

Course: EE 699-001 / EE 599-001

Title: GPU & Multi-Core Computing

Term: Spring 2022

Credit hours: 3

Meeting days/time/location: Monday, Wednesday, Friday @ Noon-12:50PM, in 253 FPAT

Instructor Information

Name: Professor Henry (Hank) Dietz

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Office phone: (859) 257 4701

Office hours: schedule and live office camera are posted at <http://aggregate.org/hankd>

Email is the preferred contact method; please place "EE699" in the *Subject* line.

Office meetings can be physically in the Davis Marksbury Building, or can be online via Zoom.

Course students and staff must abide by all relevant pandemic safety guidelines, currently including wearing a mask for all in-person meetings.

Course Description

GPU & Multi-Core Computing is about the large-scale parallel processing within a modern computer (although a bit about cluster computing will also be covered). Multi-core refers to the multiple conventional processors now found within a processor chip. Graphics Processing Units (GPUs) were once all about video output, but have mutated into the dominant general-purpose many-core parallel computing architecture. In this course, you'll not only learn about the key architectural features of both, but also how to use them effectively -- primarily by directly programming them, but we'll also discuss some libraries. The goal is for students to be able to write efficient programs using these forms of parallel processing. Somewhat different from previous offerings, the intent is to spend relatively little time discussing computer architecture and to instead add coverage of program optimization tools and techniques that may be used both for sequential and parallel programs. All the projects will be C/C++ based, but you'll be using various other languages/libraries/tools, including CUDA and OpenMP, for your projects.

The primary difference between undergraduate (599) and graduate (699) students will be the structure of the projects: graduate students will have some additional project requirements.

Course Prerequisites

A good knowledge of C/C++ programming and basic understanding of computer architecture (e.g., CPE 380 would suffice).

Required Materials

Various materials for the course will be provided, primarily via canvas or the course website, <http://aggregate.org/GPUMC>. There is no textbook, but many references will be linked from the course website.

Associated Expenses

Students are strongly encouraged to use their own computers, either laptops or desktops, for the projects. However, some projects require a multi-core processor and others require a CUDA-capable GPU. Remote access will be provided to facilities in Marksbury (Dietz's research lab). All the required support software is freely available.

Activities Outside of Regular Class Meetings

In previous offerings, it became clear that student programming skill was not starting at an appropriate level and projects thus had to be watered-down somewhat. Instead, the tentative plan for this semester is to use a virtual flipped classroom approach to bolster student programming skills on the projects. Up to about 1/3 of the class meetings may thus be done in the form of live Zoom sessions with students coding projects on their machines following instructor directions in real time, interactively sharing their work, and getting feedback. Any such sessions would generally replace in-person meetings in the same timeslots.

Skill and Technology Requirements

Students are expected to have some C/C++ programming experience, exposure to computer architecture, and generally be computer literate.

For technical/account help, students can contact Information Technology Services by phone 859-218-HELP (4357) and via the [ITS Customer Services](https://www.uky.edu/its/customer-support-student-it-enablement/customer-services) page. (<https://www.uky.edu/its/customer-support-student-it-enablement/customer-services>)

Student Learning Outcomes

After completing this course, a student will be able to:

- Describe the concept of a performance-critical architectural feature and give examples [1]
- Analyze and optimize performance of sequential C/C++ programs [2,4,6]
- Describe MIMD parallel architectures and programming concepts [1]
- Write efficient MIMD programs using OpenMP, MPI, etc. [1,6]
- Describe SIMD/GPU parallel architectures and programming concepts [1]
- Write efficient SWAR programs [1,6]
- Write efficient GPU graphic programs using OpenGL [1,6]
- Write efficient programs using a GPU for general-purpose computation CUDA, etc. [1,6]
- Write programs using heterogeneous parallelism to boost efficiency [1,6,7]
- Create semi-formal Implementor's Notes for complex projects [3,5]

The 1-7 Computer Engineering Program Student Outcomes are listed at <http://www.engr.uky.edu/about-us/accreditation/computer-engineering> – each of the above course outcomes is marked with the most relevant program outcome number(s) in [].

Regular and Substantive Interaction/Academic Engagement

As per <https://www.uky.edu/tlai/compliance-faculty>, regular and substantive interaction (RSI) opportunities will be provided to ensure academic engagement even if portions of this nominally in-person course are taught using online mechanisms (e.g., due to pandemic-related issues).

