USC
SCHOOL OF
ENGINEERING

Advanced Computer Graphics: Photographic Image Synthesis

COURSE CODE 599 (3 Units)

Objective This course covers modern techniques for realistic image synthesis, with an emphasis on data-driven computer graphics. The objective of the course is to introduce the student to recent trends in advanced photographic image synthesis including image-based synthesis and alternative offline photorealistic rendering techniques, with applications in the entertainment industry.

Concepts Topics include high dynamic range imaging (HDRI), matting, bidirectional reflectance distribution functions (BRDFs), image-based relighting, global illumination, augmented reality, and computational photography. Furthermore, the course will also provide a brief introduction in the mathematical theory of Monte Carlo integration and the physics of light transport.

Prerequisites CS-480 or CS-580 or equivalent introduction to computer graphics. It is assumed that the student is familiar with basic linear algebra (e.g., vector and matrix math, linear least-squares, ...).

Lecture 3hrs/week

Textbook *The following textbooks are recommended but optional:*

- *"Physically Based Rendering : From Theory to Implementation", Morgan Kaufmann, ISBN-13: 978-0125531801*
- *"High Dynamic Range Imaging: Acquisition, Display, and Image-Based Lighting", Morgan Kaufmann, ISBN-13: 978-0125852630*

Grading Grading will be based on 3 homework assignments (2 weeks each, during the 1st half of the semester), a project (2nd half of the semester), and participation during the lectures. A project presentation is required at the end of the semester.

Academic Integrity USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless

otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus,* the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to your TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m. - 5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

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Course Outline

Week 1 – Introduction & High Dynamic Range Imaging

Lecturer: Dr. Paul Debevec

This will give a general introduction to advanced photorealistic computer graphics. Additionally, we will cover high dynamic range photography, and essential tool for image-based computer graphics. As an application the acquisition of light probes is discussed.

Homework 1 (HDRI)

Week 2 –Image-based Lighting and Relighting

Lecturer: Dr. Paul Debevec

This series will introduce the concept of illuminating a computer-generated scene with captured real-world illumination from an HDRI omnidirectional image. We will also show how a light stage can acquire reflectance field datasets allowing real-world object to be re-illuminated with captured lighting conditions.

Week 3 – Advanced Image-based Relighting

Lecturer: Dr. Pieter Peers

Here we will discuss advances in image-based relighting to handle dynamic performances, and multiple viewpoints.

Homework 2 (IBR)

Week 4 – Introduction to Global Illumination

Lecturer: Dr. Abhijeet Ghosh

This will cover an introduction to radiometry and the physics of light transport with a focus on measurement and modeling in computer graphics. Topics to be covered include the bidirectional reflectance distribution function (BRDF), Snell's laws for geometric optics, Fresnel reflectance, microfacet models.

Week 5 – Global Illumination: Sampling

Lecturer: Dr. Abhijeet Ghosh

This will cover an introduction to Monte Carlo integration and sampling from a probability distribution function (PDF) with a focus on solving the rendering equation. Topics to be covered include the Monte Carlo sampling techniques for BRDFs, and illumination models such as area light sources and HDR environment maps.

Homework 3 (radiometry and sampling)

Week 6.1 – Matting & Environment Matting

Lecturer: Dr. Pieter Peers

This will cover an introduction into different matting techniques, and the introduction of the concept of environment matting. Topics include: background subtraction, blue screen methods, natural image matting, environment matting.

Week 6.2 – Guest Lecturer

Lecturer: To be announced

A guest lecture from a professional from the game or movie industry.

Week 7 – Environment Matting

Lecturer: Dr. Pieter Peers

This will further cover different environment matting techniques that focus on faster acquisition and/or better quality.

Project Proposals due this week.

Week 8 – Global Illumination: Rendering

Lecturer: Dr. Abhijeet Ghosh

This will cover realistic rendering techniques for computing global illumination such as Monte Carlo path tracing, Metropolis light transport, irradiance caching, photon mapping. We will also look at some recent techniques for computing direct illumination from HDR environment maps based on product distribution sampling.

Week 9 – Global Illumination: Advanced Material Models

Lecturer: Dr. Abhijeet Ghosh

This will cover more advanced models and measurement techniques of light transport in scattering materials and participating media. Topics to be covered are radiative transfer and diffusion of light with applications for simulating subsurface scattering in translucent materials, and single and multiple scattering of light in participating media such as smoke and heterogeneous layered media such as skin.

Week 10 – Image-based Material Representations

Lecturer: Dr. Pieter Peers

This session will cover alternative image-based material representation methods. This will cover BRDF, spatially varying BRDFs and heterogeneous subsurface scattering. Special attention is given to the acquisition of these material representations.

Week 11 – Intermediate Project Presentations

Status update project presentations.

Week 12 – Photoreal Digital Actors

Lecturer: Dr. Paul Debevec

This series of lectures will describe techniques for creating realistic models of the geometry and reflectance of human faces to be used in creating photorealistic digital actors. Topics will include high-resolution geometry scanning, facial reflectance models, accurate integration into scenes, and modeling changes in geometry and reflectance during facial animation.

Week 13.1 – Guest Lecture

Lecturer: To be announced

A guest lecture from a professional from the game or movie industry.

Week 13.2 – **Advanced Topics: Computational Photography**

Lecturer: Dr. Pieter Peers

An introduction to computational photography: novel ways of using consumer level cameras to overcome their shortcomings and/or achieve new functionalities.

Week 14 – Advanced Topics: Computational Photography and 3D Display Techniques

Lecturer: Dr. Paul Debevec

This class will cover advanced methods for computational photography and computational illumination. In addition, a spectrum of techniques for displaying photorealistic scenes three-dimensionally will be presented.

Week 15 - Final Presentations

Project presentations

Grading

Each homework (1 – 3) is worth 15% of the class grade. The grading of each homework will be on whether the solution fulfills the requirements for that homework. The grading will be either "fulfills the goals" or "does not fulfill the goals". Students in this class will build and maintain a web site describing their work. This web site must be maintained weekly to advise the lecturers on the status. The final project and presentation is 45% of the class grade. Daily class attendance is required for full participation and for full credit for this course.