Benchmarking and Tuning for Parallel Programs

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Introduction to Parallel Programming and Distributed Computing
NCSI and Blue Waters
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Introduction

• Benchmarking and tuning parallel software is just like improving the performance of serial software, just roughly $-n_p \times$ times harder to do...

• What is benchmarking? Accurately measuring the time and resource consumption profile of a program built with particular options with a given set of input data and run-time options.

• What is tuning? Improving the performance and/or resource consumption profile of a program built with particular options with a given set of input data and run-time options.

• Big question - How to use a given set of computational resources to solve a particular problem efficiently?
Resources

- CPU utilization
- Memory utilization (cache, RAM; space, bandwidth)
- Disk utilization (intentional and unintentional (e.g. paging))
- Network utilization (bandwidth, latency)
Overall Process

• Looking at the outside; what resources is it using?
• Looking at the inside; what is it doing to consume those resources?
• Working from the highest level to the lowest level; the most change is possible at the highest level, as you go down less change is possible since the lower layers are all in response to the higher layers.
  – The algorithm
  – The implementation of the algorithm
  – The compiler
  – The operating system
• The 80/20 rule.
• Time/space tradeoffs.
• The effect of the memory hierarchy.
• Style, clarity, generality; then tuning only if necessary.
Benchmarking

• Accurately measuring the time and resource consumption of a program built with particular options with a given set of input data and run-time options to find the nature and location of the bottleneck(s).

• Operating system level
  - `time` - system call, shell built-in and standalone
  - `vmstat`
  - `top`
  - `iostat`

• Program level
  - `printf()` or `cout` statements
  - `MPI_Wtime()` and `MPI_Wtick()` and `MPI_WTIME_IS_GLOBAL`
  - `gprof` - statistical profiling (lab)
  - `getrusage()` - resource measurement from within the program
  - Performance counters (lab)
Tuning

- Improving the performance and/or resource consumption profile of a program built with particular options with a given set of input data and run-time options.

- Working from the top down because the most change is possible at the highest levels since lower levels are just responses to what happens at the levels above them.

- What work is being done? Where is it being done? Is there a more efficient way to accomplish the task?

- The process: measure, think, change one thing; measure, think, change one thing; measure, think, ...
Tuning - Continued

- Choice of algorithm
- Resource limits (ulimit -a)
- Compiler choice (GNU, Intel, etc.)
- Compiler optimizations (-O N, loop unrolling, etc.)
- Find an optimized library, e.g. Goto’s BLAS, that does what you need more efficiently/quickly
Parallel and Distributed Specific Tuning

- Latency and bandwidth; aggregation
- Synchronization
- Memory copies
- Network port contention
- Communication barriers
- Load balancing
The gprof Lab

- The lab is located at

- You will need a piece of serial code as one of the inputs to the lab, for today I suggest you use the serial area under a curve. Note that you will need to significantly increase the problem size to see meaningful results. There is a serial version of this code contained in the lab.
Resources

- gprof lab -

- man gprof

- IBM whitepaper on low–level tuning -

- *High Performance Computing 2e*, Severance and Dowd, O’Reilly, Sebastopol, CA

- *Performance Optimization of Numerically Intensive Codes*,
  Goedecker and Hoisie, SIAM Publishing, Philadelphia, PA