EE 5xx – GPU-Accelerated Interactive Scientific Visualization Techniques (SciVis)

Professional Master's Program (PMP)

Instructor: Dr. Colin Reinhardt, EE Affiliate Assistant Professor

Overview:

In today's high-tech fully-connected world, the new problem is too much data. How can we make sense of all the tera/peta-bytes of data available at our fingertips? How do we extract useful information from the vast raw data?

In many fields of engineering, medicine, and scientific research, interactive multidimensional computer visualization techniques can provide crucial insight. Scientific data visualization (SciVis) is a hybrid field at the cutting-edge intersection of real-time interactive computer graphics, parallel software algorithms, and high-performance heterogeneous and GPU parallel computing hardware architectures.

Course Outline:

In this course, we'll learn the fundamentals of developing interactive 3D visualization tools for a variety of applications which generate large-scale complex multidimensional datasets, such as CT/MRI biomedical imagery, fluid flows from computational fluid dynamics (CFD) simulations, convective and radiative heat transfer modeling for aerospace engineering, and lidar remote-sensing point-clouds.

In the process we will study the following topics:

- fundamentals of scientific visualization: scalar, vector, and volumetric field visualization methods, data representations, mesh and grid generation, sampling and interpolation, iso- surfaces, and basic color theory concepts.
- design and implementation of fundamental SciVis volumetric algorithms such as marching cubes, ray casting, and direct volume rendering (DVR).
- programming optimized SciVis algorithms using the parallelized GPU graphics pipeline (OpenGL) and compute kernel shaders.
- GPU hardware internals and how to design our programs to take advantage of the host-device data interface, GPU cache and memory architecture, 2D/3D texture units, and the SPMD execution model.
- Domain-modeling and visualization techniques for point-cloud scattered datasets: radial basis functions, grid construction, triangulation, surface reconstruction methods.

Prerequisites:

This class will move quickly and assumes intermediate/advanced programming experience. Proficiency with C/C++ is strongly recommended. Familiarity with 3D computer graphics principles suggested. OpenGL preferred. Familiarity with modern microprocessor and computer architecture suggested.

Course Structure & Grading:

- A hands-on, in-lab, project-oriented curriculum.
- Class grade is based on 5 homeworks (60%), and an in-depth final project (40%).

(Tentative) Weekly Schedule:

1. Overview of SciVis. Intro to OpenGL and OpenCL. GPU Hardware-Intro
2. Scalar visualization with OpenGL and curve-plot. GPU Hardware-1
3. Vector visualization with OpenCL vector kernel. GPU Hardware-2
4. Volume visualization-1
5. Volume visualization-2.
6. Volume visualization-3.
7. Applications-1: CT/MRI biomedical imagery
8. Applications-2: Heat transfer models for aerospace engineering
9. Applications-3: Fluid flows from CFD simulations

A: Applications-4: Lidar point-cloud datasets

Religious Accommodations:

Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at Religious Accommodations Policy (https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/).
Accommodations must be requested within the first two weeks of this course using the Religious Accommodations Request form (https://registrar.washington.edu/students/religious-accommodations-request/)