Course Details

Tentative Course Schedule

Topic	Weeks	Exam
Introduction; concept of performance-critical architectural features, parallel processing, attached processors, heterogeneity, set-up for projects	1	0, 1
Optimizing code (sequential C/C++ code) — Performance analysis tools — Tuned libraries, magic algorithms — Software tools: specializers, superoptimizers, genetic programming (GP)	2	0, 1
Introduction to MIMD parallel architecture	1	0, 1
Shared memory programming & multi-core processors (Pthreads, OpenMP)	2	0, 1
Distributed memory programming & clusters (MPI)	2	0, 1
<i>Review for Exam 0: The C/C++ Exam</i>		
Introduction to SIMD parallel architecture	1	1
SWAR: SIMD Within A Register and vectors	1	1
GPUs: Graphics Processing Units (OpenGL)	1	1
GPGPU: General-Purpose GPU coding (CUDA , OpenCL)	2	1
All together	2	1
<i>Review for Exam 1 (the final): The And SIMD Too Exam</i>		

The above schedule describes the currently intended order and approximate weighting of the material, but significant adjustments are expected depending on student input and performance on projects.

Course Activities and Exams

There are two exams planned. Exam 0 will cover approximately half of the material and will be administered online using software that allows each student to take the exam at a time of their choosing within a window of several days. Exam 1 will be the final exam, which may be given either online or in person in the timeslot designated by the registrar: **1:00-3:00PM on Monday, May 2, 2022**, with the mode determined primarily by the need to accommodate pandemic issues at that time. It would be appropriate to think of the final as primarily covering the last half of the material, but it will include some earlier material. Thus, exam 0 will count for approximately 15% of your grade, while the final will count for about 25%.

The remaining 60% will be divided between homework assignments/projects and possibly random in-class quizzes. Each of the projects will involve significant programming and creation of a semi-formal Implementor's Notes document; some may be team efforts. Weighting will favor projects over simple homework assignments, and will be reflect the relative complexity of each. All projects and homeworks are submitted online. In-class quizzes may be simple questions or "participation" grades for flipped meetings done via Zoom. If any are given this semester, they will be given in class without prior warning

and each will be worth 2% of your grade. A quiz missed cannot be made up, but if it is missed for an excused absence, the quiz will be treated as having earned full credit.

Of course, especially in these pandemic times, we reserve the right to adjust the course activities and grading scheme should any unanticipated issues make it appropriate to do so. Students would be notified of any significant changes via canvas and/or the course web site.

Grading Scale

Nominally, the grading scale is:

90 - 100% = A

80 - 89% = B

70 - 79% = C

60 - 69% = D

Below 60% = E

Adjustments may be made to scores of specific graded materials (e.g., adjusting everyone's score for exam 0 if there was an issue with a question). The exam and homework/project grades will be computed separately, and the additional grading rule applied that your letter grade for the course cannot be more than one letter grade higher than the lower of the two scores. For example, 100% on exams and 69% on projects would numerically average to a grade of B, but this rule would limit it to C because the project grade alone was a D. Similarly, 50% on exams and 100% on projects would yield a course grade of D.

Midterm Grades

For undergraduates, midterm grades will be posted in myUK by the deadline established by the University Senate and published in the [Academic Calendar](http://www.uky.edu/registrar/content/academic-calendar). (<http://www.uky.edu/registrar/content/academic-calendar>) . Note that midterm grades will be based on the work completed and graded up to that point, which do not necessarily have the same exam vs. homework/project ratio as the course overall. For this reason, the midterm grade may be computed by a different weighting formula than your course grade in order to better estimate your likely performance in the course as a whole based on the work done to that point.

Attendance Policy/Acceptable Documentation

The University of Kentucky generally expects appropriate documentation for an excused absence: e.g. a letter from a healthcare provider. In general, notification beforehand via email to hankd@engr.uky.edu, with "EE699" in the subject line, will be accepted as a valid reason for an excused absence. Students missing class meetings generally are responsible for catching-up on the material missed even if the absence is excused. However, an excused absence will avert being penalized if a quiz is missed, and class presentation recordings are planned to be available to help those with an excused absence.

Assignment Policies

Assignment Submissions

All assignments will be collected electronically using software to be discussed in class and via canvas.

Returning Assignments to Students

The system we created for online exams will immediately let the student know their grade, but will not allow access to the graded exam until after the window for taking the exam has closed. The graded final

exams are kept on file and can be accessed by meeting with the course instructor. Assignments, projects, and quizzes may be handled in different ways.

