Welcome

Welcome to High-Performance Computing

Tell me about you!
- What is your name, major, and year?
- Why did you register this course?
- What do you expect from this course?
- Any experience with HPC?
Instructor

- Dr. Tae-Hyuk (Ted) Ahn
  - Office: 305 Ritter Hall
  - Office Hours: Tue 10:00 – 11:30am, Wed 12:00 – 1:30pm
  - Appointment or Email
Topical Outline

- Introduce High-Performance Computing (HPC)
- Profiling applications for run time and parallel speed-up
- Brief introduction of computer organization and HPC architecture
- Shared-memory programming with OpenMP
- Distributed-memory programming with MPI
- MATLAB Parallel Computing Toolbox
- GPU programming with OpenACC (optional: CUDA)
- Cloud Computing and Apache Spark
Student Learning Outcomes

After successfully complete this course, students are expected to:

- Know fundamental concepts and new trends of high-performance computing
- Optimize software to take advantage of processor feature
- Design, implement, and analyze with OpenMP for shared-memory system
- Design, implement, and analyze with MPI for distributed-memory programming
- Parallelize an existing application using an appropriate parallel programming paradigm
- Utilize MATLAB parallel computing toolbox
- Understand the concept and implement simple GPU programs with OpenACC (or CUDA)
- Learn cutting-edge cloud computing techniques using Amazon AWS and Apache Spark
Course Textbook and Resources

- No textbook required.
- My website and CS GIT will be used for
  - Post lectures and other materials
  - Assign and submit homework
  - Grade and post homework and exam scores

- Again, I am ready to talk with you!
  - Office Hours
  - Email or make appointment
Grading

- Homework Assignments (50%)
  - 6-10 assignments

- Exams (50%)
  - Take-home Midterm Exam (20%), Tue 03/06/2018 – Thu 03/08/2018 (tentative)
  - Take-home Final Exam (30%), Thu 05/03/2018 – Wed 05/09/2018 (tentative)
Question About Syllabus?

- Question?
What is HPC?

“High-Performance Computing most generally refers to the practice of aggregating computing power in a way that delivers much higher performance than one could get out of a typical desktop computer or workstation in order to solve large problems in science, engineering, or business” – insideHPC.
What is HPC?

- Definition depends on individual person
  - HPC is when I care how fast I get an answer

- Thus HPC can happen on:
  - A workstation, desktop, laptop, smartphone!
  - A supercomputer
  - A Linux/MacOS/Windows/... cluster
  - A grid or a cloud
  - Cyberinfrastructure = any combination of the above

- HPC also means High-Productivity Computing
Welcome to HPC World!

Climate

Finance

Medical

Bioinformatics

Physics

Entertainment
Why do we need HPC?

Save Time and Money

$500,000 \text{ vs } $10
Why do we need HPC?

Human cannot calculate, but computer can!
Grand Challenge Problems

Big problems

- A “Grand Challenge” problem is a problem that cannot be solved in a reasonable amount of time with today’s computers

- Examples of Grand Challenge problems:
  - Applied Fluid Dynamics
  - Meso- to Macro-Scale Environmental Modeling
  - Ecosystem Simulations
  - Biomedical Imaging and Biomechanics
  - Molecular Biology
  - Molecular Design and Process Optimization
  - Fundamental Computational Sciences
  - Nuclear power and weapons simulations
Why would HPC matter to you?

- **Scientific computing** is becoming more important in many research disciplines.
- Problems become more complex, need teams of researchers with diverse expertise.
- Scientific (HPC) application development often limited by lack of training.
- More knowledge about HPC leads to more effective use of HPC resources and better interactions with (computational) colleagues.
Your Laptop is HPC?
Workstation, Cluster, Supercomputer?

- Most computers today are parallel workstations with multi-core processors.
- Running Linux OS (or MacOS X) allows programming like traditional Unix workstation.
- All processors have access to all memory:
  - Uniform memory access (UMA): 1 memory pool for all, same speed for all.
  - Non-uniform memory access (NUMA): multiple pools, speed depends on “distance”.
A cluster needs:

- Several computers, **nodes**, often in special cases for easy mounting in a rack
- One or more networks (interconnects) to hook the nodes together
- Software that allows the nodes to communicate with each other (e.g. MPI)
- Software that reserves resources to individual users

A cluster is: all of those components working together to form one big computer
A supercomputer is a computer with a high-level computational capacity compared to a general-purpose computer.

- The most visible manifestation of HPC
- Programs run on the fastest and largest computers in the world (Top500 List, [https://www.top500.org/](https://www.top500.org/))
- Performance of a supercomputer is measured in floating-point operations per second (FLOPS)
"Cloud Computing", by definition, refers to the on-demand delivery of IT resources and applications via the Internet with pay-as-you-go pricing.

Cloud Computing provides a simple way to access servers, storage, databases and a broad set of application services over the Internet.

Cloud Computing providers such as Amazon Web Services own and maintain the network-connected hardware required for these application services, while you provision and use what you need via a web application.
What is Parallel Computing?

- Parallel computing is the use of multiple processing entities in combination to solve a single problem.

- It is not always obvious that a parallel algorithm has benefits, unless we want to do things …
  - faster: doing the same amount of work in less time
  - bigger: doing more work in the same amount of time

- Both of these reasons can be argued to produce better results, which is the only meaningful outcome of program parallelization.