EE 590 – 3D Computer Graphics Techniques for High-Performance Data Visualization (SciVis)
PMP, Winter 2017/18

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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:

- the necessary 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 SciViz volumetric algorithms such as marching cubes, dividing cubes, ray casting, splatting.
- programming optimized SciVis algorithms using the parallelized GPU graphics pipeline (OpenGL) and compute kernel (OpenCL) APIs.
- 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, 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.
Familiarity with modern microprocessor and computer architecture suggested.

Course Structure & Grading:
A hands-on, in lab, project-oriented curriculum.
Class grade is based on 4 homeworks, and an in-depth final project.

(Tentative) Weekly Schedule:
1: Overview of SciVis. Intro to OpenGL and OpenCL. GPU Hardware-Intro
2: Scalar vis. OpenGL and curve-plot. GPU Hardware-1
3: Vector vis. OpenCL vector kernel. GPU Hardware-2

4: Volume vis-1
5: Volume vis-2.
6: Volume vis-3.
7: App1: CT/MRI biomedical imagery
8: App2: heat transfer models for aerospace engineering
9: App3: fluid flows from CFD sims
A: App4: lidar point-cloud datasets