ECE 8780 Section 001
High-Performance Computing with GPUs

Class Location/Time: TTh 1100-1215, Riggs Hall 301 **Modality: In-Person**

Instructor: Dr. Melissa C. Smith **Email: smithmc@clemson.edu**
Office: 110 Riggs Hall or 262 Sirrine Hall **Phone: 864-656-2119**
Office Hours: TBD (will be posted on Canvas), or by appt.

Important Dates
Term: January 8, 2025 – May 2, 2025
Last day to withdraw without a W: January 22, 2025
Last day to drop without final grade: March 14, 2025
Exam/Final Project Presentations: Wednesday, May 1st 1500-1730

Course Description & Objectives

This course aims to provide students with the knowledge and hands-on experience in developing application software for processors with massively parallel computing resources. In general, we refer to a processor as massively parallel if it can complete more than 64 arithmetic operations per clock cycle. Many commercial offerings from NVIDIA, AMD, and Intel already offer such levels of concurrency. Effectively programming these processors will require in-depth knowledge about parallel programming principles, as well as the parallelism models, communication models, and resource limitations of these processors. The target audiences for this course are students who want to develop exciting applications for these processors, as well as those who want to develop programming tools and future implementations for these processors.

We will be using NVIDIA processors and the CUDA programming tools in the project sections of the course; high-performance computing exercises will be conducted on Palmetto and/or AWS. Many have reported success in performing non-graphics parallel computation as well as traditional graphics rendering computation on these processors. You will go through structured programming assignments before being "turned loose" on the group project. Each programming assignment will involve successively more sophisticated programming skills. The final project will allow you to explore the use of GPUs more broadly. You will be given a general framework that the project must involve a computationally demanding application followed by some form of visualization and/or display of results.

This is a course in programming massively parallel processors for general computation. The lectures will be based on the suggested texts and current literature. **Building on general C programming knowledge**, we will expose you to the tools and techniques you will need to attack a real-world application. There will also be lectures on programming computing clusters based on heterogeneous computing nodes and the use of cloud computing such as AWS.

Course webpage: **https://clemson.instructure.com**
Prerequisites: **Strong C programming background or consent of the Instructor**

Required Materials

Reference Text: ***Programming Massively Parallel Processors: A Hands-on Approach, 3rd Edition (or later)*** by Wen-Mei Hwu, and David Kirk.
(students can order a copy at www.store.elsevier.com using the discount code "COMP315" at checkout to receive 30% off and free shipping worldwide)

Supplement Text: ***Multicore and GPU Programming: An Integrated Approach***, by Gerassimos Barlas, ISBN: 9780124171374
Readings from the literature

Reference: NVIDIA, *NVidia CUDA C Programming Guide*

Laptop with design tools installed or other access to design tools.

Topical Outline

1. Introduction
2. CUDA Programming Model
    a. CUDA Threads
    b. CUDA Memories
3. GPU Performance Considerations and Techniques
    a. Memory Access
    b. Computation Patterns
    c. Floating Point
    d. Efficient Data Transfer
4. Advanced Techniques for High-Performance Computing (Case Studies & Examples)
5. Multi-GPU Systems
    a. MPI
    b. Heterogeneous Systems
6. Machine Learning Application with GPUs

*** The above schedule, policies, procedures, grading, and assignments in this course are subject to change in the event of extenuating circumstances, by mutual agreement, and/or to ensure better student learning. If we are required to pivot to an on-line modality, see additional information in the ECE Common Syllabus.**

Grading

- Quizzes: 15%
- Research Paper: 10%
- Labs (small problems), Hackathons, and other Homework: 30%
    - Demo/knowledge (oral presentation): 25%
    - Functionality and Performance: 40%
    - Report including code submission: 35%
- Project: 45%
    - Design Document 25%
    - Project Oral Presentation 25%
    - Demo/Functionality/Performance/Report including code submission: 50%

