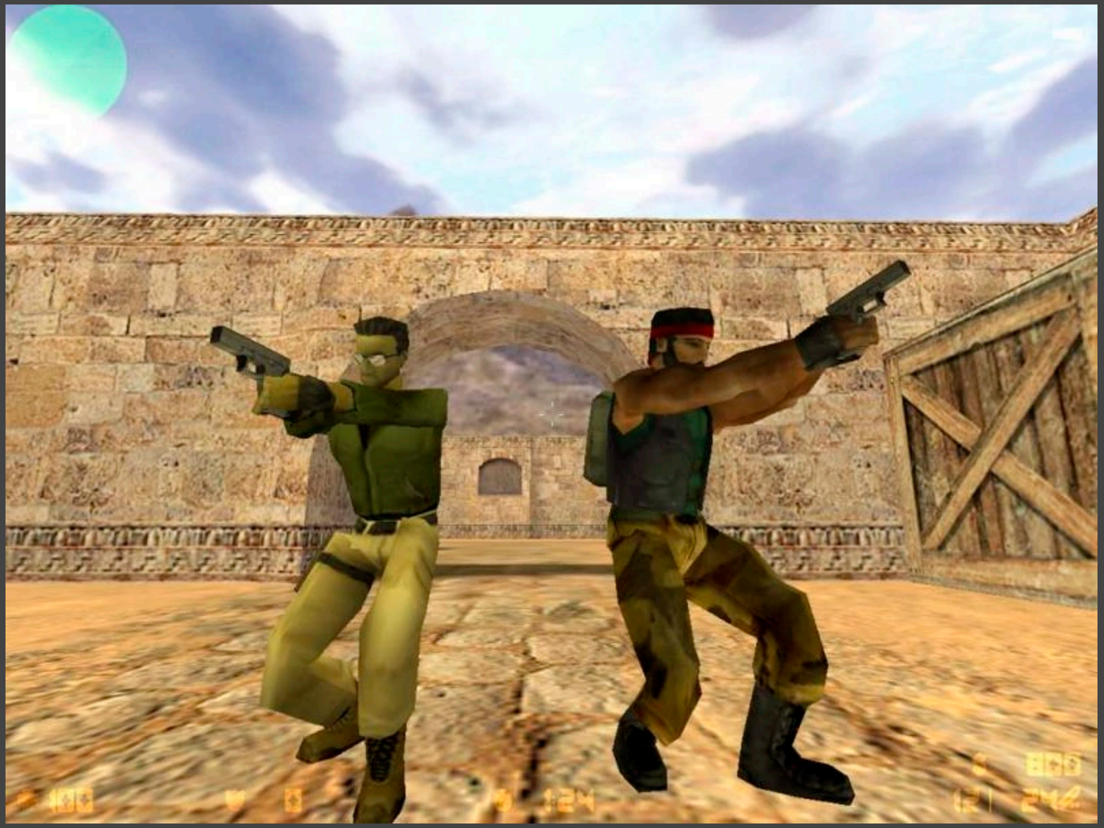
SGI Reality Engine 93
(Kurt Akeley)

Evolution of Real-Time Rendering

- 20 years ago
  - Interactive 3D geometry with simple texture mapping, fake shadows (OpenGL, DirectX)



