

Computer Graphics

Lecture 01:

Introduction

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Contact Information

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 - Lab time: Thursday 8:00 – 10:00



What is Computer Graphics?

- Computer Graphics is the science and art of communicating visually via a computer's display and its interaction devices
- The visual aspect of the communication is usually in the computer-to-human direction
- The human-to-computer direction is mediated by devices like the mouse, keyboard, joystick, game controller, or touch-sensitive overlay



History of Computer Graphics

- William Fetter coined term “computer graphics” in 1960 to describe new design methods he was pursuing at Boeing for cockpit ergonomics
- Created a series of widely reproduced images on “pen plotter” exploring cockpit design, using 3D model of human body.
- *“Perhaps the best way to define computer graphics is to find out what it is not. It is not a machine. It is not a computer, nor a group of computer programs. It is not the know-how of a graphic designer, a programmer, a writer, a motion picture specialist, or a reproduction specialist. Computer graphics is all these – a consciously managed and documented technology directed toward communicating information accurately and descriptively.” Computer Graphics, by William A. Fetter, 1966*

What is Interactive Computer Graphics?

- User controls content, structure, and appearance of objects and their displayed images via rapid visual feedback
- Basic components of an interactive graphics system
 - input (e.g., mouse, stylus, multi-touch, in-air fingers...)
 - processing (and storage of the underlying representation/model)
 - display/output (e.g., screen, paper-based printer, video recorder...)
- Real time rendering



First interactive graphics system

- Sketchpad, pioneered by Ivan Sutherland 1963 Ph.D. thesis “Sketchpad, A Man-Machine Graphical Communication System”
- Used TX-2 transistorized “mainframe” at MIT Lincoln Lab
- Note CRT monitor, light pen, and function-key panels – the “organ console” showing bi-manual operation



Sketchpad

- <https://www.youtube.com/watch?v=546ADZMBT8&feature=youtu.be>

Application of Computer Graphics (Movies)



Jurassic World (2015)

