USC Viterbi School of Engineering
Ming Hsieh Department of Electrical Engineering

Course Announcement

EE/CSCI 451: PARALLEL AND DISTRIBUTED COMPUTATION
TTH 330-450, LAB/DISCUSSION F 330-450
FALL 2022

The course will focus on broad principles of parallel and distributed computation. The Lab associated with the course will illustrate the principles through parallel programming examples.

INSTRUCTOR: VIKTOR K. PRASANNA

Prerequisite: (EE 355x or CSCI 201L) or consent of the instructor.
Text: Introduction to Parallel Computing, Second edition, Grama, Karypis, Kumar, Gupta, Addison-Wesley.
Course Grade: based on home works, parallel programming assignments, midterm(s), and final and course project.

Course Outline:

1. **Introduction (1):** Architectural advances, technology perspectives, motivating examples**,** challenges.
2. **Architectural Principles for Application Developers (2): 1.** Pipelined processor organization: data and control hazards, ILP, out of order execution, multithreading. **2.** Memory systems: DRAM organization, cache organization. Impact on software performance, locality, multithreading. **3.** Interconnection networks: static, dynamic networks.
3. **Analytical Models for Parallel Systems (4): 1.** Architecture performance metrics: CPI, MIPS, SpecMark. Software performance benchmarks: Peak performance, sustained performance, LinPack, Bandwidth benchmarks. **2.** Limits on achievable performance, Amdhal's Law, Gustafson's Law, Scaled speed-up, scalability definitions, work optimality, Iso efficiency function, Order notation. **3.** Communication costs in parallel machines: start-up cost, throughput, latency. Routing mechanisms: packet routing, cut through, virtual channels. Modeling message passing and shared address space machines. Data layouts and graph embeddings. **4.** Multi-core, many-core architectures.
4. **PRAM and Data Parallel Algorithms (4): 1.** PRAM model of computation, Brent's theorem, illustrative examples. **2.** Max, Scan operations. **3.** Recursive doubling, graph algorithms. **4.** Performance analysis, scalability. **5.** FFT.
5. **Basic Communication Primitives (4): 1.** Broadcast and all to all, communication costs on various topologies. **2.** Personalized communication. **3.** Reduce, prefix sum and scatter and gather**. 4.** Graph embeddings.
6. **Message Passing Programming Model (2): 1.** Message passing abstraction, send receive primitives, blocking and non-blocking commands, collective operations. **2.** Illustrative examples: Canon's algorithm, overlapping computation and communication, Odd even merge sort.
7. **Shared Address Space Programming Models (2): 1.** Pthreads**,** OpenMP. **2.** Illustrative examples.
8. **Data Parallel Programming Abstraction of GPUs (2): 1.** GPU architecture, SIMT execution model, CUDA programming model. **2.** Illustrative examples and application mapping, optimizations, OpenCL.
9. **Parallel Dense Algebra (2): 1.** Matrix vector, matrix matrix computations. **2.** Solution to linear systems.
10. **Parallel Search and Sorting (2): 1.** Parallel search, illustrative example applications, throughput optimization. **2.** Multi-dimensional search, decision trees. **3.** Sorting techniques, bitonic sort. **4.** Mapping onto parallel architectures.
11. **Cloud, Big Data and Map Reduce (2): 1.** Cloud as a computing platform, Large data sets and organization. **2.** Map Reduce as a parallel programming model, Hadoop. **3.** Frameworks for graph analytics. **4.** Illustrative examples.
12. **Heterogeneous Computing (1): 1.** Accelerators. **2.** Spatial Computing (FPGAs) **3.** Parallel Programming Models **4.** Examples. DPC++, OneAPI, Syce, etc.

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EE 451
Student Course Projects completed in Spring 2022

Benchmarking Parallel Algorithms for Vehicle Routing Problem
Optimizing Monte Carlo Path Tracer based Rendering System using CUDA programming
Evaluation of Parallel Gradient Descent Methods
Triangle counting on large graphs using SpMM on GPU
Application for Predictive Analysis of Stock Price Data using Parallel Computation of TA Indicators
Ray tracer with Pthreads and CUDA: Evaluating CUDA performance on control-intensive applications
Depthwise Separable Convolution Acceleration on GPU
Spatial Separable Convolutional Neural Networks Parallelization and Acceleration
Parallel first-order logic inference
Parallel deep learning inference on IoT edge clusters application
Accelerating the Application of Gabor Filter Banks to Images using GPU
Parallel Genetic Algorithm to solve Traveling Salesman Problem using MapReduce
Accelerated Matrix Factorization using CUDA
Parallelization of Fast Fourier Transform
Parallel Implementation of histogram based object detection
Evaluation of Connected Components Problem with Shared Memory and Message Passing
Implementation and Analysis of Parallel Delaunay Triangulation
Sorting Improvement: Comparing the Performance of Different Serial Sorting Algorithms and their Parallel Versions with Large Data Sets
Parallelizing Image Processing Filters
Implementation and analysis of parallel LZW algorithm
Implementation and Analysis of Parallel Algorithms for the Maximum Flow Problem in a Network

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