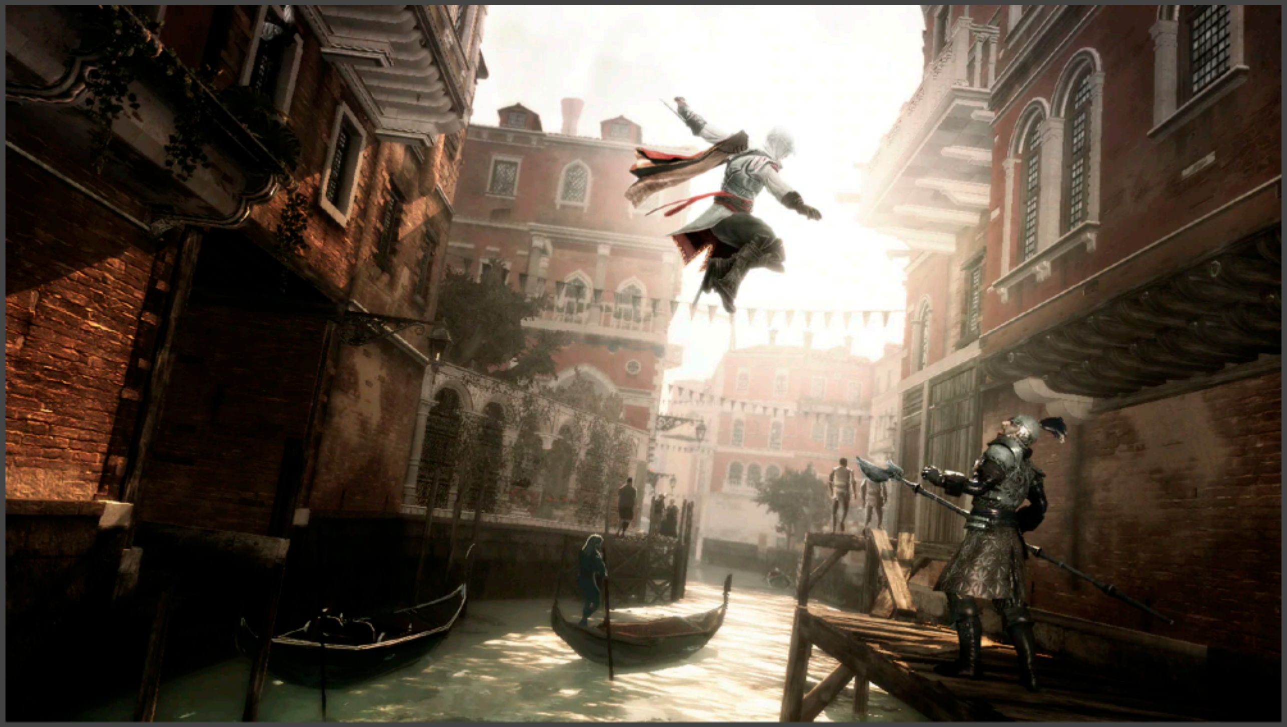
Final Fantasy VII
(1997)



Counter Strike
(1999)