- <https://www.youtube.com/watch?v=-6tlKc6kTg>

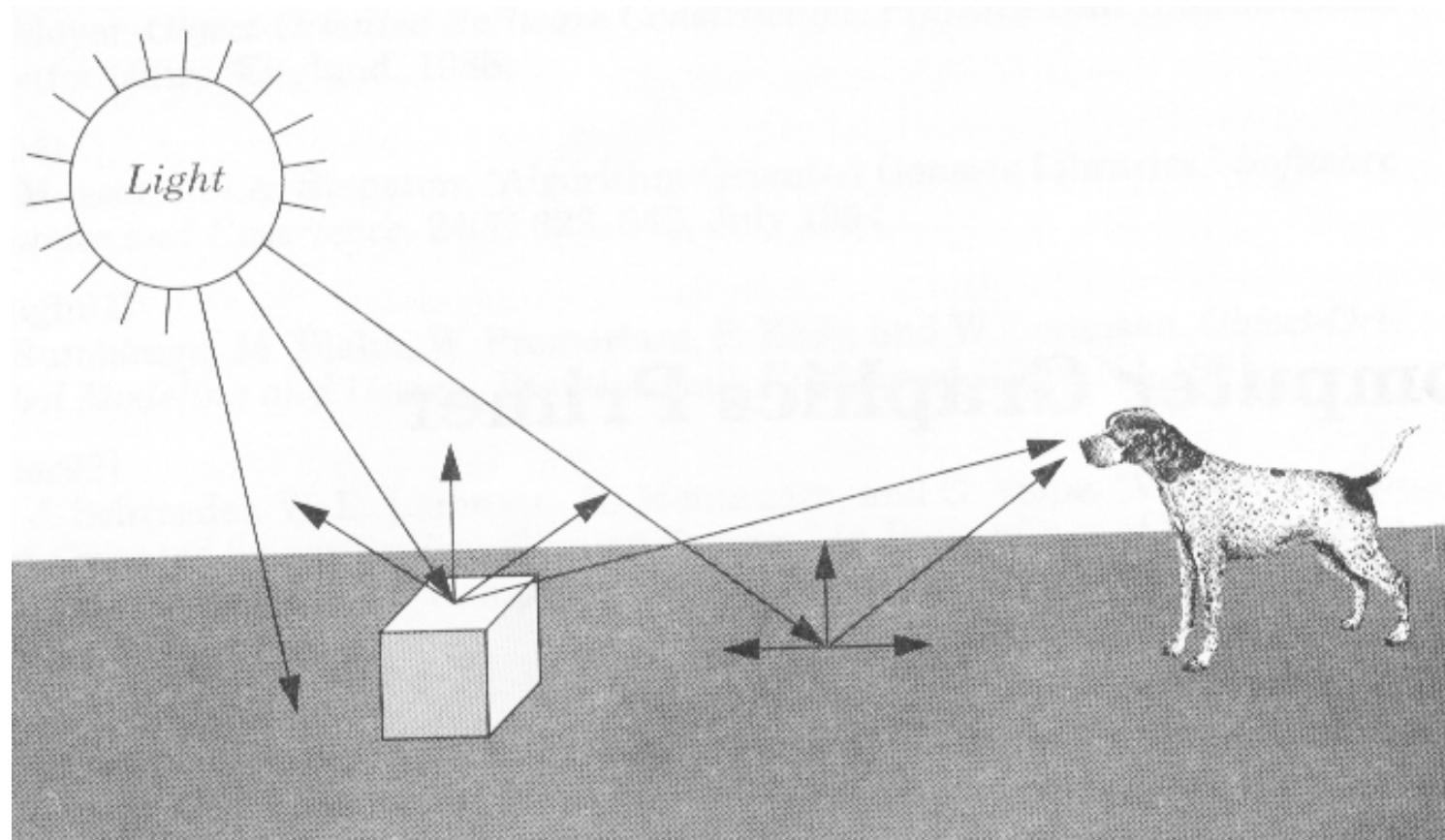


Rendering

- A process of generating an image from a 2D or 3D model, by means of computer programs.



Rendering - Example



Rendering Methods

- Forward tracing

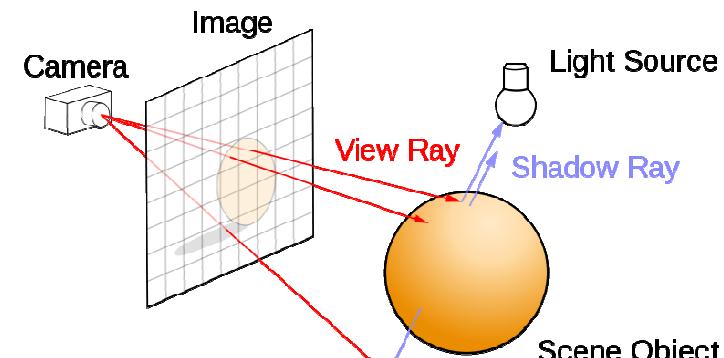
- Consider every photon emitted by light source
- Inefficient and extremely slow
- Large number of light rays

- Backward tracing (ray tracing)

- Trace hypothetical photo backwards from eye in particular direction
- Slow
- Number of light rays equals to the screen resolution

- Surface rendering

- What light shines on surface?
- How does material interact with light?
- What part of result is visible to eye?



Camera in Unity3D

- <https://www.youtube.com/watch?v=xvyrzwwU1DE>



Modeling vs. Rendering

- Modeling
 - Create models
 - Apply materials to models
 - Place models around scene
 - Place lights in scene
 - Place the camera
- Rendering
 - Take “picture” with camera
 - Both can be done with commercial software:
 - Autodesk Maya™ ,3D Studio Max™, Blender™, etc.

