Optimization and Scalability Lab

Carlos Rosales
carlos@tacc.utexas.edu

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Introduction to Parallel Computing

Labs Description

- Automatic Optimization
  - Compile a code with different optimization levels and study the run times.
  - This example shows how automatic optimization can greatly improve code performance without effort.
- Vectorization
  - Try to find why a kernel is not being vectorized by the compiler and change the code to fix the problem.
  - This example illustrates the common problem of data dependencies.
- Scalability
  - Run a given code on multiple processors and study the run times.
  - This example shows that codes should not be expected to have perfect scalability, and that scalability depends on problem size.

Setup

- Login to Ranger:
  - `ssh username@ranger.tacc.utexas.edu`
- Make sure you are using the intel compiler
  - `module swap pgi intel`
  - `module list`
- Untar the lab files:
  - `cd`
  - `tar xvf ~train00/opt_lab.tar`
- Change directories and ls to see the files:
  - `cd opt_lab`
  - `ls`

Lab 1: Automatic Optimization

- Compile auto.c or auto.f90 with increasing levels of automatic optimization:
  - `icc -O0 -vec-report3 auto.c -o auto_O0`
  - `icc -O1 -vec-report3 auto.c -o auto_O1`
  - `icc -O2 -vec-report3 auto.c -o auto_O2`
  - `icc -O3 -vec-report3 auto.c -o auto_O3`

  - `ifort -O0 -vec-report3 auto.f90 -o auto_O0`
  - `ifort -O1 -vec-report3 auto.f90 -o auto_O1`
  - `ifort -O2 -vec-report3 auto.f90 -o auto_O2`
  - `ifort -O3 -vec-report3 auto.f90 -o auto_O3`

- Notice the optimization messages printed by the Intel compiler.
  - At the O2 level three loops are vectorized
  - At the O3 level three loops are fused into one, and then the larger loop is vectorized

- Compile using **-opt-report 2** to get additional information on the optimizations performed

- Submit the job through the SGE queue system:
  - `qsub ./auto_job.sge`

Lab 1: Automatic Optimization

- You can look at the execution status using qstat or showq.
- Once the job completes an output file called **auto.$JOBID.out** is generated, where **$JOBID** is the job number.
- Fill the table below with the execution times for the different optimization levels (get the timings from the output file **auto.$JOBID.out**)
- You should see a progressive improvements in the timings as more aggressive optimizations are used.

OPT Level	0	1	2	3
Setup Time				
Kernel Time				

Lab 1: Vectorization

- Compile the vec.c or vec.f90 source code:
  - `icc   –vec-report3 ./vec.c   –o vec`
  - `ifort –vec-report3 ./vec.f90 –o vec`

- The compiler should notify you that it is only possible to vectorize one of the loops in the code due to data dependencies.

- Submit the job to the batch system:
  - `qsub ./vec_job.sge`

- Once the job completes an output file called **vec_job.$JOBID.out** is generated, where **$JOBID** is the job number. Take note of the time spent in the kernel.

Lab 2: Vectorization

- Open the source code with your favorite text editor and look at the loop named **KERNEL**.
- Identify the source of the data dependence and correct it, so that the compiler is able to vectorize both the setup and the kernel loops.
- Recompile and verify both loops are vectorized.
- Submit the job again and compare the timings with the original.
- The vectorized version should be significantly faster.

Lab 3: Parallel Scalability

- In this example you will evaluate the scalability of a smoothing kernel code.

- Compile the matmult.c or matmult.f90 source code:
  - `mpicc  -O3 -xW ./parallel.c`
  - `mpif90 -O3 -xW ./parallel.f90`

- Submit the job through the SGE queue system:
  - `qsub ./parallel_job.sge`

- The initial submission uses 2 processing cores only (-pe 2way 16). Check execution and MPI times in the **parallel_job.$JOBID.out** file created.

Lab 3: Parallel Scalability

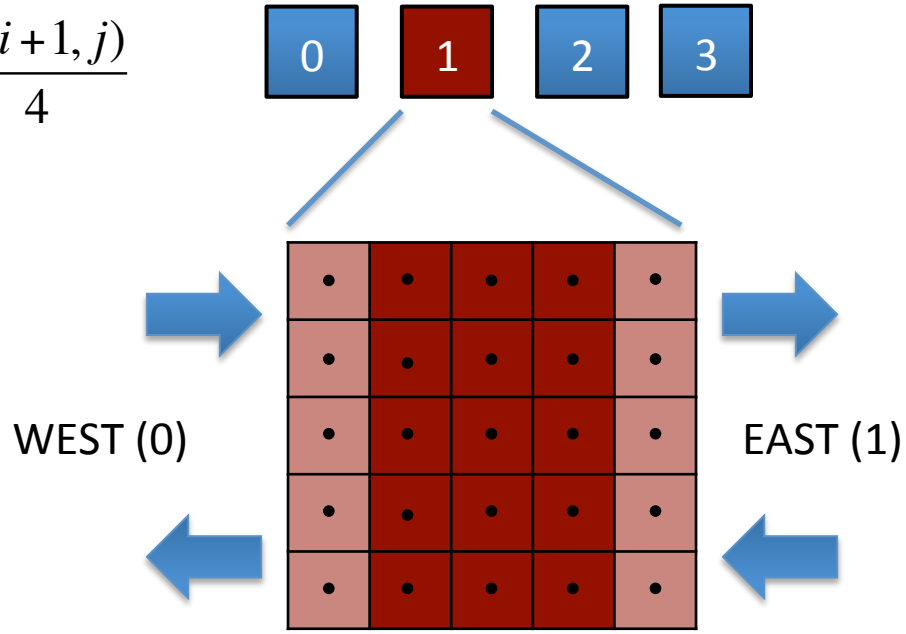
- Change the submission script to use 4 cores (-pe 4way 16), 8 (-pe 8way 16) and 16 (-pe 16way 16), and build a table with the execution times.
- Does the execution time decrease linearly with the number of cores? Why do you think that is?
- Open the parallel.c or parallel.f90 file and change the parameters **xmax** and **ymax** from the default 160 to 800. Recompile the code.
- Repeat runs for 2, 4, 8, and 16 cores using this size and fill in the table below.
- Is there a difference in the scaling when you compare the results for the two different size problems? Why do you think that is?

SIZE	2 cores	4 cores	8 cores	16 cores
160 x 160				
800 x 800				

Lab 3: Parallel Scalability

Simple smoothing kernel with a regular 1D task partition

$$A(i,j) = \frac{A(i-1,j)}{4} + \frac{A(i,j)}{2} + \frac{A(i+1,j)}{4}$$



Problem requires regular data exchange on task Boundaries

Light colored nodes are ghost nodes, used for data exchange

2D ghost cells

Problem requires regular data exchange on task boundaries