Evolution of Real-Time Rendering

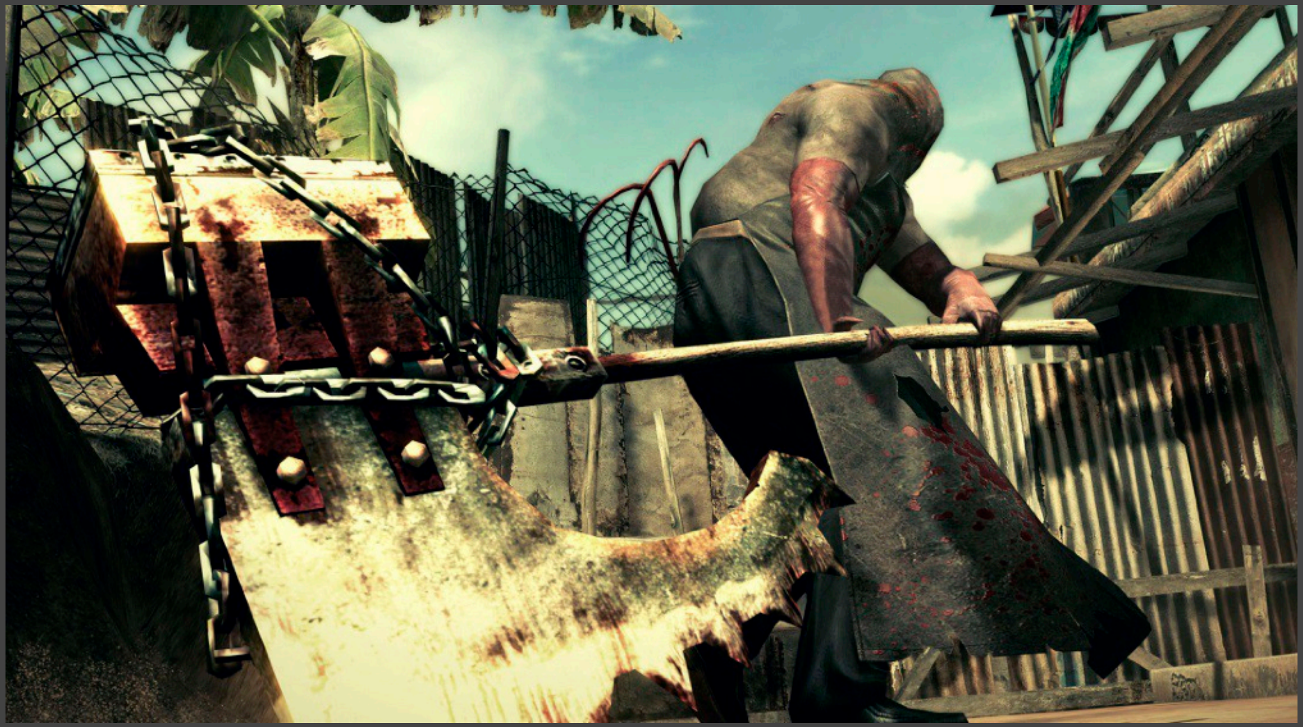
- 20 -> 10 years ago
  - A giant leap since the emergence of programmable shaders (2000)
  - Complex environment lighting, real materials (velvet, satin, paints), soft shadows



Assassin's Creed II
(2009)

DARK

OILY



Resident Evil 5
(2009)

Evolution of Real-Time Rendering

- Today
  - “Stunning graphics”

God of War (2018)