Application of Computer Graphics (Video Games)



Tom Clancy's Division (Pre-Rendered)

- <https://www.youtube.com/watch?v=ais1yAtVS2A>

What is Pre-Rendering?

- Today, we still use non-interactive *batch mode* (a.k.a. offline rendering or pre-rendering) for final production-quality video and film (i.e. special effects – FX)
- Rendering a single frame of *The Good Dinosaur* (2015, a 24 fps movie) averaged 48 hours on a 30,000-core render farm



Tom Clancy's Division (Real-time Rendered)

- <https://www.youtube.com/watch?v=EWJD8DMasCU>

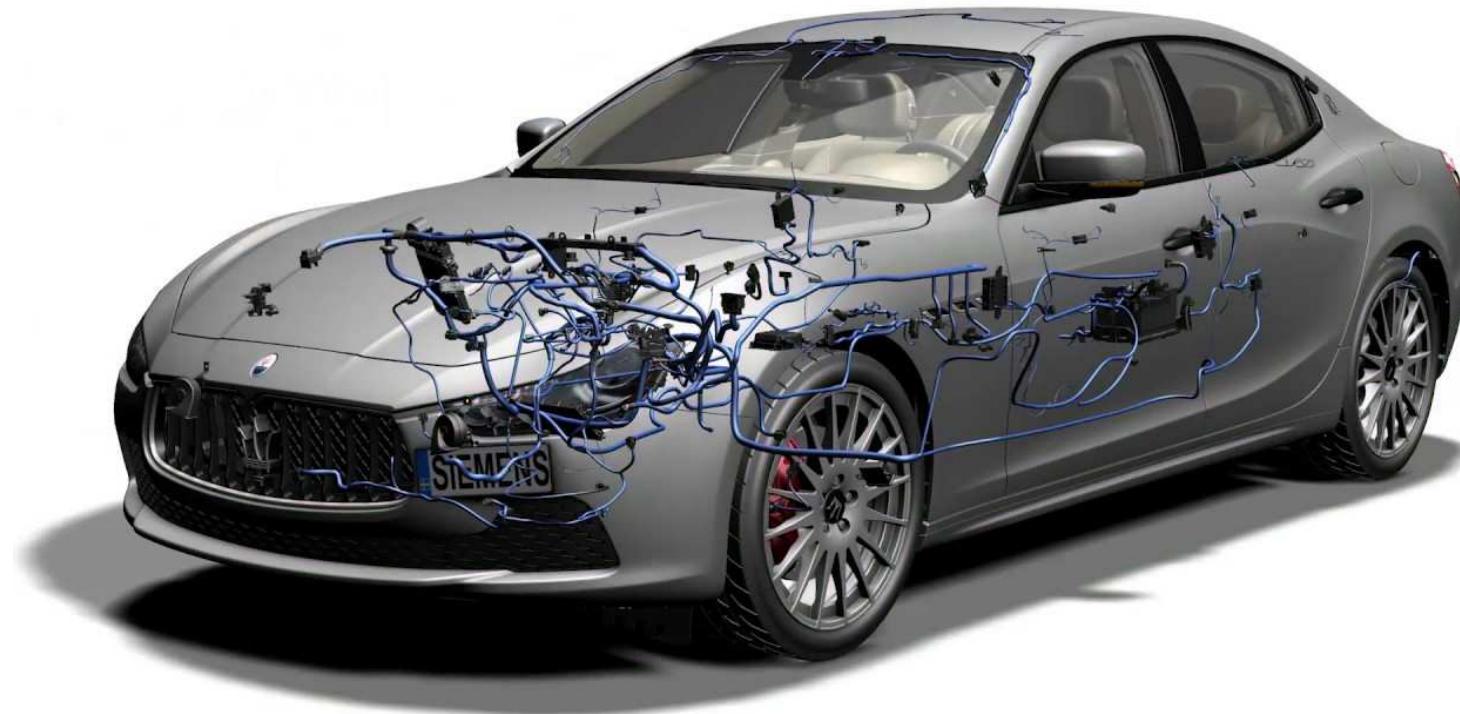


What does it mean by real-time?

