CS 6451 – Foundations of Computer Graphics

Instructional Team

Jeff Wilson, Ph.D.
Creator and Instructor

Overview

This course explores the mathematical, physical, and perceptual principles behind computer graphics, focusing on techniques for creating, representing, and displaying three dimensional shapes and their properties. Designed for students with diverse backgrounds, the course includes a brief review of fundamental concepts in computer graphics.

The curriculum covers both Image Synthesis and Modeling. The first half of the course focuses on Image Synthesis, with an emphasis on the principles and implementation of Ray Tracing. The second half transitions to various techniques in 3D Modeling.

This course balances foundational concepts with advanced topics, offering a comprehensive introduction to the field of computer graphics at the graduate level.

Sample Topics

(specific topics and presentation schedule subject to change)

- **3D Graphics Geometry Basics**
  Introduction to vectors, transformations, and coordinate systems for 3D graphics.
- **Introduction to Ray Tracing**
  Fundamentals of ray tracing, ray-surface intersections, and light modeling.
- **Ray Tracing Intersections**
  Parametric and implicit geometry for ray-object intersection testing.
- **Optimizing Ray Tracing**
  Acceleration techniques, including bounding volumes, spatial hierarchies, and instancing.
- **Reflection and Refraction**

Light behavior modeling for reflective and transparent materials, including Fresnel and other effects.

- **Radiometry and BRDFs**
  Principles of radiometry and Bidirectional Reflectance Distribution Functions (BRDFs).
- **Distribution Ray Tracing**
  Advanced techniques for soft shadows, glossy reflections, and motion blur.
- **Tone Mapping and Sampling**
  Managing high-dynamic-range lighting and anti-aliasing techniques.
- **The Rendering Equation**
  Monte Carlo methods, importance sampling, and solving the rendering equation.
- **Texture Mapping**
  Fundamentals of texture mapping, mipmaps, and sampling artifact mitigation.
- **Procedural Texturing**
  Algorithmic texture generation, including Perlin noise and volumetric textures.
- **Implicit Surfaces**
  Defining and rendering implicit surfaces with ray marching and iso-surface extraction.
- **Geometric Primitives and Meshes**
  Properties of geometric primitives, mesh structures, and efficient data representation.
- **Mesh Smoothing and Interpolation**
  Subdivision surfaces, smoothing algorithms, and advanced curve modeling.
- **Distance Transforms**
  Applications of distance transforms in shape analysis, segmentation, and skeletonization.
- **GPU Ray Tracing**
  GPU acceleration techniques for real-time ray tracing and advanced rendering.

Grading

Programming Assignments: 80%

There will be around five programming projects. These projects will allow students to demonstrate the techniques presented in lecture including raytracing, implicit surfaces, mesh manipulation, etc.

Modules Quizzes: 20%

All graded assessments are individual effort (no collaborative work).

Texts

Fundamentals of Computer Graphics (4th edition), by Peter Shirley and Steve Marshner. Free on-line access through https://learning.oreilly.com/ (use your @gatech.edu email)

Physically Based Rendering (3rd edition), by Matt Pharr, Wenzel Jakkob and Greg Humphreys. https://pbr-book.org/

Technical Requirements and Software

Students are required by the institute to own an approved Windows or Mac OS laptop. This course will use Java and the Processing graphics library.

Late Policy

A 24-hour grace period with no penalty for late submission is permitted. No submissions later than this are permitted unless approved by the Dean of Students Office. See the Course Catalog for more details about the institute's attendance policy and impact on course deliverables.

Academic Integrity

All Georgia Tech students are expected to uphold the Georgia Tech Academic Honor Code.

All assignments in this course are individual effort.

This course may impose additional academic integrity stipulations; consult the official course documentation for more information.