Evolution of Real-Time Rendering

- Today
  - Extended to Virtual Reality (VR) and even movies

Beat Saber, VR Game

Zafari, animation series rendered completely using Unreal game engine

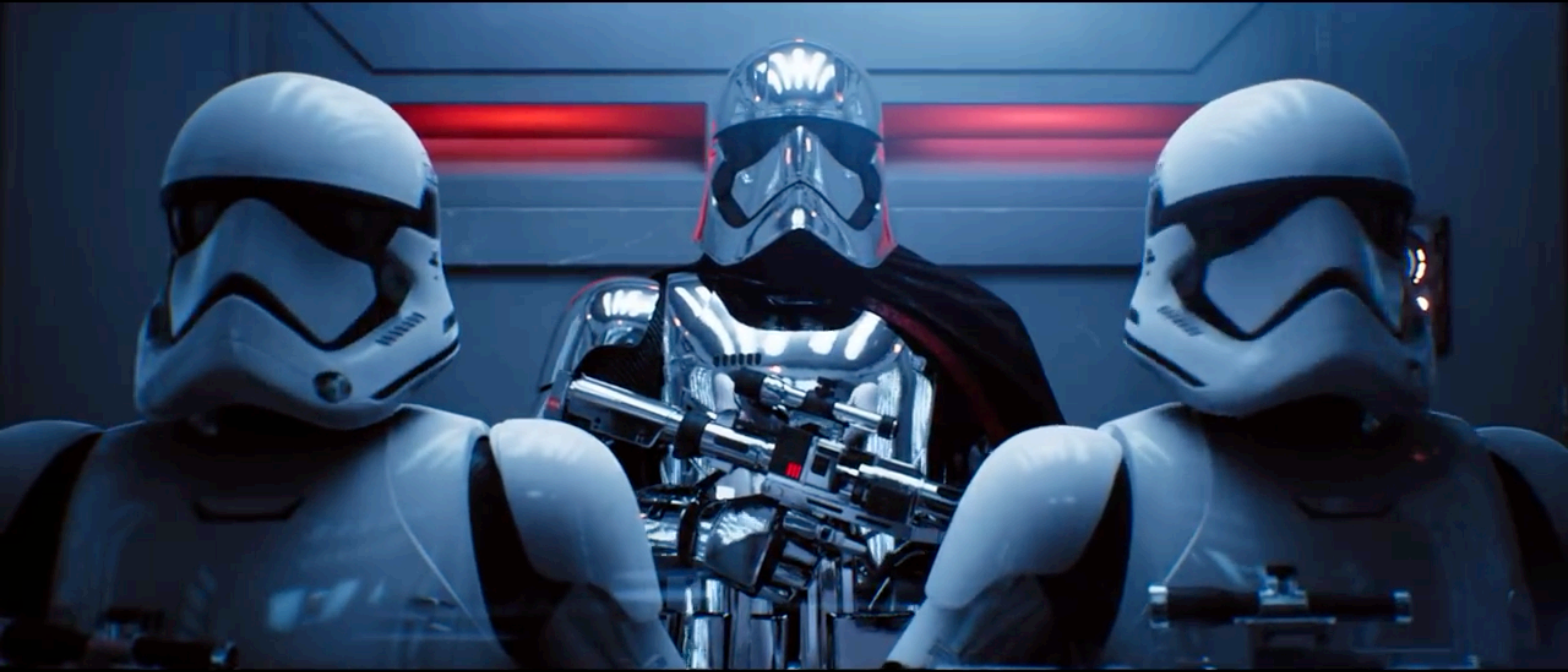
Evolution of Real-Time Rendering

- Today

(2018) - Photorealistic Forests with Unreal Engine 4

Evolution of Real-Time Rendering

- Today



(2018) - Real-Time Ray Tracing Demo, NVIDIA

Evolution of Real-Time Rendering

- In the future

The Matrix (1999 movie)

Evolution of Real-Time Rendering

- In the future

Ready Player One (2018 movie)

