

# Parallel Computer Architecture

EEL 6763 All sections

**Class Periods:** MWF 5<sup>th</sup> period, 11:45 AM - 12:35 PM

**Academic Term:** Spring 2022

## **Instructor:**

Dr. Herman Lam

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Benton 313

Office Hours: TBA

## **Course (Catalog) Description**

Advanced architecture emphasizing design and quantitative analysis of parallel architecture and systems, including theory, hardware technologies, parallel and scalable architectures, and software constructs.

## **Course Pre-Requisites / Co-Requisites**

EEL5764 Computer Architecture; or consent of instructor

## **Course Objectives**

The main objective of this course is to study the fundamental and newly developing hardware and software topics in parallel computer architecture (PCA), including concepts, models, methods, metrics, systems, and applications. Parallel computing (taking advantage of parallelism in computing) has become one of the most challenging and important areas of Computer Engineering, and it is now a dominant theme throughout computer architecture, systems, and programming, from low-power embedded systems to high-end supercomputers, and featuring various forms of fixed-logic (e.g., CPU, GPU, DSP), reconfigurable-logic (e.g., FPGA), and hybrid (e.g., CPU + GPU, CPU + FPGA, CPU + GPU + FPGA + other emerging accelerators) processing devices.

Students will gain fundamental knowledge and understanding of principles and practice in parallel computer architecture and computing, emphasizing both hardware and software challenges and their interactions. Additionally, students will be exposed to fundamental co-design techniques in order to optimize parallelism and gain practical insight into the parallelization process, as well as exposure to state-of-the-art and emerging research challenges in this field. Using HiPerGator, the University of Florida supercomputer, extensive on-hand experience is provided through labs and a class project.

## **Required Materials**

- Textbook – none
- Research papers to be assigned
- Course notes will be provided on the class website via Canvas
- Vendor documentation

## **Recommended Materials**

- P. Pacheco, M. Malensek, An Introduction to Parallel Programming (2nd Edition), Morgan Kaufmann, Publishers, 2022.
- J. L. Hennessy and D. Patterson, Computer Architecture: A Quantitative Approach (6th Edition), Morgan Kaufmann Publishers, 2019.

## **System/software:**

- HiPerGator, the University of Florida supercomputer provided by UF Research Computing (UFRC), will be used to implement the labs and projects. The programming languages used will be C/C++, combined with parallel programming languages such as MPI, OpenMP, and CUDA.

## **Course Topics:**

- General Overview
  - Motivation: why parallel computing
  - Fundamentals of parallel computing
    - PCA components & systems
    - PCA architectures: Flynn's taxonomy, based on memory organization
    - Parallel programming models
- PCA Architectures
  - Classical HPC architectures
    - Memory architectures: shared memory, distributed memory, hybrid
    - Communication architectures: interconnect topology, routing
  - Emerging parallel computing architectures
    - Warehouse-scale computers, cloud computing, domain-specific architectures
- Parallel programming models and languages
  - Message passing: e.g., MPI
  - Shared memory: e.g., OpenMP
  - Other programming models (e.g., hybrid, PGAS) and languages (CUDA, OpenCL)
- Parallel application design and implementation
  - Parallel algorithm design: decomposition techniques, mapping and scheduling, synchronization
  - Optimization strategies: load-balancing, scalability, locality/communication, memory optimization
- Performance evaluation
  - Analytical modeling, simulation, benchmarking & performance measurement
  - Performance metrics: speedup, efficiency, scalability
  - Performance tools: gprof, vtune, mpip, node and system simulators, etc.
- Case studies and special topics
  - Case study HPC systems: e.g., HiperGator, TOP500 HPC systems (<https://www.top500.org/lists/top500/>)
  - Case-study HPC research projects
  - Emerging heterogeneous HPC systems: Combination of CPUs, GPUs, other accelerators (e.g., FPGAs), and emerging devices (e.g., emerging memory devices)

**Lab Experiments:** A series of laboratory experiments (spanning the first half of the semester) will be assigned in synchronization with the topics covered in class lectures.

