EEL 6763 Parallel Computer Architecture

Department of Electrical and Computer Engineering
University of Florida

Fall Semester 2019

***Description*:** Introduction to fundamental and newly developing hardware and software topics in parallel computer architecture (PCA) including concepts, models, methods, metrics, systems, and applications. PCA has become one of the most challenging and important areas of ECE, 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, DSP, GPU), reconfigurable-logic (e.g., FPGA), and hybrid (e.g., CPU+DSP, CPU+FPGA, CPU+GPU, CPU+FPGA+GPU) 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.

Prerequisites: EEL5764 Computer Architecture; *or consent of instructor*

***Instructor*:** Dr. Herman Lam

- Office: Benton Hall, Room 313
- Office hours: TBD
- Telephone: (352) 392-2689
- Email: hlam@ufl.edu

Teaching Assistant:

- TBD

Class lectures:

- MWF 5th period (11:45 am – 12:35 pm, Black Hall BLK 415

Required textbook: none

- Research papers
- Vendor documentation

Recommended references:

- A. Grama, A. Gupta, G. Karypis, and V. Kumar, Introduction to Parallel Computing, 2nd Edition, Pearson: Addison-Wesley, 2003. An errata list is available by John Kirk.
- D. Culler and J. Singh, Parallel Computer Architecture: A Hardware/Software Approach, Morgan Kaufmann, 2013.
- P. Pacheco, An Introduction to Parallel Programming, Morgan Kaufmann, 2011.
- B. Gaster, L. Howes, D. Kaeli, P. Mistry, and D. Schaa, Heterogeneous Computing with OpenCL, Morgan Kaufmann, 2011.

Grading:

- Mid-term: 25%
- Final exam: 30%
- Labs: 15%
- Project: 30%

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

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 taxonomy
  - Memory architectures: Shared memory, distributed memory
  - Communication architectures: interconnect topology, routing
- Parallel program models and languages
  - Message passing: MPI
  - Shared memory: 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, benchmarking & performance measurement
  - Performance metrices: speedup, efficiency, scalability
  - Performance tools: gprof, vtune, mpip, etc.
- Case studies and special topics
  - Case study HPC systems: e.g., Titan, Summit
  - Case-study HPC research projects: e.g., CMT-nek, BE-SST
  - Emerging Heterogeneous HPC systems: Combination of CPUs, GPUs, other accelerators (e.g., FPGAs), 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 in order 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 more deeply explore fundamental issues 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.

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.

Honesty Policy: All work submitted in this course must be your own and produced exclusively for this course. The use of sources (ideas, quotations, paraphrases) must be properly acknowledged and documented. Your professor in this course requires the utmost degree of academic honesty and ethics, and thus any violations (e.g., plagiarism) will be treated and handled very seriously. All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action. This statement is a reminder to uphold your obligation as a UF student and to be honest in all work submitted and exams taken in this course and all others. Every assignment and exam is subject to the requirements stated in the Academic Honesty Student Guide . The items listed in the Academic Honesty Guidelines in that document will be strictly enforced.

***Accommodation for Students with Disabilities*:** Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the Instructor when requesting accommodation.

UF Counseling Services: Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:

- University Counseling Center, 301 Peabody Hall, 392-1575, Personal and Career Counseling.
- SHCC mental Health, Student Health Care Center, 392-1171, Personal and Counseling.
- Center for Sexual Assault/Abuse Recovery and Education (CARE), Student Health Care Center, 392-1161, sexual assault counseling.
- Career Resource Center, Reitz Union, 392-1601, career development assistance and counseling.

Software Use: All faculty, staff and student 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.