EE 5xx – GPU-Accelerated Interactive Scientific Visualization Techniques (SciVis)
Professional Master's Program (PMP)

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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'll 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