Late Assignments

Online exams and assignments are expected to be submitted no later than the specified deadline, but the server will accept late submissions. Except where University Senate Rules about excused absences apply, it is entirely at the discretion of the instructor as to how much, if any, credit will be awarded for a late submission. Late assignments that are submitted after the assignment answers are posted or discussed in class are given zero credit, but ones submitted before any answers have been made available are more likely to be given some credit. It is also useful to note that most assignments can be submitted multiple times without penalty, and all such submissions are typically logged, but generally only the last one submitted before the deadline is considered for grading.

Assignments Due during Prep Week

No assignments will be due during Prep Week (which isn't really a week long). However, it is possible that activities making-up for an absence would be scheduled during that time.

Academic Policy Statements

Whatever is stated in the current Senate's [Academic Policy Statements](#) document applies.

Academic Offenses (Cheating, Plagiarism, and Falsification or Misuse of Academic Records)

Whatever is stated in the current Senate's [Rules Regarding Academic Offenses](#) document applies.

In the classroom, students should not take any actions that would disrupt the classroom environment (e.g., talking on a cell phone during class). In general, students are expected to behave in a respectful way towards their fellow students, the TA, and the instructor. **Failure to follow University of Kentucky guidelines involving appropriate precautions against spread of the pandemic will be treated as very serious offenses and dealt with as specified by the University.**

Students are expected to generally behave in an ethical manner, but violations will be treated as serious offenses. Altering graded exams and then submitting them for regrade is obviously unethical, but you do not need to be trying to enhance your grade in order for your behavior to be inappropriate. For example, attempts to break into computer accounts associated with this course or to falsely identify yourself are serious ethical violations even if there was no intent to "cheat" per se.

There are lots of study materials for this course, including old exams, widely available; using them as study aids is perfectly acceptable, but be warned that an apparent reuse of an old question usually has the question slightly reworded so that repeating the old answer will get no credit. Although students are encouraged to discuss course material with one another, everything you submit must be entirely your own original work. Similarly, for in-class exams that specify no textbooks, no calculators, etc., use of the banned resources is a serious offense. Online exams will specify what is and is not permitted, but the general rule is that referencing your notes, looking at online materials at the course web site, etc. is OK – however, getting help from another human while working on an online exam is not OK. Neither is it permissible for you to offer such help to a classmate.

Resources

There are a wide range of resources available to help you with this course, the most relevant of which will be cited at either canvas or the course web site. Arguably the most important resources are the instructor, TA, and your classmates – and you are strongly encouraged to interact.

In addition, the University of Kentucky offers facilities/services such as [Distance Learning Library Services](#) and [Tutoring and Coaching Resources](#).

Diversity, Equity, and Inclusion

The Senate [Syllabus Statement on Diversity, Equity, and Inclusion \(DEI\)](#) applies. Basically, I expect that we will all be open and nice to each other – that's what makes the best academic environment.

Student Resources

The University offers a variety of resources to students. Visit the University Senate's [Resources Available to Students](#) to access that list .

Course Recordings

The University of Kentucky Code of Student Conduct defines Invasion of Privacy as using electronic or other devices to make a photographic, audio, or video record of any person without their prior knowledge or consent when such a recording is likely to cause injury or distress.

Meetings of this course may be recorded. All video and audio recordings of lecturers and class meetings, provided by the instructors, are for educational use by students in this class only. They are available only through the Canvas shell or website for this course and are not to be copied, shared, or redistributed.

As addressed in the Code of Student Conduct, students are expected to follow appropriate university policies and maintain the security of linkblue accounts used to access recorded class materials. Recordings may not be reproduced, shared with those not enrolled in the class, or uploaded to other online environments.

If the instructor or a University of Kentucky office plans any other uses for the recordings, beyond this class, students identifiable in the recordings will be notified to request consent prior to such use. In anticipation of such cases, students may be asked to complete an “authorization of use” form by a faculty member.

Video and audio recordings by students are not permitted during the class unless the student has received prior permission from the instructor. Any sharing, distribution, and or uploading of these recordings outside of the parameters of the class is prohibited. Students with specific recording accommodations approved by the Disability Resource Center should present their official documentation to the instructor.

Course Copyright

All original instructor-provided content for this course, which may include handouts, assignments, and lectures, is the intellectual property of the instructor. Students enrolled in the course this academic term may use the original instructor-provided content for their learning and completion of course requirements this term, but such content must not be reproduced or sold. Students enrolled in the course this academic term are hereby granted permission to use original instructor-provided content for reasonable educational and professional purposes extending beyond this course and term, such as studying for a comprehensive or qualifying examination in a degree program, preparing for a professional or certification examination, or to assist in fulfilling responsibilities at a job or internship; other uses of original instructor-provided content require written permission from the instructor in advance.