- “Real-time” is the basic requirement for interactive computer graphics (especially for games)
- Classical CRT display device: 24 fps
- Modern LED display device:
 - 30 fps
 - 60 fps (why?)
 - Or more (140 fps?)



Application of Computer Graphics (CAD/CAM Design)



Application of Computer Graphics (Virtual Reality)



GTA 5 in VR Cyberith VIRTUALIZER + Oculus RIFT

- <https://www.youtube.com/watch?v=6CZmJvl8mfc>



Real or CG (1/4)?



Real or CG (2/4)?



Real or CG (3/4)?

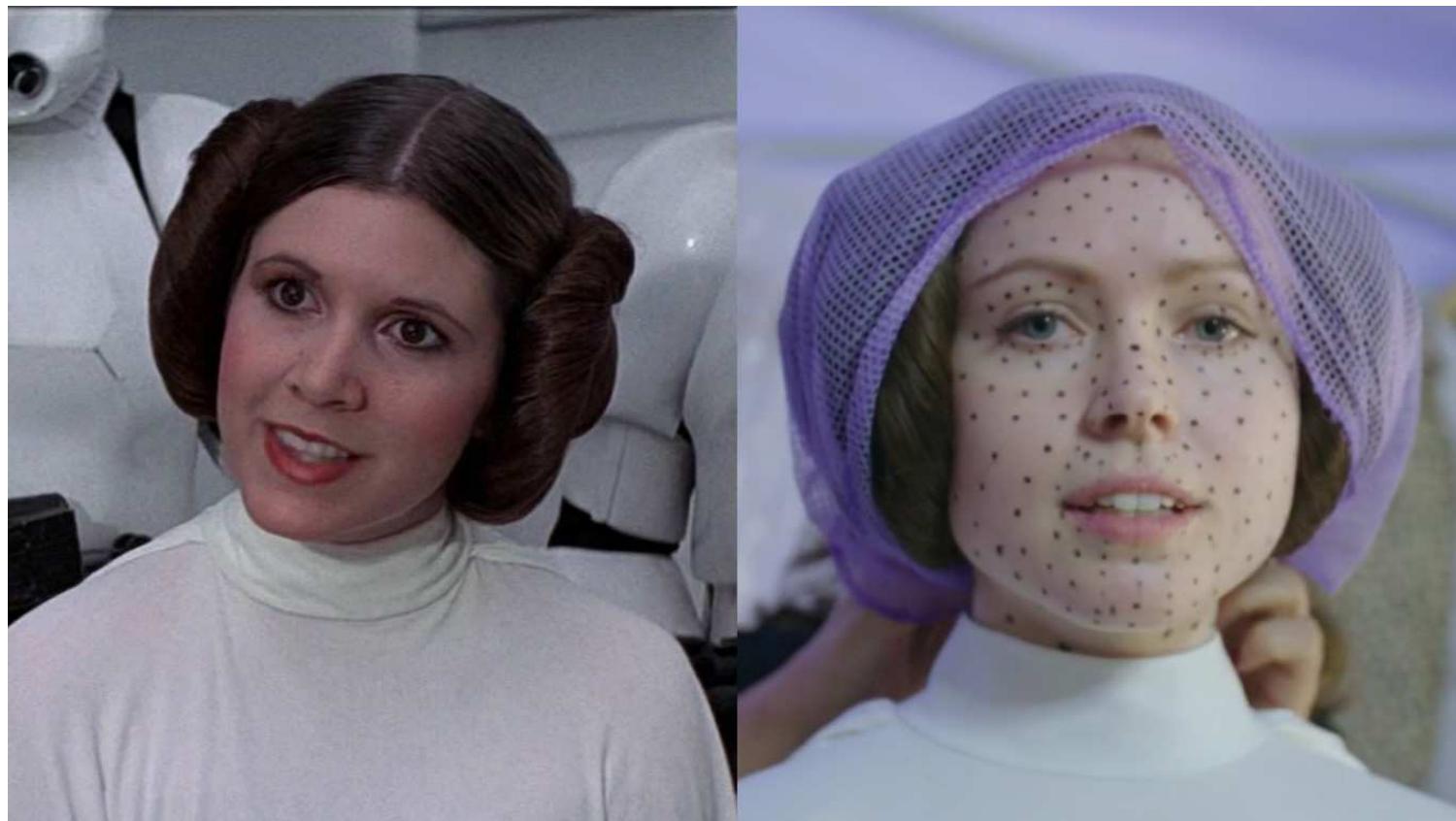


Rogue One: A Star Wars Story (2016)

- <https://www.youtube.com/watch?v=6Yj31YCa3Xw>



This is how they do it



Real or CG (4/4)?



Graphics Hardware

- Moore's Law: every 12-18 months, computer power improves by factor of 2 in price / performance as size shrinks
- Newest CPUs are 64-bit with 4, 8, 16, even up to 22 cores
- Intel Kaby Lake – consumer processor with 4 cores, 8 threads, and a fully featured graphics chip built in to the processor
- Significant advances in commodity graphics chips every 6 months vs. several years for general purpose CPUs
 - NVIDIA GeForce GTX Titan Xp... 3840 cores, 12GB memory, and 12 teraflops of processing power in a single chip



Graphics Hardware

- GPU
 - Offloads graphics processing from CPU to chip designed for doing graphics operations quickly
 - NVIDIA GeForce™, AMD Radeon™, and Intel HD and Iris Pro Graphics
 - GPUs originally designed to handle special-purpose graphics computations
 - Increasingly, GPUs used to parallelize other types of computation (known as GPGPU, or General-Purpose Computing on the Graphics Processing Unit)
- NVIDIA GeForce GTX 1080 Ti (2017)
