Homework1
OpenMP parallelization with the FX10 or own PC

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Summary of this lesson

- There are two ways to do this lesson.
  1. By using own PC
     - Use Linux, and gnu tools (gcc or gfortarn).
     - 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)

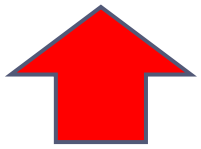
- If the run is successfully ended, you can see the follows:

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)

1. 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.oXXXXX
```

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.] =  0.18022635299971242
MFLOPS =  11097.15622433085
OK!
```

Homework 1 (FX10)

1. Parallelize MyMatMat function by using OpenMP.
   - Make sure processes of programing 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