- MPI programming assignment
- OpenMP programming assignment
- CUDA programming assignment
- Profiler tools for performance analysis

**Research Project:** A research project will be assigned to explore fundamental issues in parallel computer architectures, systems, and applications. This project will span more than half of the semester and provide students the opportunity to explore fundamental issues more deeply in PCA. Students will form small teams to propose and then conduct an experimental research project on a topic in PCA of their choosing (subject to professor approval). Each project will involve elements of both hardware and software in parallel computing. The culmination of each project will be a clear and concise technical report suitable for potential publication discussing project concepts, development, experiments, results, and analyses. The most important outcome of each project will be the research results that are achieved, analyses rendered, and conclusions drawn with demonstrable insight.

## ***Attendance Policy, Class Expectations, Makeup Policy***

This class will be presented online using Zoom and requires access to a working webcam and stable internet connection. I prefer that students keep their camera on during the class so that I can see you as I would during normal face-to-face classes. Studies show that if we can see each other's faces then we will have more engagement, more student success, and more faculty success. However, this is not a requirement. I understand if on certain days you can't have your camera on due to internet bandwidth limitations, other family members, health issues, or any other reasons.

There are no scheduled makeup exams. Makeup exams are handled case-by-case, mainly for documented illness and emergencies.

## ***Evaluation of Grades***

<b>Assignment</b>	<b>Total Points</b>	<b>Percentage of Final Grade</b>
Midterm exam	100	25%
Final Exam	100	30%
Labs	100 each	Cumulatively 15%
Project	100	30%

## ***Grading Policy***

The following is the standard grading scale and serves as the basic guideline. Final grade assignments will be adjusted based on class performance (e.g., class averages on different class deliverables).

<b>Percent</b>	<b>Grade</b>	<b>Grade Points</b>
90.0 - 100.0	A	4.00
89.0 - 89.9	A-	3.67
85.0 - 88.9	B+	3.33
80.0 - 84.9	B	3.00
79.0 - 79.9	B-	2.67
75.0 - 78.9	C+	2.33
70.0 - 74.9	C	2.00
69.0 - 69.9	C-	1.67
65.0 - 68.9	D+	1.33
60.0 - 64.9	D	1.00
59.0 - 59.9	D-	0.67
0 - 58.9	E	0.00

More information on UF grading policy may be found at:

<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

## ***Students Requiring Accommodations***

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

## ***Course Evaluation***

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluer.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

## **In-Class Recording**

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

## **University Honesty Policy**

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Conduct Code (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. If you have any questions or concerns, please consult with the instructor or TAs in this class.

## **Commitment to a Safe and Inclusive Learning Environment**

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, [jpennacc@ufl.edu](mailto:jpennacc@ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

## **Software Use**

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

## ***Student Privacy***

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

## ***Campus Resources:***

### ***Health and Wellness***

#### **Covid-19 Protocols:**

- You are expected to wear approved face coverings at all times during class and within buildings even if you are vaccinated.
- If you are sick, stay home and self-quarantine. Please visit the UF Health Screen, Test & Protect website about next steps, retake the questionnaire and schedule your test for no sooner than 24 hours after your symptoms began. Please call your primary care provider if you are ill and need immediate care or the UF Student Health Care Center at 352-392-1161 (or email [covid@shcc.ufl.edu](mailto:covid@shcc.ufl.edu)) to be evaluated for testing and to receive further instructions about returning to campus.
- If you are withheld from campus by the Department of Health through Screen, Test & Protect, you are not permitted to use any on campus facilities. Students attempting to attend campus activities when withheld from campus will be referred to the Dean of Students Office.
- UF Health Screen, Test & Protect offers guidance when you are sick, have been exposed to someone who has tested positive or have tested positive yourself. Visit the UF Health Screen, Test & Protect website for more information.
- Please continue to follow healthy habits, including best practices like frequent hand washing. Following these practices is our responsibility as Gators.

#### **U Matter, We Care:**

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

**Counseling and Wellness Center:** <https://counseling.ufl.edu>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

#### **Sexual Discrimination, Harassment, Assault, or Violence**

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **[Office of Title IX Compliance](#)**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

#### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.  
<https://lss.at.ufl.edu/help.shtml>.

**Career Connections Center**, Reitz Union, 392-1601. Career assistance and counseling; <https://career.ufl.edu>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.  
<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.  
<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus**: <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>; <https://care.dso.ufl.edu>.

**On-Line Students Complaints**: <http://www.distance.ufl.edu/student-complaint-process>.