 - 3584 cores, 1.58 GHz clock, 11GB memory, 139 billion pixels/second fill rate
- NVIDIA GeForce GTX 970 (2014)
 - 1664 cores, 1.05 GHz clock, 4GB memory, 75 billion pixels/second fill rate
- NVIDIA GeForce GTX 460 (2010)
 - 336 cores, 1.35 GHz clock, 1GB memory, 37.8 billion pixels/second fill rate

Input Devices

- Mouse, tablet & stylus, multi-touch, force feedback, and other game controllers (e.g., Wii U), scanner, digital camera (images, computer vision), etc.
- Body as interaction device
 - <http://youtu.be/zXghYjh6Gro>



Xbox Kinect



Leap Motion



Nimble UX

Platforms

- Many form factors
- Smartphones/laptops/desktops/tablets
- Smart watches
- Head-mounted displays (HMDs)
 - HTC Vive
- Augmented Reality
- Virtual Reality
 - AR vs VR: Different experiences!



Apple iPhone



Android Phones



Tablets



Microsoft's first Surface



Apple Watch



Android Wear



Vive



Oculus Rift



Google Cardboard



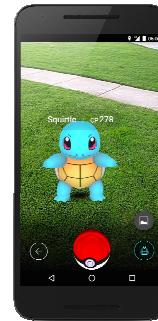
Brown's old Cave



Microsoft Hololens

Augmented Reality

- Easily accessible AR through smartphones



- Advanced AR through Microsoft Hololens
 - <https://youtu.be/tYPlodStLTc>



Modern Computer Graphics Hardware

- Software Improvements
 - Algorithms and data structures
 - Modeling of materials
 - Rendering of natural phenomena
 - “Acceleration data structures” for ray tracing and other renderers
 - Parallelization
 - Most operations are embarrassingly parallel: calculating value of one pixel is often independent of other pixels
 - Distributed and Cloud computing
 - Send operations to the cloud, get back results, don’t care how
 - Rendering even available as internet service!



