CIS 631
Advanced Parallel Computing
Course Overview

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Department of Computer and Information Science
Winter 2022
Outline

- Logistics
- Background
- Overview
  - What is CIS 631
  - What is expected of you?
  - What will you learn in CIS 631?
Course Logistics

- **CIS 631 – Advanced Parallel Computing**
  - “Parallel Processing” in course listing
- **Lecture**
  - Tuesday/Thursday 14:00 – 15:20, 360 Condon
- **Final project presentations**
  - Wednesday, 12:30, March 16, 360 Condon (during final exam period)
- **No midterm or final exams**
- **Undergraduate course prerequisite**
  - CIS 431/531 – Introduction to Parallel Computing
  - CIS 429/529 – Computer Architecture
- **Webpage:** [http://www.cs.uoregon.edu/Classes/22S/cis631](http://www.cs.uoregon.edu/Classes/22S/cis631)
- **Assignment 0 (skills survey)**
  - Due Thursday, 12:00, January 6 (before class)
- **Assignment 1 (get system accounts!!)**
  - OACISS account: [https://systems.nic.uoregon.edu/account](https://systems.nic.uoregon.edu/account)
  - Use “Malony / CIS 631” for class affiliation
  - Provide temporary password (to be changed after account set up)
Heritage of CIS 631

- CIS 631 has been graduate course since I began at UO
- Parallel computing in undergraduate curriculum
  - CIS 607
    - Winter 2014 seminar to plan undergraduate course
    - Develop 410/510 materials, exercises, labs, …
    - Intel Parallel Computing Center (IPCC)
      [http://ipcc.cs.uoregon.edu](http://ipcc.cs.uoregon.edu)
  - CIS 410/510
    - Spring 2014 and Winter 2015 “experimental” course
  - CIS 431/531 – Introduction to Parallel Computing
    - Proposed in AY 2015/16 as a formal course
    - Spring 2017 (Norris) and Winter 2018 (Malony)

- Ok, so what about CIS 631?
CIS 631 – Advanced Parallel Computing

- CIS 631 is intended to be more “advanced”
  - Assume basic parallel computing knowledge
    - CIS 431/531 and 429/529 is a prerequisite (or equivalent)
  - Assume some experience with shared and/or distributed memory parallel programming
    - multi-threading and message passing
  - Assume experience with Unix/Linux program development environments

- Focus on more state-of-the-art methodologies, systems, environments, tools, ….

- Take on more sophisticated projects
- Consider current research and development directions
- Continued development of CIS 631 course
People in Parallel Computing at CIS/UO

- Allen D. Malony
  - Scalable parallel computing
  - Parallel performance analysis
  - Taught CIS 631 for many years
- Boyana Norris
  - High-performance computing
  - Automated software analysis / transformation
  - Performance analysis and optimization
- Hank Childs
  - Large-scale, parallel scientific visualization
  - Visualization of large data sets
- Jee Choi
  - High-performance tensor decomposition
  - Big Data analytics with HPC
Course Plan

- Cover main areas of parallel computing (lectures)
  - Introduction and Architecture (1 week)
  - Programming models (paradigms) (1 week)
  - High-level programming frameworks (1 week)
  - Runtime systems (1 week)
  - Performance analysis and tools (1 week)
  - Heterogeneous computing (1 week)
  - Libraries, algorithms and applications (1 week)
  - Parallel systems environments (1 week)

- Parallel programming training (tutorials)
Course Assignments

- Parallel programming training
  - Gain (greater) proficiency in parallel programming
  - Exercises to gain skills

- Individual project
  - Done after training
  - Demonstrate technical skills with parallel programming
  - Topic of individual interest
  - Due Sunday, February 19, midnight

- Team term project
  - Major programming project for the course
  - Non-trivial parallel application
  - 2-3 person team
  - Proposal: Friday, January 21, 17:00
  - Presentation: Wednesday, March 16, 12:30
  - Report: Wednesday, March 16, 12:30

- Research summary paper
  - Due Thursday, March 16, 17:00
Term Paper

- Investigate parallel computing topic of interest
  - More in depth review
  - Individual choice
  - Summary of major points

- Requires minimum of ten references
  - Book and other references has a large bibliography
  - Google Scholar, Keywords: parallel computing
  - NEC CiteSeer Scientific Literature Digital Library

- Paper topic due Tuesday, February 1, 14:00
  - Abstract and 8 research references
  - Final term paper due Thursday, March 16, 17:00
Grading

20%  parallel programming training
20%  individual programming project
35%  team term project
25%  research paper
Parallel Programming Technologies

- Strong focus on learning certain parallel programming methodologies and technologies
  - Objective is to increase your skill to a higher level
- Distributed memory message passing
  - MPI ([https://www.mpi-forum.org](https://www.mpi-forum.org))
- Shared memory multi-threading
  - OpenMP ([https://www.openmp.org](https://www.openmp.org))
- Multicore (accelerator, coprocessor) programming
  - OpenACC ([https://www.openacc.org](https://www.openacc.org))
- Excellent tutorials for each of these
Parallel Programming Training

- Several excellent online resources and tutorials
- See course website

Schedule for training

- **MPI**
  - Date: January 10-17 (2\textsuperscript{nd} week)
- **OpenMP**
  - Date: January 17-24 (3\textsuperscript{rd} week)
- **OpenACC**
  - Date: January 24-31 (4\textsuperscript{th} week)
- **CUDA**
  - Date: February 1-8 (5\textsuperscript{th} week)