Technological and Algorithmic Milestones

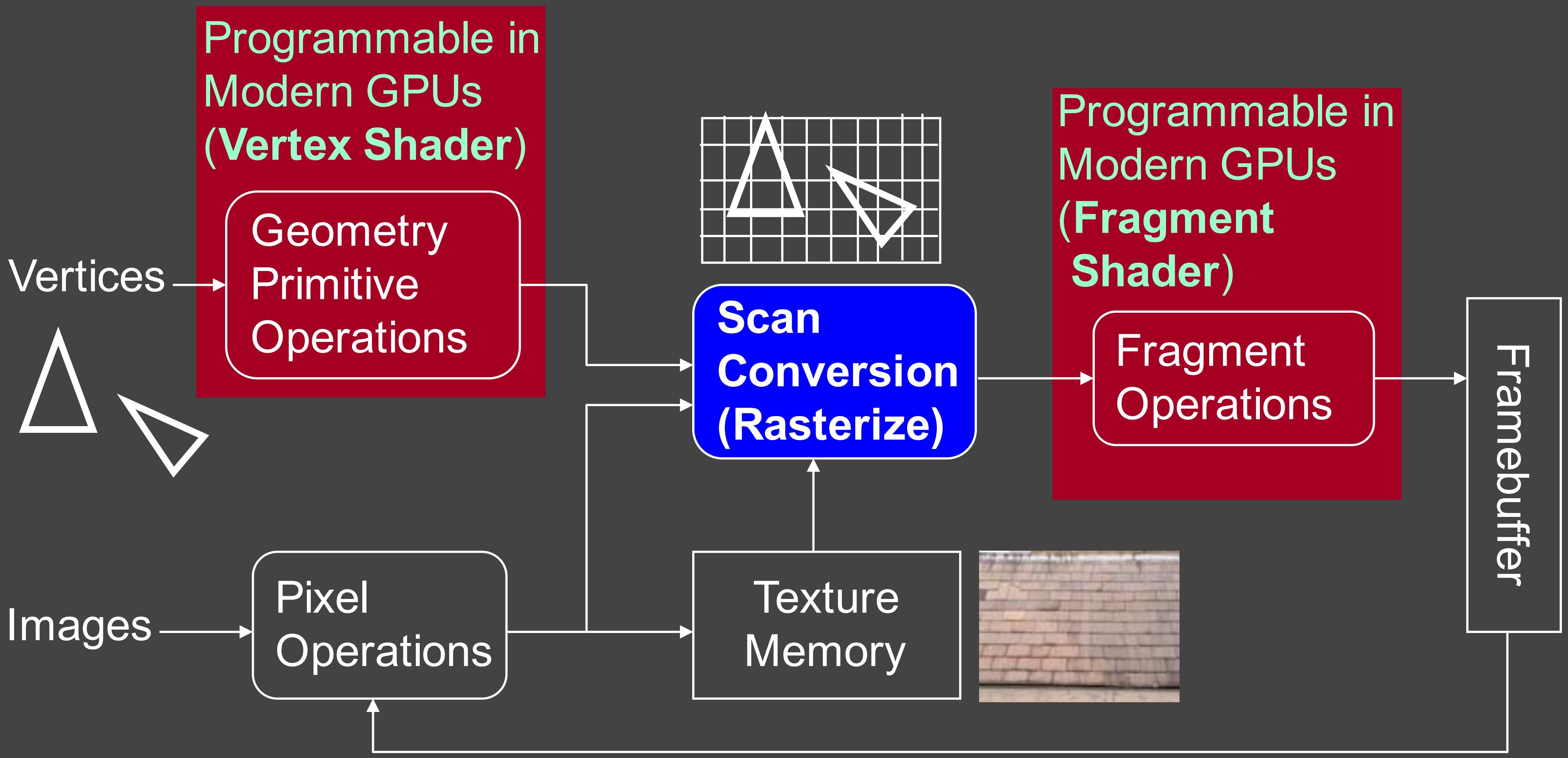
- Programmable graphics hardware (shaders) (20 years ago)

A New Dawn demo, NVIDIA

https://www.geforce.com/games-applications/pc-applications/a-new-dawn/videos

Technological and Algorithmic Milestones

- Programmable graphics hardware (shaders)



Programmable in Modern GPUs (**Vertex Shader**)

Vertices

Geometry Primitive Operations

Scan Conversion (Rasterize)

Programmable in Modern GPUs (**Fragment Shader**)

Fragment Operations

Framebuffer

Images

Pixel Operations

Texture Memory

Image courtesy of Prof. Ravi Ramamoorthi

Technological and Algorithmic Milestones

- Precomputation-based methods (15 years ago)
  - Complex visual effects are (partially) pre-computed
  - Minimum rendering cost at run time