Graphics Library

- Examples: OpenGL™, DirectX™, Windows Presentation Foundation™ (WPF) accessed via XAML, RenderMan™, HTML5 + WebGL™
- Primitives (characters, lines, polygons, meshes,...)
- Attributes
 - Color, line style, material properties for 3D
- Lights
- Transformations
- Immediate mode vs. retained mode
 - immediate mode: no stored representation, package holds only attribute state, and application must completely draw each frame
 - retained mode: library compiles and displays from scenegraph that it maintains, a complex DAG. It is a display-centered extract of the Application Model



Graphics Library used in this course

- OpenGL
- Unity3D

Course Objectives

- To provide an introduction to the theory and practice of computer graphics.
- To help students to understand standards based graphics systems in several programming projects illustrating the theory and practice of programming computer graphics applications.



What this course is NOT about

- Expertising OpenGL and DirectX
 - They usually become obsolete in 5 years
- Design Software
 - CAD-CAM, 3D Studio MAX, Maya, Photoshop
- Artistic skills
- Game play design



What this course is about

- This course is purely technical
- To teach computer graphics from a “science and engineering” point of view
- Emphasize on real-time interactive computer graphics and game development
- i.e. This course is for hardcore tech geeks (bad news?)



Game Development Technologies

- Game development makes use of many of the technologies you studied for your computer science degree (who did?)
- The following subjects are involved:
 - Computer Graphics
 - Computer Networking
 - Distributed Systems
 - Computer Security
 - Database Management Systems
 - Artificial Intelligence
 - Software Engineering
- However, it is more than that.....



Unique Aspects of Game Development

- This course covers some unique aspects of game development. For examples:
 - Collision detection
 - Communication architectures for online games
 - Schemes of game state replication
 - Analysis of attacks on multiplayer games
 - Physics for computer games
 - Load balancing of online game systems



Middleware

- What is a middleware?
- Examples of game engines, graphical libraries, and SDKs
 - OpenGL + GLUT
 - Java3D
 - DirectX
 - Unreal
 - Unity3D
- They all become obsolete in 5 years

Course Outline

- Lecture 01: Introduction
- Lecture 02: Introduction to 2D and 3D Graphics
- Lecture 03: Mathematics of Computer Graphics
- Lecture 04: Transformation in 2D and 3D
- Lecture 05: Camera and Viewing
- Lecture 06: Colour and Lighting
- Lecture 07: Shading and Ray Tracing
- Lecture 08: Texture Mapping
- Lecture 09: Real-time Shadows



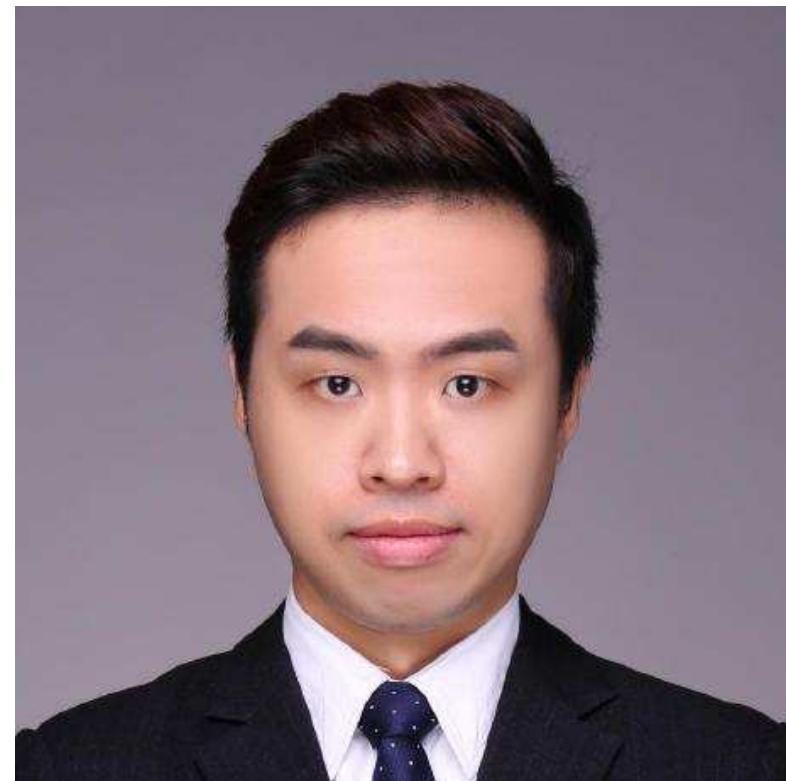
Course Outline (cont.)