- Self-guided with exercises
- Complete all exercises by February 14
NVIDIA Educator Resources

- Part of NVIDIA Developer

- NVIDIA teaching kits
  - Accelerated computing training
    - lecture slides, lecture videos, e-books
    - hands-on labs and coding projects
    - source code solutions
  - Access to online labs using cloud-based GPUs

- NVIDIA Deep Learning Institute (DLI)
  - DLI self-paced labs and workshops

- CUDA and OpenACC
PGI Community Edition

- PGI products deliver world-class multicore CPU performance, an easy on-ramp to GPU computing with OpenACC directives, and performance portability across all major HPC platforms
  - Free PGI Community Edition
  - Part of NVIDIA HPC SDK

- Features
  - PGI Accelerator Fortran/C/C++ compilers
    - Linux x86-64, Linux OpenPOWER, or macOS
  - OpenMP 3.1 for multicore CPUs
  - OpenACC 2.5 for multicore CPUs and manycore GPUs
Reference Parallel Programming Book

- Presents parallel programming from a point of view of patterns relevant to parallel computation
- Focuses on the use of shared memory parallel programming languages and environments
- Used in CIS 431/531
Reference Algorithms Books

  http://lotsofcores.com/

- Leverage parallelism on multicore processors and manycore processors
- Examples of successful programming efforts from industries and domains such as chemistry, engineering, environmental science
- Provides detailed explanations of the programming techniques used, with source code available
Recent OpenACC Books

- Both edited books with chapters by leaders in the parallel computing field
AXIS Cluster (OACISS)

- Nodes (repurposed ACISS cluster circa 2010)
  - (8x) ProLiant DL 580 G7
  - Four Intel X7560 2.266 GHz
    - 8-core CPU
      (32 cores total per node)
    - 2-way hyperthreaded
      (64 hardware threads per node)
  - 384GB DDR3 per node!

- Interconnect
  - 10 GigE (10 Gbits/second)
  - Infiniband (IB) (40 Gbits/second)

- Get accounts
WOPR Cluster (OACISS)

- WOPR (What Operational Parallel Resource)
- Built as a Next Unit of Computing (NUC) cluster with Intel funds
  - 16x Intel NUC
    - Haswell i5 CPU (2 cores, hyperthreading)
    - Intel HD 4000 GPU (OpenCL programmable)
    - 1 GigE, 16 GB memory, 240 GB mSATA
    - Logitech keyboard and mouse
  - Head node and GigE switch
- Cerberus head node
  - Dell 2x4 core E5-2603v2 CPU, 1.8 GHz, 32GB
  - Linux environment
  - Compilers: GCC, Intel 17, PGI
- WOPR accessed through Cerberus using SLURM
- ISO image with HPC Linux environment
  - Available for booting or running in VirtualBox
NVIDIA Jetson TX1 Cluster (OACISS)

  - NVIDIA Tegra SoC
  - Maxwell architecture GPU
- 16x TX1 development kits (http://www.nvidia.com/object/jetson-tx1-dev-kit.html)
- Can use the Jetson cluster for parallel programming projects
Accelerator Resources (OACISS)

- Variety of NVIDIA GPUs
  - GTX 980
    - Maxwell architecture, 2048 cores
  - K80
    - Kepler architecture, 4992 cores (dual-GPU)
  - Tesla P100
    - Pascal architecture, 3584 cores
  - Quadro GV100
    - Volta architecture, 5120 cores

- Several Intel Xeon MIC
  - Many Integrated Cores (MIC)
  - Knights Landing architecture
  - 72 cores each with
    - 2 vector processing units (AVX512)
Talapatas Cluster

- HPC cluster at UO
  - 250 Tflops and 1.5 Petabytes
- Maintained by RACS
  - Research Advanced Computing Services (RACS)
    - https://hpcf.uoregon.edu
- Talapas specifications

<table>
<thead>
<tr>
<th>Qty</th>
<th>Node Type</th>
<th>Processors (total cores)</th>
<th>Memory</th>
<th>Local Storage</th>
<th>Networking</th>
<th>Accelerator</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>Standard Nodes</td>
<td>dual E5-2690v4 (28 cores)</td>
<td>128GB</td>
<td>200GB SSD</td>
<td>Single Port EDR InfiniBand</td>
<td>N/A</td>
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<td>24</td>
<td>GPU Nodes</td>
<td>dual E5-2690v4 (28 cores)</td>
<td>256GB</td>
<td>200GB SSD</td>
<td>Single Port EDR InfiniBand</td>
<td>Dual NVIDIA Tesla K80</td>
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<tr>
<td>8</td>
<td>Large Memory Nodes</td>
<td>quad E7-4830v4 (56 cores)</td>
<td>1TB, 2TB, or 4TB</td>
<td>dual 480GB SSD</td>
<td>Single Port EDR InfiniBand</td>
<td>N/A</td>
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What will you get out of CIS 631?

- In-depth understanding of parallel computer design
- Knowledge about how to program parallel computer systems
- Understanding of parallel programming paradigms
- Exposure to different forms of parallel algorithms
- Practical experience using parallel technology
- Background on parallel performance modeling
- Techniques for empirical performance analysis
- Fun and new friends!
COVID-19

- All UO courses will be in-class for Winter 2022 (for the time being)
  - If you not feeling well, please do not come to class
- CIS 631 lectures will be in-class
  - Zoom will be used for remote presentation if you can not attend
    https://uoregon.zoom.us/j/96135388067
  - Lectures will be recorded and made available
- Please try to healthy with masking and testing