
Homework1

OpenMP parallelization with the FX10 or own PC

名古屋大学情報基盤中心 教授 片桐孝洋

Takahiro Katagiri, Professor,
Information Technology Center, Nagoya University

台大数学科学中心 科学計算冬季学校



I

Introduction to Parallel Programming for
Multicore/Manycore Clusters



Summary of this lesson

- ▶ There are two ways to do this lesson.
 1. By using own PC
 - ▶ Use Linux, and gnu tools (gcc or gfortan).
 - ▶ Download sample program via the HP.
 2. By using the FX10
 - ▶ Use FX10 account and ssh connection to ITC. U.Tokyo.
 - ▶ Lecture that how to use the FX10 will be done in this afternoon. Refer to the lecture notes.

Execute sample program by
using own PC
(Matrix-Matrix Multiplication)

Note: Sample program of matrix-matrix multiplication (**OpenMP**) by using own PC

- ▶ Common file name of C/Fortran languages:
Mat-Mat.tar
- ▶ Download the **Mat-Mat.tar** via homepage of the lecture.

Execute sample program of dense matrix-matrix multiplication

- ▶ Install Mat-Mat.tar to your PC.
- ▶ Type followings in command line:
`$ tar xvf Mat-Mat.tar`
`$ cd Mat-Mat`
- ▶ Choose the follows:
`$ cd C` : For C language.
`$ cd F` : For Fortran language.
- ▶ The follows are common:
`$ make`
- ▶ Confirm executable code (mat-mat.exe).
`$ ls`
- ▶ Execute mat-mat.exe
`$./mat-mat.exe`

Output of sample program of dense matrix-matrix multiplication (C Language)

- ▶ If the run is successfully ended, you can see the follows:

N = 1000

Mat-Mat time = 2.532533 [sec.]

789.723319 [MFLOPS]

OK!



The execution time depends on ability of computations for your PC.

Output of sample program of dense matrix-matrix multiplication (Fortran Language)

- ▶ If the run is successfully ended, you can see the follows:

NN = 1000

Mat-Mat time [sec.] = 1.6323672519647516

MFLOPS = 1225.2144807139712

OK!



The execution time depends on ability of computations for your PC.

Explanation of sample program (C Language)

- ▶ You can change size of matrix by the number:

```
#define N      1000
```

- ▶ By setting 1 in the follow “0”, result of matrix-matrix multiplication is verified:

```
#define DEBUG 0
```

- ▶ Specification of **MyMatMat** function
 - ▶ Return result of A times B with size of [N][N] of **double** by setting C with size of [N][N] of **double**.

Explanation of sample program (Fortran Language)

- ▶ You can find declaration of size of dimension N in the following file:

`mat-mat.inc`

- ▶ Variable of the size of dimension is NN, such as:

`integer NN`

`parameter (NN=1000)`

Homework 1 (Own PC)

- I. Parallelize **MyMatMat** function by using OpenMP.
 - ▶ Modify source code (**mat-mat.c** or **mat-mat.f**) by using a text editor, such as **emacs**.
 - ▶ Type “**make clean**”, then “**make**” again.
 - ▶ Before execution, specify number of threads as follows:
\$ export OMP_NUM_THREADS=4

Note: Homework 1 (Own PC)

- ▶ If your PC does not have a multicore CPU, there is no effect for parallelization.
- ▶ If your PC has a multicore CPU, evaluate parallel efficiency by varying the number of threads, such as from 1 to 4 (or more).
- ▶ You may change size of matrices to obtain better parallel efficiency. For example, modify the size from 1000 (original) to 2000 or more.
 - ▶ You also take care of physical memory capacity, such as 8GB.

Answer code of sample program of matrix-matrix multiplication

Answer code of matrix-matrix multiplication (OpenMP) (C Language)

- ▶ The main program is as follows:

```
#pragma omp parallel for private (j, k)
for(i=0; i<n; i++) {
    for(j=0; j<n; j++) {
        for(k=0; k<n; k++) {
            C[i][j] += A[i][k] * B[k][j];
        }
    }
}
```

Answer code of matrix-matrix multiplication (OpenMP) (Fortran Language)

- ▶ The main program is as follows:

```
!$omp parallel do private (j, k)
do i=1, n
  do j=1, n
    do k=1, n
      C(i, j) = C(i, j) + A(i, k) * B(k, j)
    enddo
  enddo
enddo
```

Execute sample program by
using the FX10
(Matrix-Matrix Multiplication)

Note: Sample program of matrix-matrix multiplication (**OpenMP**) by using the FX10

- ▶ Common file name of C/Fortran languages:
Mat-Mat-openmp-fx.tar
- ▶ Modify queue name from **lecture** to **lecture6** in job script file **mat-mat-openmp.bash**. Then type “pjsub”.
 - ▶ **lecture** : Queue in out of time of this lecture.
 - ▶ **lecture6** Queue in time of this lecture.

Execute sample program of dense matrix-matrix multiplication

- ▶ Type followings in command line:

```
$ cp /home/z30082/Mat-Mat-openmp-fx.tar ./  
$ tar xvf Mat-Mat-openmp-fx.tar  
$ cd Mat-Mat-openmp
```

- ▶ Choose the follows:

```
$ cd C : For C language.  
$ cd F : For Fortran language.
```

- ▶ The follows are common:

```
$ make  
$ pjsub mat-mat-openmp.bash
```

- ▶ After finishing the job, type the follow:

```
$ cat mat-mat-openmp.bash.oXXXXXX
```

Output of sample program of dense matrix-matrix multiplication (C Language)

- ▶ If the run is successfully ended, you can see the follows:

Note: OpenMP parallelization is not implemented.

N = 1000

Mat-Mat time = 0.181551 [sec.]

11016.210378 [MFLOPS]

OK!

Output of sample program of dense matrix-matrix multiplication (Fortran Language)

- ▶ If the run is successfully ended, you can see the follows:

Note: OpenMP parallelization is not implemented.

N = 1000

Mat-Mat time[sec.] = 0.1802263529971242

MFLOPS = 11097.15622433085

OK!

Homework 1 (FX10)

- I. Parallelize **MyMatMat** function by using OpenMP.
 - ▶ Make sure processes of programming for the FX10. Refer to lecture of “How to use the FX10.”
 - ▶ By using emacs, modify queue name.
 - ▶ Modify number of threads in **mat-mat-openmp.bash** as follows:
`export OMP_NUM_THREADS=16`