- Lecture 10: Introduction to Computer Games
- Lecture 11: Collision Detection
- Lecture 12: Spatial Data Structure
- Lecture 13: Field Trip to Tencent (tbc.)
- Lecture 14: Special Topics in Computer Graphics I – Industrial Talk
- Lecture 15: Special Topics in Computer Graphics II – Industrial Talk
- Lecture 16: Presentation of Project



Week 14 Speaker: Mr. Milo Yip (Tencent)

- Expert Engineering of Game Engine Technology Center, R & D Department, Interative Entertainment Group (IEG), Tencent
- Former Ubisoft Developer
- Award-winning Blogger at Zhihu
- <https://www.zhihu.com/people/milo-yip/activities>



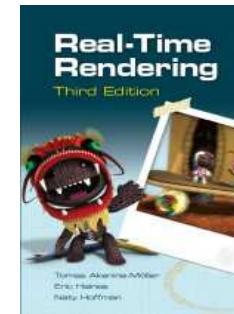
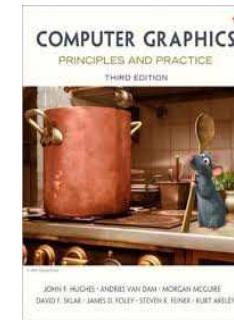
Week 15 Speaker: Dr. Simon Lui (Tencent)

- Expert Engineer of Tencent
- Former Assistant Professor of SUTD Singapore



Reference Books (We don't have a text book)

- John F. Hughes, Andries van Dam, Morgan McGuire, David F. Sklar, James D. Foley, Steven K. Feiner, and Kurt Akeley (2013). *Computer Graphics: Principles and Practice (3rd Edition)*. Addison-Wesley Professional.
- Tomas Akenine-Möller, Eric Haines, Naty Hoffman (2008). *Real-Time Rendering, Third Edition*. A K Peters/CRC Press.



What I assumed you know (The bad news)

- Programming Language:
 - Any (e.g. C++, Java, C#)
- Basic Concepts:
 - Mathematics (Set theory, Numerical methods, Linear Algebra)
 - Data Structures
 - Algorithms
- Gaming Experience:
 - Any 3D game



Assessments

- Course Assessments 50%
 - Assignment 10%
 - Laboratory 10%
 - Group Project 30%
- Examination 50%



Group Project

- To build a 3D interactive game
- Graphics Library/Tool/Game Engine/Programming Language: any
- Any Platform: PC, mobile phone, tablet, console, etc.
- Presentation (15 mins)
 - 10 mins demonstration (live demo is a MUST)
 - 5 mins Q&A
- Number of group members: at most 4
- Source code must be submitted
- Deadline: Week 15 (Friday)



Computer Game Club

- A club to research and develop computer game technologies at Sustech
- Volunteers
- Regular meetings
- Individual and group projects
- Outbound competitions



I WANT YOU



Wechat Group

- Sustech Computer Graphics Group
- I will use this group to send notifications instead of email