Examples/Tutorials: Where appropriate, examples or tutorials will be covered in class and/or assigned for students to complete for practice. These will not be graded but are essential to the successful completion of the assigned projects.
Labs: Students are expected to work individually unless specified by the instructor. Labs will be assigned to give students practice with the GPU programming models (CUDA and OpenCL), performance optimizations, and their use in heterogeneous systems. The culmination of each lab will be a clear and concise technical report including results, analysis, and conclusions drawn. Expect approximately four to five labs.
Project: The report for *large* projects should suitable for publication, discussing project concepts, development, experiments, results, and analyses. The most important outcome of each project and report will be the research results that are achieved, analyses rendered, and conclusions drawn with demonstrable insight.
Papers/Reports/Written Work: During the semester, students will be asked to research a selected topic related to the course material and/or complete homework assignments from the textbook or other sources. Further, if the opportunity presents, students will participate in a paper review either for journal submission or conference that is related to the course material.
Hackathons: In place of lectures, some class periods or portions will be designated as Hackathon Days. These will be small open-ended projects where teams will compete to find the best solution given some criteria. These will not require a written report but rather, an oral presentation and demo as appropriate.
Grading Scale: Final grade to be determined by the curved average with the weighting indicated above for quizzes, assignments, and projects. See the grading scale below.
Make-up Quiz Policy: Missed quizzes cannot be made up, except in case of a documented medical emergency. Dates for quizzes will be announced.

Grading System
Grades will be based on the following percentages (the +/- scale will NOT be used):
A – 90 and above
B – 80 to 89
C – 70 to 79
D – 60 to 69
F – 59 and below

Additional Policies

Students may leave after 15 minutes if the professor or guest lecturer does not arrive in that time. Attendance, while not required, is highly recommended. Students who regularly attend class and participate will receive special consideration if the course average is borderline; students that regularly miss required oral presentations and status updates will lose points on those respective projects (these oral updates will not be rescheduled). Students are responsible for obtaining lecture notes, handouts, and homework assignments for missed classes from fellow students or the class website when applicable.

- In the event of an emergency, students should contact the course instructor, preferably before class or the exam. Students should notify instructors regarding any scheduled absence through the Absence Notification in Canvas as soon as possible and develop a plan for any make-up work, if allowed by the instructor; do not email the instructor or TA directly. It is the student's responsibility to secure documentation of emergencies, if required by the instructor. A student

with an excessive number of absences may be withdrawn at the discretion of the course instructor. Only absences submitted through the notification system will be considered for an "excused absence".

- Assignments are due on the date and time specified in the assignment instructions; late assignments will not be accepted.
- Zeros will be given for missed in-class graded activities including oral presentations, assignments that require oral participation, and oral status updates; if you will miss one of these due to attending a conference, please clear that with the instructor before the class time that will be missed.
- Make-ups for graded activities and homework assignments are possible *only* with a valid, written, medical or university excuse. It is the student's responsibility to give the professor the written excuse and to arrange for any makeup work to be done *before* the quiz for that unit is taken.
- Students are expected to complete all assignments independently unless the instructor specifies team collaboration is permitted.
- **Students MUST complete ALL projects on time and submit all code to receive a passing grade in the course**.
- The use of a pen on exams will result in point deductions.
- Any exam scheduled at the time of a class cancellation due to inclement weather will be given at the next class meeting unless rescheduled by the instructor.
- Any assignments due at the time of a class cancellation due to inclement weather will be due at the next class meeting unless rescheduled by the instructor.

It is recommended that students check their school email and canvas daily for important announcements, assignments, and other class-related information. It is preferred that you use your **g.clemson.edu** account and not forward it to another account (e.g. Hotmail, Yahoo, etc.) as there is the potential for lost information with these systems.

Academic Integrity

This course follows Clemson University procedures. Students suspected of violating academic integrity will be reported. All work on quizzes, tests, exams, design assignments, projects, and labs is to be wholly your own unless otherwise instructed. Possessing, using, providing, or exchanging improperly acquired written, verbal, or electronic information (including but not limited to submitting code found on the internet) will be considered a violation of the academic honor code. Violations may result in a grade of F for the semester. See additional information in ECE Common Syllabus.

A FAQ regarding the university policy can be found at: http://www.clemson.edu/academics/academic-integrity/integrityfaq.html

I suggest that you read it, even if you have read it previously as there have been recent modifications.

Medical Withdrawal

A medical withdrawal request may be considered in unexpected cases in which serious illness or injury (medical) or other documentable challenge prevents a student from continuing academic work during the semester, and an arrangement for incompletes is not possible. Medical withdrawals can be considered for both physical and mental health circumstances. Approved medical withdrawals will replace all course grades for the approved term with a W grade. This action applies to all courses a student is enrolled in during the semester in question; it may not be applied selectively to some courses but not others.

Requests and supporting documentation must be received before the last day of classes for the respective term. In cases where a matriculated student needs to take time away from the program or needs to withdraw before classes start (e.g., anticipated surgery) a Leave of Absence request should be submitted instead of a medical withdrawal request. More information about medical withdrawal requests may be found in the Graduate School Policy Handbook.
All graduate policies are collected in the Graduate School Policy Handbook (http://www.clemson.edu/graduate/students/policies-procedures/index.html) for easy reference.