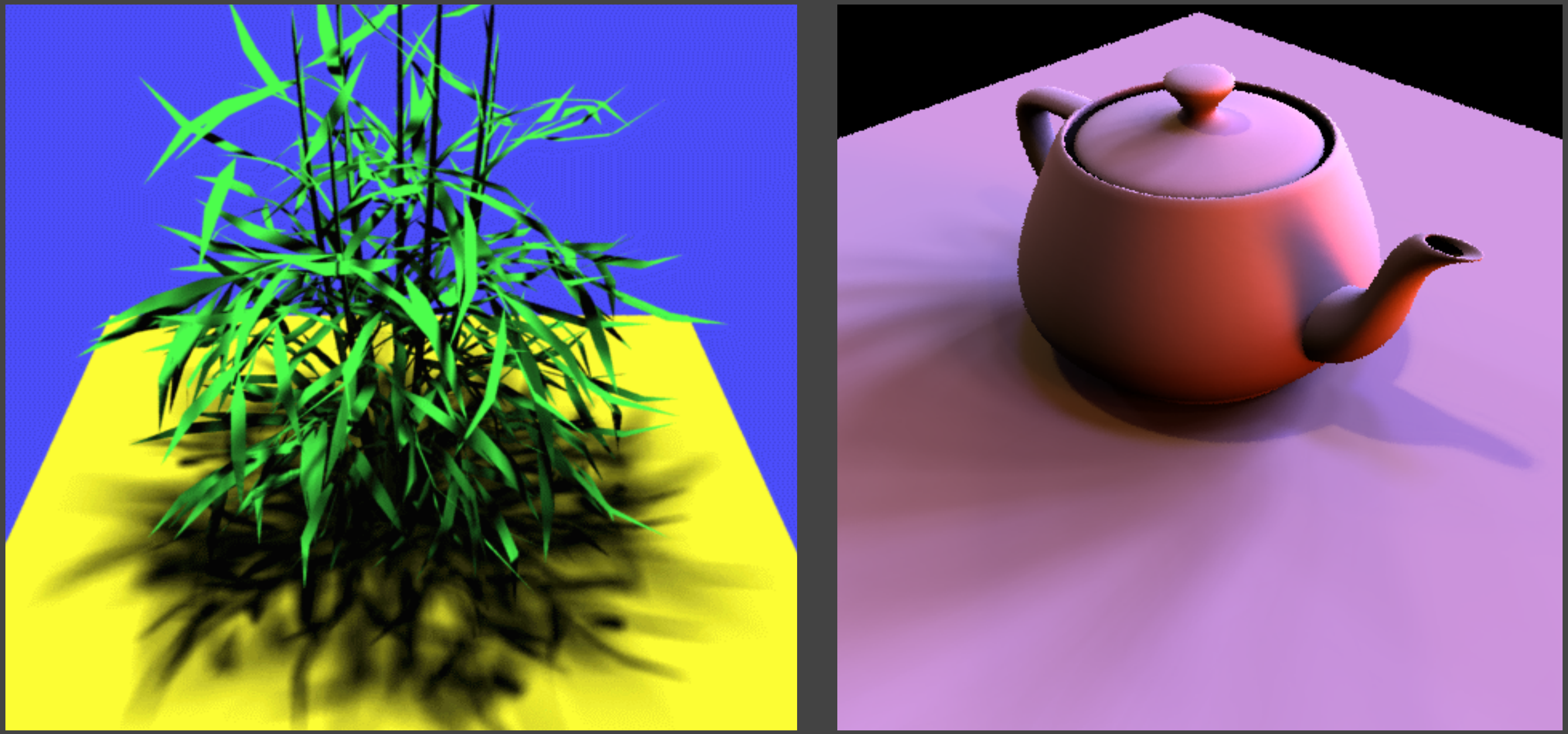


Image courtesy of Prof. Ravi Ramamoorthi

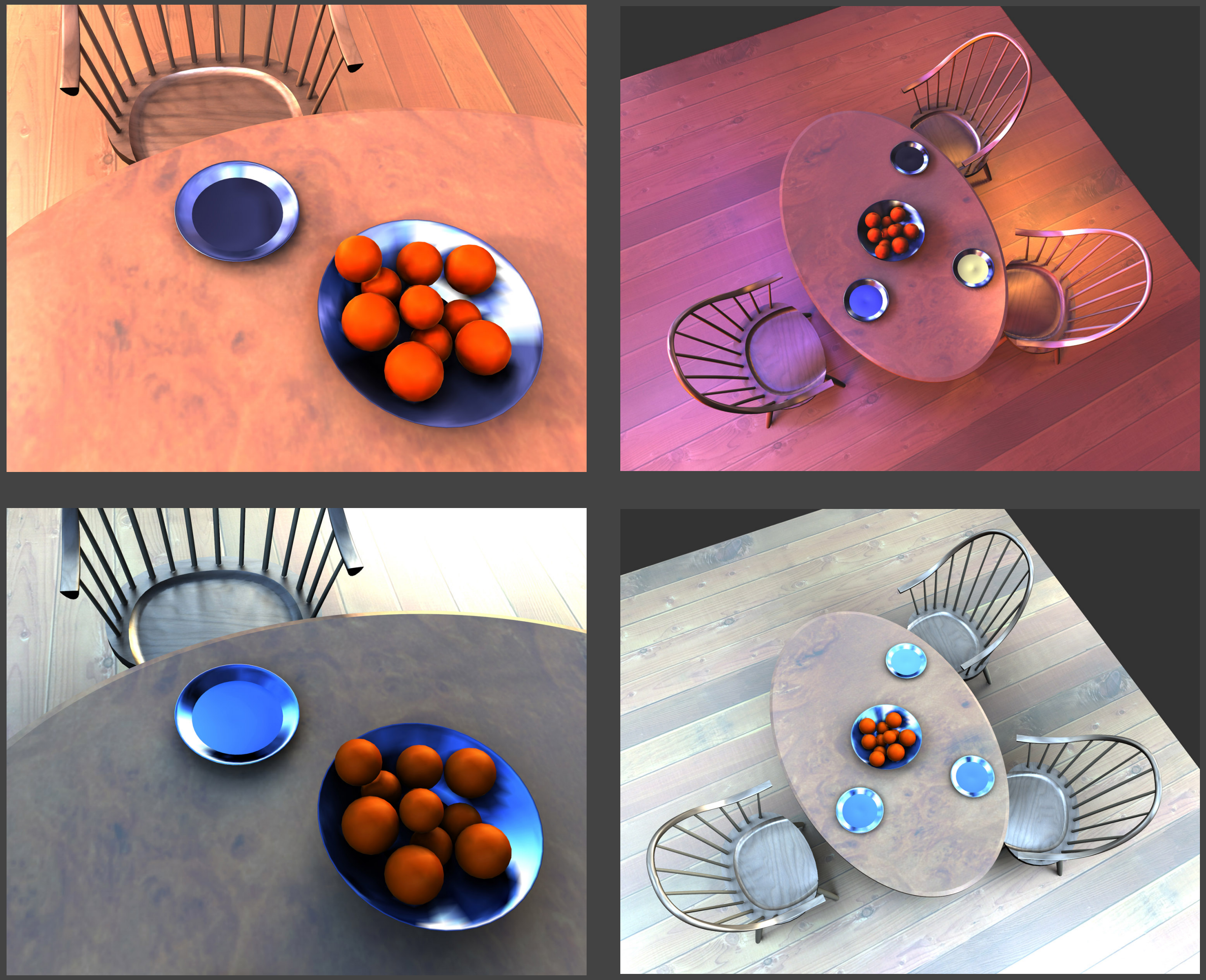
Technological and Algorithmic Milestones

- Precomputation-based methods

All-Frequency Rendering of Dynamic, Spatially-Varying Reflectance
Wang et al.

Technological and Algorithmic Milestones

- Precomputation-based methods: Relighting
  - Fix geometry
  - Fix viewpoint
  - Dynamically change lighting



[Ng, Ramamoorthi, Hanrahan 04]

Technological and Algorithmic Milestones

- Interactive Ray Tracing (8-10 years ago: CUDA + OptiX)
  - Hardware development allows ray tracing on GPUs at low sampling rates (~1 samples per pixel (SPP))
  - Followed by post processing to denoise

Car interactively rendered using NVIDIA OptiX

Pixar’s real-time previewer

Questions?

Next Lecture

- A swift and brutal recap of some important concepts
  - Graphics Pipeline
  - Shader Language
  - Rendering Equation
  - Calculus
  - etc.

Thank you!